
12. Errors and Bias in XMPIs

A. Introduction

12.1 A number of sources of error and bias have been discussed in the preceding chapters and will be discussed again in subsequent chapters. The purpose of this chapter is to briefly summarize such sources to provide a readily accessible overview. Both conceptual and practical issues are covered. To be aware of the limitations of export and import price indices (XMPIs), it is necessary to consider what data are required, how they are to be collected, and how they are to be used to obtain overall summary measures of price changes. The production of XMPIs is not a trivial task, and any program of improvement must match the estimated cost of a potential improvement in accuracy against the likely gain. In some instances, one may have to take into account the user requirements necessary to meet specific needs or engender more faith in the index, in spite of the relatively limited gains in accuracy matched against their cost.

12.2 The nature and extent of any errors and bias and the practicalities of reducing them are, to a large extent, dictated by the different data sources used for XMPI compilation. Chapter 2 raised concerns about the bias that can arise from the use of unit value indices based on administrative customs data as proxies for price indices. Chapter 5 outlined the use establishment price surveys, administrative data, and world commodity prices as possible source data for XMPIs. Sections C to G of this chapter outline possible types of error and bias for establishment price survey data, and then revisit these possible types of errors and bias for administrative data in Section H and world commodity price indices in Section I.

12.3 The distinction between errors and bias is first considered in Section B. In sampling, for example, the nature of the sample design (e.g., the use of cutoff sampling; see Chapter 6) may bias the sample toward larger establishments whose average item price changes are below the average of all establishments. In contrast, an unrepresentative sample with disproportionate larger establishments may be selected by chance and similarly

include item prices that are, on average, below those of all establishments. This is *error* because it is equally likely that a sample might have been selected whose average price change was, on average, above those of all establishments.

12.4 Figure 12.1 outlines the potential sources of error and bias in XMPIs. The discussion of bias and errors first requires consideration of the conceptual framework on which XMPIs are to be based and the XMPIs' related use(s). This will govern a number of issues, including the decision as to the coverage or domain of the index and choice of formula. Errors and bias may arise if the coverage, valuation, and choice of the sampling unit fail to meet a conceptual need; this is discussed in Section C.

12.5 Section D examines the sources of errors and bias in the sampling of transactions. The sampling of item prices for XMPIs can be undertaken in three stages: the sampling and selection of products to be priced, the sampling of establishments producing the selected products, and the subsequent sampling of items produced (or purchased) by those establishments. Bias may arise if the products, establishments, or items selected exhibit, on average, unusual price changes. Such bias may be due to omissions in the sampling frame or a biased selection from the frame.

12.6 However, sampling error, as discussed above and in Chapter 6, can arise even if the selection is random—from an unbiased sampling frame. Sampling error will increase as the sample size decreases and as the variance of prices increases. Sampling error arises simply because estimated XMPIs are based on samples, as opposed to a complete enumeration of the populations involved. Probabilistic estimates of sampling error can be undertaken. The errors and biases discussed in Section D are for the sample on initiation.

12.7 Section E is concerned with what happens to sampling errors and bias in subsequent matched price

comparisons. Once the samples of products, establishments, and their items have been selected, they will become increasingly out of date, unrepresentative, and quite possibly biased, as time progresses. The extent and nature of any such bias will vary from industry to industry. The effect of these dynamic changes in the universe of products, establishments, and the items produced on the static, fixed sample is the subject of Section E. Sample rotation will act to refresh the sample of items, while rebasing may serve to initiate a new sample of items, products, and establishments. Following rebasing, establishments will close, and items will no longer be produced, on a temporary or permanent basis. Sample augmentation and replacement attempt to forestall some of the degradation of the sample of products and establishments, although replacement occurs only when an establishment is missing. Sample augmentation tries to bring into the sample new major products and establishments. It is a more complicated process because the weighting structure of the industry or index has to be changed (Chapter 9). When item prices are missing, the sampling of items may become unrepresentative. Imputations can be used, but they do nothing to replace the sample. In fact, they lower the effective sample size, thereby increasing sampling error. Alternatively, comparable replacement items or replacements with appropriate quality adjustments may be introduced. As for new goods providing a substantively different service, the aforementioned difficulties of including new establishments extend to new goods, which are often neglected until rebasing. Even then, their inclusion is quite problematic (Chapter 9).

12.8 The discussion above has been concerned with how missing establishments and items may bias or increase the error in sampling. But the normal price collection procedure based on the matched-models method may have errors and bias as a result of the prices collected and recorded being different from those transacted. Such response errors and biases, along with those arising from the methods of treating temporarily and permanently missing items and goods, are outlined in Section F as errors and bias in price measurement. Section F is concerned with deficiencies in methods of replacing missing establishments and items so that the matched-models method can continue, while Section E is concerned with the effect of such missing establishments and items on the efficacy of the sampling procedure.

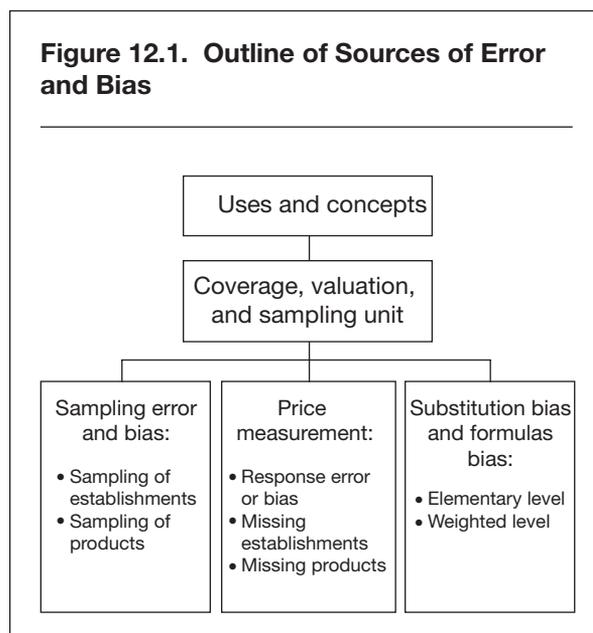
12.9 The final types of bias, outlined in Section G, are formula and substitution bias. Different formulas, as shown in Chapters 16 through 18, have different axiomatic properties and formulas that do not meet some

of these desirable properties can be considered to be biased. For example, if a formula, when measuring price changes between periods 0 and t , has the property that it will exceed unity when the prices are unchanged between these two periods, then it can be deemed to be biased upwards. Formulas can also be shown to be “exact” if they replicate different behavioral assumptions. For example, producers may substitute production (purchases) toward (away from) items whose price changes are above average. A Laspeyres fixed-weight formula would not