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A REVIEW OF BIAS IN THE CPI

Invited paper submitted by the Organisation for Economic
Cooperation and Development (OECD)*

I. Introduction

1. The possible existence of bias in measured consumer price indices (CPI) has been the subject of much discussion in recent years following the well publicised findings of the Boskin Commission¹ in the United States. The extent of discussion is due to the wide variety of ways in which the CPI is used and the significant consequences of miss-measurement. In most countries estimates of constant price GDP and measures of productivity are dependent on the rate of change in prices as measured by the CPI. Overstatement of the CPI would imply that the current growth estimates of these two series are, in fact, underestimated. Further, in many countries government budgets, general wage negotiations and many private contracts are closely linked to movements in the CPI implying a significant, real, monetary impact of miss-measurement. Possible bias in the CPI is not to be taken lightly.

2. Rather than present any new study into particular aspects of bias the aim of this paper is to identify and interpret the key elements of bias in the CPI and to try to link together the many and varied arguments which relate to bias. While it may seem a relatively recent issue, index bias is not new and indeed, the desire of economists and index number specialists to

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identify the best measure of price change has been ongoing for at least 200 years. Some great strides have been made but there remain some significant conceptual and empirical difficulties in defining the best price index. The existence of bias and the correction for it must be seen in the light of these difficulties.

3. It should also be noted that the study of bias in the CPI is incredibly broad at its extreme. It deals with practical concerns of price collection and theoretical aspects of index numbers and utility theory. While in recent years it has often been considered as an issue in its own right this is not appropriate. Rather, it should be considered as inextricably linked to the actual choice of methods used in CPI compilation. This paper attempts to highlight these links but, inevitably, the paper is not able to cover some matters in the depth which would be ideal.

4. Section 2 of the paper presents a definition of bias and section 3 provides some basic information on index construction and substitution. Section 4 discusses the five main sources of bias commenting on their definition, the relevant issues and possible solutions. Section 5 covers the measurement of bias including discussion of the way bias changes over time. The final section presents broad conclusions. The paper also contains a structured bibliography which attempts to classify some of the many documents relating to bias.

II. A definition of bias

Does bias exist?

5. While the amount of recent debate may suggest that the existence of bias can be taken for granted, there is not a straightforward answer. The study of CPI bias questions the overall relevance of a CPI in measuring actual price changes. It does this by examining situations where the use of certain techniques, practices or formula derives results that are systematically higher or lower than a true measure. Importantly, bias does not cover errors, such as sampling and non-sampling errors, which are not usually systematic in nature and are not closely associated with the relevance of the index as such. However, even though bias has a broad view it is actually observed at quite detailed levels of an index. Questions of relevance are validly applied at a detailed level since different measurement practices are used at different stages of compilation of the total index. Whether an overall bias exists is therefore a complex question requiring detailed analysis of many aspects of CPI compilation.

The true CPI

6. To measure bias some concept of a true index is required. Whether a single, true index exists is a matter of debate. Most often in the literature, bias is defined as the deviation of the measured CPI from a cost of living (COL) index. However, a CPI can be defined according to a range of other criteria and a single definition of a true index is not sought here. Rather, there is a more general focus on the definition of the index since this is central to questions of relevance and bias.

7. At the first level of definition the scope of the index is the primary concern since it is this which links the index to the intended aim. To the extent that the defined scope fits the intended aim then bias is not at issue at this level.² One effect of this conclusion is that the COL index versus inflation index debate, which is largely a debate over scope, should not be given a high prominence when discussing issues of bias.³ Once the scope of the index has been determined further definition is required regarding index number formula, collection techniques, etc. It is at this level of definition that issues of bias arise since it is at this level that questions are raised as to whether the measured index will appropriately reflect the actual price changes for the good and services within scope. This paper essentially shows how a range of decisions at this level of index definition can impact on the measured CPI.

8. The relevance of the measured index to the true index is assessed on the basis of expectations. It is the existence of expectations, derived from observation of the real world, which prompts the issue of bias. With respect to CPI there are two key areas: (i) the way in which an index number responds to price change; and (ii) the way in which consumers react to price change.⁴ While there is general support for many of the expectations involved in the first area, the second area is open to much debate. The second group of expectations is closely related to consumer or utility theory. While the theory is far from explaining all of the motivations behind consumer behaviour, some quite strong ideas, for example that prices and quantities are generally inversely related, have been shown to hold. Overall, there are certain links to economics which are relevant in the construction of CPI and hence in the assessment of the relevance of the measured index.

9. Since not all consumer behaviour has been precisely defined and the links to price change are sometimes very unclear, it is difficult to measure an expected or true index without making significant assumptions. However, such measurement difficulties should not suggest that bias from a true index is not possible. More importantly, since bias must be considered at a detailed level a range of true indices will be required depending on the issue under consideration. While not necessarily making the measurement of an overall true index easier, analysis at a detailed level does highlight the links between expectations and measurement. True indices may be difficult to define and measure but their existence is real. Bias from them will depend

on how well the chosen methods of index construction reflect the expected behaviour of the indices.

III. A brief introduction to price indices

Price index construction and assumptions

10. In order to appreciate the many issues involved in price index bias some basic understanding of the way in which price indices are constructed is required. The basic steps are that price observations for a single type of *product* (good or service) are collected from a range of different *outlets*, these are aggregated to form an *elementary aggregate index* (usually without weights) and finally these indices are aggregated, using expenditure weights, to form *upper level indices* and the total CPI.

11. Two assumptions which are particularly relevant to the assessment of bias are (i) that the product is available in consecutive periods; and (ii) that the price observations in consecutive periods refer to a product of the same quality. These assumptions are significant since the continually changing range and quality of products makes the maintenance of the two assumptions very difficult. Indeed, to a large extent, the ways in which index number compilers adjust the index to maintain these assumptions are the focus of studies of bias.

Index number formula

12. Index number formula are required at two levels of the CPI. At the elementary aggregate level there are a number of choices which are discussed in more detail in the section on elementary aggregate bias. At the upper level a number of possibilities exist. In general, countries use a Laspeyres index which uses weights from an earlier period to aggregate prices. The direct alternative is the Paasche index which uses weights from the current period. While the Laspeyres index is currently the only practical alternative because weighting information is only available with some delay, both of these indices are limited since they use only one period of weighting information in measuring price change between two periods.

13. In 1922 Fisher made famous a symmetric index, the Fisher ideal index, which uses weighting information from the two periods under consideration. In 1936 Tornqvist presented an alternative symmetric index. Both of these formula can be shown to have many properties which rate them as being "ideal" indices. Given certain basic assumptions on the nature of price and quantity relationships it has been shown that these symmetric indices lie between the Laspeyres and Paasche indices. While Konus had shown in the 1930s that the true COL index lay between the Laspeyres and the Paasche COL indices it was only in 1976 that Diewert showed the link between COL indices and ideal

indices, such as the Fisher or Tornqvist. He proved that these indices would closely approximate an exact COL index for any utility function⁵.

14. It is important to recognise that, irrespective of the links to COL indices, a Fisher index, or another ideal index, will provide a better measure of price change than either the Laspeyres or Paasche indices. In recognising the benefits of using an ideal index the important distinction is one between weights and baskets. While the basket of goods and services may remain fixed there is no requirement to use fixed weights in order to measure the price change for the whole basket⁶.

Substitution

15. Substitution occurs when, as a result of changes in relative prices, consumers switch from those products whose prices have increased relatively more (decreased less), to those whose prices have increased relatively less (decreased more). While substitution can theoretically occur between any two products, it is more likely to occur in the short term between products which fulfil similar purposes, for example between different forms of entertainment. Further, since the CPI has a number of levels and it can be observed that the substitution effect is likely to be stronger within the lower, elementary aggregate levels of the index where there are groupings of more similar products.

16. Three other points are worth noting. First, substitution occurs in response to many factors other than relative price change, for example changes in tastes, fashion, income and technology. At a more aggregate level, substitution may be observed in response to demographic changes. Second, a number of different economic models exist which assume different rates of substitution (elasticities). In general these models are unlikely to hold exactly since actual elasticities between items will vary. However, such models can be useful as a guide to understanding the various properties of different index number formula. Third, substitution need not only occur between products. Consumers often change the outlets at which they purchase products. Substitution behaviour is therefore quite a pervasive phenomenon.

IV. Sources of bias

Upper level substitution bias

Nature of the bias

17. Upper level substitution bias is probably the best known source of bias and perhaps the easiest to understand. It occurs because the use of the Laspeyres formula to form upper level indices uses weights from an earlier period and these may not reflect the consumption pattern which underlies the comparison periods. More precisely, a Laspeyres price index will be upward

biased since it weights too highly those prices which have risen relatively quickly. The extent of substitution bias can be determined by comparing the Laspeyres index with ideal indices, such as the Fisher or Tornqvist, which allow for substitution by using weighting information from both periods under consideration.

Discussion

18. The numerous studies of upper level substitution bias all point to upward bias in the Laspeyres index. Three main findings can be identified. First, the extent of measured bias depends on the level at which the measurement is undertaken. Both Aizcorbe and Jackman⁷ and Génèreux⁸ observe that the potential for finding substitution bias increases if comparisons are conducted at more detailed levels of the index. This is consistent with the observation that substitution should be more prevalent within groups of items which are similar, i.e. within elementary aggregates rather than between them. Thus, the potential for bias at the upper level is constrained.

19. Second, the extent to which bias should be found between a Laspeyres index and a Fisher index can be determined by considering the magnitude and direction of the correlation between product price changes and the related quantity changes. Génèreux found that the negative correlations that would be expected to exist to show the price substitution effect were not significant and indeed some zero and positive correlations were found.⁹ This suggests that price substitution effects may be difficult to separate from other substitution effects such as changes in tastes and technology. Further, it can be observed that these general changes are likely to be more long term in nature and thus will show up as gradual changes in consumption patterns. Génèreux's work suggests that these general changes may be more significant in interpreting overall substitution behaviour.

20. Before continuing, some discussion on chained indices is required. Over two periods the proven relationship is that a direct Laspeyres index will be higher than a Fisher index.¹⁰ Over more than two periods, theory suggests that a chained Laspeyres index which updates base period weights on an ongoing basis will be lower than the direct Laspeyres but higher than a Fisher. Chain indices work best when there is a definite negative relationship between prices and quantities and prices and quantities move smoothly over time. Génèreux found problems regarding the negative correlation and Szulc observed problems when price observations "bounce", i.e. relative prices and quantities do not move smoothly. In such situations a chain index can "drift" from the direct index result.¹¹ However, it is not clear that the direct index should be the aim and thus drift should not be construed as bias. Further, in practice it seems that the extent of drift may be limited¹² and Hill argues that the benefits of introducing more current information into an index support the use of a chain index approach.¹³ Overall, providing suitable account is taken of the nature of the underlying relative price and quantity changes, chain Laspeyres indices will provide a

lower result than a direct Laspeyres index and hence a less biased estimate at the upper level.

21. The third main finding is that the amount of bias cannot be convincingly linked to the frequency of updating the expenditure weights used in the Laspeyres formula¹⁴. The results suggest that while chaining is beneficial, very frequent chaining may not bring significant additional reductions in bias. The overall conclusion is that it is the gradual changes in consumption patterns, which can be accounted for through periodic chaining, that are more significant in explaining bias at this level. This is consistent with the relative lack of price substitution which will take place at the upper levels, with the significance of other, non-price, substitution effects and with the observation that even in a frequently updated chain Laspeyres index the weights still refer to an earlier period and therefore do not provide a symmetric index or allow for substitution¹⁵. If frequent updating is to allow for substitution then one must assume that prices for those products to which consumers have directed their expenditure in response to relative price changes will continue to show relatively low price changes¹⁶.

Possible solutions

22. Since a chained Laspeyres index will not solve the problem of substitution bias the only solution to upper level substitution bias is the use of a Fisher or other ideal index. Unfortunately, there are practical impediments, primarily a lack of weighting data available on a timely basis, and generally this solution will not be possible. However, two indices have been proposed¹⁷ which allow estimation with only base period weights but which provide very similar results to superlative indices. Further development in this direction is required to minimise bias at the upper level. A parallel suggestion from the Boskin Commission, is the construction of a second CPI which is revisable and calculated using a superlative index formula¹⁸. While this would not correct for substitution bias in the official CPI it may be a useful tool for long term analysis.

23. While the limitations in chain indices have been observed it remains the case that some chaining is required to allow for longer term changes in consumption behaviour and such chaining will reduce overall substitution bias. From a practical point of view, work by Généreux and by Bérubé suggests that bias can be reduced by introducing new weights in a more timely fashion¹⁹. If weight updates must be infrequent, consideration could be given to using an average of 2-3 years of data to calculate the weights which may reduce the effect that a non-standard year of weights could have on an index.

Elementary aggregate bias²⁰

Nature of the bias

24. Elementary aggregate bias can arise in two ways. First, the choice of formula to aggregate price observations may be biased and second, there may be systematic problems in the application of the formula when linking price observations. In part, the overall estimate of bias at this level is related to the amount of substitution within the elementary aggregate. However, even though the substitution effect may be stronger at this level, without data on both prices and quantities it is necessary to place some assumptions on the degree of substitution in choosing the best formula.

Choice of formula at the elementary aggregate level

25. There are three principal formula used in the estimation of elementary indices. These are:

- the arithmetic mean of price relatives (AR);
- the ratio of arithmetic mean prices (RA); and
- the geometric mean of price relatives (GM).

26. The first observation is that if all prices move in the same way then all three will give the same result²¹. However, this situation is unlikely to occur. More generally, theoretical and empirical research has shown that the AR formula has an upward bias²², a fact which seems to have been recognised for some time²³. The main problem is that price increases and decreases are not treated symmetrically, i.e. if prices rise and then return to their old level the AR formula will give an overall change of greater than 1. The use of this formula is not recommended.

27. Comparison of the RA and GM formulas is based on two factors. First, the ability of the formula to deal with substitution and second, their treatment of different types of price observations. Regarding substitution the GM formula represents Cobb-Douglas type preferences in which expenditure shares are assumed to hold constant over time. The effect of this is to assume that the elasticity of substitution between products within the elementary aggregate is 1. The RA formula assumes Leontief preferences where quantities are held constant over time, i.e. the elasticity of substitution is 0. Neither of these models is likely to hold perfectly and thus the choice of formula is dependent on the extent of substitution believed to be inherent in the elementary aggregate under consideration. However, where substitution is deemed to occur to even a limited extent the GM formula appears to perform better²⁴.

28. On the treatment of different price observations, the first point is that the GM formula treats all price observations equally but the RA formula gives higher weight to high price observations²⁵. Thus, depending on the

spread of prices within the elementary aggregate, the GM formula may be preferred. On the other hand, the GM formula, which involves the multiplication of prices, has been shown to perform poorly when extreme price changes are involved (often when near zero prices are in evidence)²⁶ and is undefined when zero prices exist (e.g. if the price of a government subsidised good falls to zero)²⁷. The GM formula would not be preferred in these cases.

29. Two other formula can be cited. The first is the harmonic mean of price relatives which Szulc suggests could be appropriate in cases where the products in the elementary aggregate are reasonably homogeneous in terms of quality but where there are frequent "price wars", discounts, etc.²⁸ Second, Dalén has suggested the use of a ratio of normalised mean prices which provides results very similar to the GM formula²⁹.

30. Overall, the reduction of bias of this type must consider the best formula for each elementary aggregate based on the degree of substitution and the nature of the prices within the elementary aggregate. However, residual bias will exist for any formula since the assumptions underlying each model are unlikely to hold exactly. The continuing development of scanner data is a very positive step in this respect since it allows a more precise assessment of the extent of substitution. Initial scanner data studies have shown that substitution could be significant³⁰ implying a preference for formula which allow for substitution.

Practical problems and real "formula" bias

31. The term formula bias has been used as a synonym for elementary aggregate bias and given the effect that the choice of formula has this would seem logical. However, strict formula bias is a more practical issue that arises when attempting to link changing product price observations. It was identified by Reinsdorf in the U.S. CPI in 1994³¹. To summarise, the U.S. CPI uses quantity weights at the elementary aggregate level which are calculated by dividing a base period expenditure by an observed price. Reinsdorf found that when new and old prices were linked, the derived quantity weight, which was re-calculated based on the new price, could be wrong if the new price was unusual, e.g. a sale price. The upward bias which resulted from the approach was not due to the formula as such but to the method used for linking in new prices. The problem was resolved by "seasoning" the new prices, i.e. waiting a few months to see if the new price was unusual. More recently, the problem has been resolved by the use of the GM formula for many elementary aggregates which uses base period expenditures and thus base period quantities need not be estimated. However, seasoning is still used for some aggregates where the GM formula is not used³².

32. While this precise issue is a problem only when weighting together price observations, the more general requirement to link old and new prices suggests that some problems may be found in this area. Schultz found that

frequent linking of price observations had a significant effect on the results obtained from alternative formula³³. Sabag and Finkel, in comparing chained (linked) indices and base period indices, found that generally the choice did not lead to systematic bias although a downward bias for the chain index approach was found for the consumption group "Clothing and footwear"³⁴. While the precise nature of any bias is difficult to determine, it seems that systematic problems in applying elementary aggregate formula can arise. Therefore, careful consideration of the methods used to link old and new prices is recommended to minimise the potential for bias within elementary aggregates.

Quality change bias

Nature of the bias

33. The definition of and adjustment for quality change is perhaps the most difficult area of price index construction. From a practical perspective, quality change involves trying to measure price change for a product which has exhibited some change in its characteristics from the previous period and which provides different levels of utility to the consumer. Recalling that the index requires pricing of products which are of the same quality, the aim is to determine what proportion of the total price change is due to a change in quality and what is pure price change. Quality change bias occurs when the measurement of the distinction between pure price change and quality change is not correct.

34. Quality change bias is often termed linking bias due the nature of simple adjustments for quality change which link prices for new and old products. Such adjustments lead to bias because any absolute change in price levels is not reflected in the index³⁵. However, the use of the term "linking bias" could be confusing since there are a wide variety of index number situations that require linking of some description. It is suggested that the term quality change bias or quality adjustment bias be used to reduce possible confusion in this area.

Discussion

35. Deaton presents a neat explanation of the quality change problem in terms of the links to price and quantity but concludes that in general it is not possible to identify a true, quality adjusted index³⁶. Even though a true measure is difficult to define, quality change can be observed and adjustment for it must be made. Essentially, it remains in the judgement of the compiler as to whether quality adjustment is required and whether it has been sufficient. The extent of quality change bias is therefore also a matter of judgement.

36. Overall, it is thought that most CPI underestimate the total amount of quality change and therefore have an upward bias, i.e. pure price change is

overestimated. However, there are a number of instances where observed quality has deteriorated and not allowing for this quality change would imply a downward bias in the index. However, it should also be noted that in assessing quality change bias it is important to take account of any existing procedures which attempt to adjust for quality change. Thus even though quality change may be positive, if the existing adjustment method systematically overestimates the extent of quality change the index will be downward biased.

37. The largest difficulty in defining quality change is estimating the effect on consumer utility when product specifications change. Whether this is achieved by general assessment of the change or by using a more detailed approach, some judgement on what represents quality change is required. However, changes in utility will not only be due to quality changes. In a similar manner to the way in which not all substitution effects are price induced, a consumer's utility may change for reasons of changes in taste and preference, among other things. Thus, there are likely to be a mixture of quality change, utility change and substitution effects involved which makes identifying the nature and magnitude of any quality change particularly difficult. Importantly, analysis of quality change must be conducted at a very detailed level since quality will vary by type of product rather than at a more aggregated level.

38. In practice, adjustments can be made using simple linking techniques, finding a comparable product to price, excluding the changed item or explicitly measuring the quality change, perhaps using hedonic techniques. The first two methods either assume all price change to be quality change or all price change to be pure price change and it is clear that these simple methods of quality adjustment can lead to bias, a point noted by a number of researchers³⁷. While it seems more likely that detailed methods of quality adjustment will be less biased, simple techniques may be accurate depending on the product under consideration and the nature of the quality change.

39. It may be reasonable to suppose that no real bias exists in the sense of a systematic over or understatement of quality change but rather there is a case of miss-measurement³⁸. However, while the notion of systematic bias at the aggregate level may not be justified, the potential for bias at the detailed level is quite real. Overall, bias could exist if any positive or negative quality change is not recognised or if, once recognised, the adjustment method fails to correctly adjust the index. Unfortunately no simple solution exists and the only suggestion is to consider the specific quality change issues for each product separately. It may be beneficial to target those products for which quality change is believed to be significant (e.g. computers) and which have a significant weight in the index.

New products bias³⁹

Nature of the bias

40. Over time new products appear and to the extent that the index does not adequately allow for these product range changes the index may be biased. Issues of bias centre on the nature of the product price cycle which suggests that new products will start out at a high price and fall rapidly in price following their introduction. A CPI will be upward biased if the fall in price at the start of the product's lifecycle is not reflected in the index. The magnitude of the bias will depend on (i) the extent of the initial price fall; (ii) the extent to which the price change for the new product varies from the price change for all other items in the index and; (iii) the weight that needs to be attributed to the product in the index.

41. Three main issues can be identified. First, upon introduction, even though prices can be observed, it may be difficult to introduce the new product into the index due to problems in collecting price data or in obtaining weights. This is sometimes more specifically referred to as new introductions bias. Second, since no price is observed before the product is introduced, the derivation of a price change is impossible. This can be resolved through use of Hicks' reservation price concept⁴⁰ which observes that just prior to introduction there must have been a "reservation" price that was sufficiently high to ensure that no-one purchased the item. A price change could be calculated using the theoretical reservation price and the actual price upon introduction.

42. Third, there are likely to be overall improvements in consumer utility (consumer surpluses) which can be attributed to two factors, (i) increases in the range of brands or types of a particular product (e.g. new brands of televisions)⁴¹ and (ii) the introduction of completely new products (e.g. mobile telephones). The larger choice set created by either factor allows the consumer to achieve the same level of satisfaction at lower cost⁴². It is the lower cost which is not reflected in the index and generates an upward bias. A general term may be consumer surplus bias.

Discussion

43. There seems little doubt that the arrival of new products poses problems for CPI compilers and the solution, in practical terms, is to introduce the new products as quickly as possible. If this can be done before the expenditure weight for the product becomes significant then the effect of bias is minimised. A relevant decision in this respect concerns the European Harmonised Indices of Consumer Prices (HICP) for which the general rule is that new products should be included as soon as they achieve a sales volume of over 1 part per thousand of total consumer's expenditure⁴³. It can also be observed that regular revision of the weights and the CPI basket will assist in reducing the bias associated with new products.

However, if a Laspeyres index is being used there will be residual problems since, in a situation where the weight of the product is increasing rapidly, the index will always understate the weight for the most recent periods.

44. The second and third issues are closely related since the estimation of reservation prices was designed to measure the consumer surplus from the introduction of a new product⁴⁴. Thus the consumer surplus bias mentioned above can be solved using the reservation price technique. Unfortunately, as one might expect, the measurement of unobserved prices is difficult to say the least. Models have been developed, most notably by Hausman and Nordhaus, but the range of commodities investigated is limited⁴⁵. Balk has suggested an alternative approach using a modified version of the constant-elasticity-of-substitution (CES) cost function but this remains to be tested⁴⁶.

45. There are however, some economists who suggest that consumer surplus bias is not as large as may be imagined⁴⁷. In part, its significance is dependent on the change from reservation price to initial market entry price. If this change is small then the resulting consumer surplus would be small, at least for any particular product. This could occur in the case of new brands where it could be argued that the new products act as substitutes for existing goods. Also, it has been noted that some overall offset to the consumer surplus exists since the consumer loss associated with the disappearance of products should be taken into account. However, not all new products are close substitutes for existing products and, if one accepts the reservation price logic and the continually increasing range of products, there is likely to be an overall, upward consumer surplus bias of some magnitude.

46. There is a question of whether consumer surplus bias is relevant to all types of CPI. If a CPI only focuses on market transactions, the price change from unobserved, reservation price to initial market price should be considered out of scope⁴⁸. Thus new products bias may simply be seen as a practical problem of identifying and pricing new products on their introduction without the additional concern of measuring consumer surplus.

Outlet substitution bias

Nature of the bias

47. Outlet substitution bias involves two main considerations. First, there are weighting and scope issues involved when consumers switch their expenditure among existing outlets and between existing and new outlets, and second there are issues of quality change involved in the provision of service by different outlets. The general effect of outlet substitution is to lower the average price paid for a particular product since it is assumed that consumers will move from high to lower cost outlets. Upward outlet substitution bias will occur if index compilers do not correctly acknowledge the shift from higher to lower priced outlets. The bias is usually

associated with the increasing number of new, low cost outlets and thus is often termed new outlet bias. But the logic of the arguments relates directly to substitution between any outlets.

Discussion

48. In the first instance reducing this type of bias is a matter of monitoring where representative prices should be collected. Using this information, two adjustment methods are available. The first is to link the average price from the new outlet mix to the level of the old index. Since this method takes no account of the lower average price it implicitly assumes that all of the fall in price is attributable to a quality difference between outlets. The second method is to treat the whole movement in average prices as price change. This result can also be achieved by using market share information to adjust for outlet change. These methods assume that there are no quality change issues involved.

49. There is a basic assumption that the price of a product will be higher in those outlets which provide more service. As well, the provision of more service, all other things being equal, can be seen as a quality difference between a product sold in different outlets. The switch by consumers to lower cost outlets could therefore imply the consumption of an overall lower quality product. This logic supports the use of the first method described above. However, differences in price level reflect many factors (e.g. transport costs, buying power, outlet location) not only service levels. More importantly, for quality change to be identified there must also be a change in consumer utility. If consumers are indifferent to the varying levels of service between outlets then there can be no perceived quality change and all of the lower average price should be treated as price change. If one makes the assumption that consumers do not deliberately lower their utility through their choice of outlet then the second method seems more applicable. The first method will therefore be upward biased to the extent that this assumption holds.

50. Importantly, this conclusion holds whatever the apparent difference in level of service between outlets. Often the observation is made that different levels of service for the same product actually reflects a different product and hence outlet substitution could be seen as a new products issue. However, this approach appears to significantly complicate the issues involved. Certainly from the point of view of price collection it would mean that the current concept of an elementary aggregate was not applicable and it would be necessary to separately collect sets of prices from similar types of stores for the same good. While differences in service quality may be apparent, from a quality change perspective, the real issue is the effect on consumer utility. If this has not been reduced by switching to a lower service outlet then no quality change can be estimated.

51. Empirical studies of outlet substitution bias are rare. The most well known is by Reinsdorf whose work suggested a small upward bias⁴⁹. However, the results were not statistically significant⁵⁰ and, after further research, Reinsdorf concluded that much of the bias was actually due to problems in the construction of the elementary aggregates, the previously discussed formula bias⁵¹. Estimates for France⁵² also suggest a small upward bias⁵³. Some authors have suggested the possibility of applying hedonic techniques to outlet characteristics as a means of determining the change in consumer utility associated with the existence of lower cost outlets but, overall, further investigation into quality of service issues is required before any conclusions can be drawn. Based on the theoretical discussion bias can be minimised by treating the move to a lower average price as pure price change.

52. It may be the case that the shift to large low cost outlets is a once off phenomenon and that, in general, changes in the locations of consumer purchases will be small over time thus reducing the potential for bias in the index. However, while this may be true from the perspective of traditional retail shopping, the increasing importance of internet, telephone, home shopping and direct to the customer type sales means that it is not a straightforward task to monitor all outlets through which consumers purchase products. Indeed the switch from smaller to larger stores may be the easiest one to recognise.

V. The measurement of bias

Measurement techniques

53. The discussion of the different sources of bias has indicated that in most cases accurate estimation of bias is extremely difficult. To a large extent this is due to the inherent difficulties of measuring quality change and the lack of data available to investigate the many lower level issues that exist. As well, it is reasonable to suggest that further development of the conceptual aspects may be required before significant progress in measurement can be made. Nonetheless, estimates of bias exist.

54. The basic philosophy is to identify the true index and measure deviation from this index. Diewert has provided a list of equations which allow estimation of the true indices under a COL framework⁵⁴ and Shapiro and Wilcox also provide a range of equations⁵⁵. The more "hands-on" approach is estimation of the true index using a variety of different data, for example on the prevalence of new products, new outlets and quality change. In general however, empirical studies of bias require assessments of the economic issues involved and some subsequent back-of-the-envelope calculations to arrive at overall estimates. Judgements on the validity of these different techniques can only be based on detailed examination of the underlying assumptions on a case by case basis and these are not examined here. However, it is noted that different studies tend to emphasise

different sources of bias and few cover the complete range of biases described here. As a result it is difficult to compare different overall estimates of bias. In part this is due to the range of data available for analysis of the different aspects of bias which may be limited in some cases. Complete measurement of bias should be recognised as being a very significant and resource intensive exercise.

55. Bias is usually expressed in terms of the percentage points by which the rate of growth in the CPI under or overestimates the rate of growth in the true index. While bias could be expressed as the average difference in level between the actual and a true index, in most cases a true index cannot actually be estimated as such. Thus measurement of bias is a comparative, time based, exercise which determines what the rate of growth would have been if the various sources of bias had been taken into consideration.

56. An important point to recognise is that bias can be upward or downward. While it seems more likely that the CPI will overstate the rate of price change, it is quite possible for individual sources of bias to be downward biased, particularly in the area of quality change, and thus when analysing bias it is important to remain open-minded about the possibilities. As well, given the inherent uncertainties it seems that the provision of a range rather than a point estimate of bias is more suitable. Also related to the uncertainties involved, it is worth noting that few countries have attempted to measure bias in their CPI⁵⁶, and the number of studies in the United States is certainly exceptional. Indeed, the range of the estimates of total bias for the U.S. points to the measurement difficulties involved⁵⁷.

57. In passing, it is noted that a different approach to the measurement of CPI bias been attempt by Nordhaus and by Krueger and Siskind who have investigated the issue from an income perspective⁵⁸.

Additivity of individual biases

58. Total bias is usually determined as the sum of the bias from different sources. However, a number of commentators are unsure as to whether different sources of bias can be treated as additive. The fact that the Boskin Commission treated quality change and new products as one item points to the difficulties involved and a number of commentators allude to the interdependent nature of sources of bias⁵⁹. However, even though separation of each source of bias is difficult, this does not prove non-additivity. Nonetheless, a lack of independence of each source is of concern in an overall measure. In the event that individual estimates are made, addition would seem to be the only approach to obtaining total bias but the difficulties should be recognised.

Changes in bias over time

59. Since long run analysis of price changes and inflation is required, the question of whether bias changes over time is important. As noted, bias is expressed as a difference in growth rate and consequently, a constant rate of bias does not mean that the effect of bias is constant. Rather, there will be a cumulative effect over time. Minimising the effect of bias therefore requires that every effort should be made to reduce any measured bias as far as possible. It could be argued that if there is only interest in month to month movements the effect of bias is very small. However, the widespread use of CPI data over long periods of time makes bias an issue for most users.

60. The actual changes in bias over time are, however, difficult to determine. There is the theoretical suggestion that upper level substitution bias should increase over time but this has not been proven. There would seem to be some support for the notion that outlet substitution bias would vary at different points in the economic cycle due to increases or decreases in the emergence of new businesses but no studies of this have been completed. There have been general comments that bias is counter-cyclical, i.e. lower when the economy is improving, but again there are no studies which seem to have examined this point. There is some work which indicates that bias would be lower in periods of low inflation. However, overall, while it is not difficult to postulate that bias of any type could change over time and there is little reason why it should always be the same, there is no firm evidence to conclude how bias changes over time.

61. Aside from conceptual issues, perhaps the most important consideration is how changes in the methods of index compilation will affect bias. Cunningham points out that one might expect bias to fall over time as CPI compilers implement improved methodologies⁶⁰ and this is certainly the expectation from the range of changes to the U.S. CPI in recent years. Indeed it would be strange to recommend suggestions to reduce bias if in fact these had no influence on the problem. However, since most CPI are not revised, improved methodology will still leave bias in earlier periods. Continued improvements are nonetheless recommended and it is likely that over time, as some practical steps are introduced and as further strategies are developed, the potential for bias can continue to be reduced.

Other measurement issues

62. Three final issues are considered. The first is the extent to which different population sub-groups, for example, the elderly or the poor, are affected by bias in different ways. The main areas in which this is considered an issue are quality change and new products. To a large extent this problem is related to whether the CPI can reflect the inflation experiences of different sub-groups and to date the case is not clear. Again, as for changing bias over time, it is possible to postulate reasons

for bias affecting different groups in different ways but firm evidence is difficult to find.

63. Second, bias is most likely to be higher when rates of inflation are high. Indeed the economics of the issues involved are also likely to change. All of the analysis completed so far has been for developed economies with relatively low inflation levels. While the issues for CPI construction noted here are likely to be relevant for countries with very high inflation, the significance of issues of bias may well be different. Careful consideration of the factors involved is required.

64. Third, it is important to note that the index bias issues discussed here are not constrained to the CPI. Certainly some are reasonably specific to the CPI but other index numbers, such as producer price indices (PPI), will also be subject to potential bias since the limitations of index numbers, data availability and measuring quality change are very real in all areas of the economy.

VI. Conclusion

65. Bias is an issue of index relevance which examines the difference between a measured index and a true index which reflects some expected view of how the index should behave. Bias focuses on the practical link between the methods used for index compilation and the economic interpretation of real world observations. It should be seen as important not because of the possible inaccuracy of the overall index but because defining the most relevant index possible is a matter of importance. The inability to accurately measure the extent of bias should assist in moving focus away from overall measures of bias and towards the close links between sources of bias and practical choices in index construction. The overall aim therefore should be a better measure of price change and not simply a reduction in bias.

66. Because of the difficulties in measuring bias, general statements on its likely significance cannot be made. Further the need to analyse issues of bias in detail means that significance will depend on the overall importance of individual products. The general assessments from OECD countries made during a review in 1997 indicate that statistical offices do not believe their CPI are significantly biased,⁶¹ however, few comprehensive studies have been conducted. Perhaps more significantly, the OECD review indicated that policy makers did not think that CPI bias was a large problem⁶².

67. In general, an index which regularly updates weights and baskets, considers quality change issues and allows for new products will be more relevant and hence have a reduced potential for bias. However, index compilers should be aware that a fixed basket, fixed weighted index which

does not allow for outlet substitution can lose its relevance if there are rapid changes in the range of products, the quality of products and the range of outlets. The significance of bias may therefore be assessed by examining any data which measure these types of changes in the economy⁶³. Testing the significance of upper and lower level substitution bias requires the comparison of different formula. In the end, the significance of bias is really a judgement on the relevance of the index and can only be assessed on a case by case basis.

68. Whatever the actual significance of bias, the existence of change in the economy and the difficulty of measuring price change creates a clear potential for bias in a CPI. It is the potential for bias which should be minimised and, based on the discussion in this paper, the following seem the most logical steps in this direction.

69. *Upper level substitution bias*: The real time compilation of a Fisher or other similar indices requires further investigation if this bias is to be overcome. Until then, the use of chained Laspeyres indices will reduce the bias at this level although the benefits of annual chained Laspeyres indices are not distinct.

70. *Elementary aggregate bias*: First, it is necessary to examine the nature of prices and the degree of substitution within each elementary aggregate. Then, depending on the results use of either the geometric mean of price relatives formula or the ratio of arithmetic mean prices formula seem preferred. The arithmetic mean of price relatives formula should be avoided. Increased use of scanner data would be a positive development.

71. *Quality change bias*: The potential for bias is clearly increased if no account is taken of quality change. From a practical perspective it is necessary to consider where the largest quality changes are likely to occur and to institute practices which adjust for these changes, taking care that the adjustment itself does not lead to bias. Further development of techniques for adjustment and discussion of possible areas of quality change will help to reduce potential bias.

72. *New products bias*: The practical estimation of reservation prices is not possible at present and more work into accounting for consumer surplus is required. However, this may only be necessary for certain CPI types. It remains to introduce practices which identify and incorporate new products into the CPI in as timely a fashion as possible. Regular revision of baskets and weights will reduce the potential for bias in this area although the limitations of the Laspeyres index should be noted.

73. *New outlets bias*: In the first instance it is necessary to monitor and introduce new outlets and other changes in purchasing patterns. While further work is needed on the nature of quality change involved in outlet substitution, it seems reasonable to conclude that the treatment of the fall

in average prices as a pure price change is the least biased option. Methods which link new average prices to the old index level should be avoided.

74. There are some distinct areas requiring future research. These include the practical application of an upper level formula which accounts for substitution, the development of scanner data, general investigation into quality change and relevant adjustment techniques, further consideration of the measurement of consumer surplus and examination of differences in service levels between outlets. However, investigation into these areas can be considered simply from the point of view of improving the CPI and a direct link to reducing bias is not required. Minimising bias is a question of maintaining the relevance of the index and this should be a goal of all CPI compilers.

ANNEX

Bibliography

The range of issues covered by bias means that almost any research into price indices and CPI creates documents of interest. This bibliography has been structured to allow easier reference to particular documents although most documents fall under the general category of "Estimation of overall bias and critiques". For the individual sources of bias there are a great many papers, particularly on quality change, which have not been cited. Documents marked with an asterisk have not been read in researching this paper. Most represent primary reference material and are noted for the information of readers.

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END NOTES

¹ More formally the Advisory Commission to Study the Consumer Price Index. In December 1996 this commission produced their final report to the United States Senate Finance Committee entitled "Toward a More Accurate Measure of the Cost of Living". Michael Boskin was chairman of the commission and Ellen Dulberger, Zvi Griliches, Robert Gordon and Dale Jorgensen were the other members.

² Most CPIs are not biased in this way. Some issues may arise when considering the treatment of consumer durables within a COL index framework but these have not been assessed to the author's knowledge.

³ At the first level of index definition, questions are also raised concerning the choice of sampling methodology and the choice of population and geographic scope. Such choices are not generally considered to lead to problems of bias and are not considered here but it is noted that there may be issues which warrant consideration.

⁴ This argument may be seen to relate purely to the economic approach to selecting index numbers however a quick check of the basic tests employed in the axiomatic approach shows that the link to real world expectations of price change and index numbers is equally apparent. Axiomatic and economic approaches can be seen as complements rather than alternatives.

⁵ Moulton (1996a) p164

⁶ See Hill (1997) for an explanation of the issues involved in the choice of a symmetric formula.

⁷ Aizcorbe & Jackman (1993) p29

⁸ Génèreux (1983) p497-498

⁹ Génèreux (1983) p498

¹⁰ Used here as an example of an ideal or similar index such as a Tornqvist.

¹¹ Drift can be shown with simple examples, see Szulc (1983) p540-541. See Poinat (1996) for empirical estimation of drift for the French CPI.

¹² Szulc (1983) p556

¹³ Hill (1988) p140

- ¹⁴ See Généreux (1983) and Greenlees (1997a)
- ¹⁵ Greenlees (1997a) p2
- ¹⁶ Greenlees (1997a) p2
- ¹⁷ See Moulton (1996b) and Shapiro and Wilcox (1997)
- ¹⁸ Boskin, et al., (1996) p79
- ¹⁹ Généreux (1983) p500, Ducharme (1997) p16
- ²⁰ Also known as elementary index bias and lower level substitution bias.
- ²¹ Abraham, Greenlees & Moulton (1998) p29
- ²² See for example Dalen (1992) or Diewert (1995)
- ²³ See Fisher's comment quoted in Diewert (1995) p4
- ²⁴ Moulton (1993) p18
- ²⁵ Schultz (1995) p14
- ²⁶ Moulton & Stewart (1997) p8
- ²⁷ Australian Bureau of Statistics (1999) p26
- ²⁸ Szulc (1989) p176
- ²⁹ Dalen (1992) p145
- ³⁰ See for example Silver (1995) Reinsdorf (1996)
- ³¹ See Reinsdorf (1994)
- ³² For more information see Dalton, Greenlees & Stewart (1999)
- ³³ Schultz (1995) p12
- ³⁴ Sabag & Finkel (1993) p11
- ³⁵ Diewert (1996b) p3
- ³⁶ Deaton (1998) p40

³⁷ See Lequiller (1997), Reinsdorf, Leigey & Stewart (1996), Schultz (1995)

³⁸ Fixler (1993) p10

³⁹ The more common term is new goods bias but as this bias is equally applicable to new goods and new services a broader term is thought to be appropriate.

⁴⁰ See Hicks (1940)

⁴¹ Ducharme (1997) refers to this as new brands bias.

⁴² Diewert (1996a) p5

⁴³ Eurostat (1999) p17

⁴⁴ Moulton (1996a) p173

⁴⁵ See Hausman (1994) and Nordhaus (1997)

⁴⁶ See Balk (1999)

⁴⁷ Moulton (1996a) p173

⁴⁸ Hill (1997) p7-8

⁴⁹ See Reinsdorf (1993)

⁵⁰ Bureau of Labor Statistics (1997) p4

⁵¹ Moulton (1996a) p166

⁵² Saglio (1995), Prime & Saglio (1995) and Debeaux & Saglio (1995)

⁵³ Lequiller (1997) p40

⁵⁴ See Diewert (1996b)

⁵⁵ See Shapiro and Wilcox (1996)

⁵⁶ To date overall estimates only exist for the United States, Canada, the United Kingdom and France. For Canada and France these estimates exclude quality change bias which is deemed to be immeasurable.

⁵⁷ The range of estimates for the U.S. is from -0.14 (Baker, 1998) to 2.5 (Darby, 1995) percentage points per year. See Moulton (1996a) p160 for a table of results for the U.S.

⁵⁸ See Nordhaus (1998) and Kreuger & Siskind (1998)

⁵⁹ See Boskin et al. (1996) p33 and Moulton (1996a) p173

⁶⁰ Cunningham (1996) p54

⁶¹ OECD (1997) p9

⁶² OECD (1997) p15

⁶³ See Moulton (1996a) p169 for an example of how this could be done in relation to outlet substitution.
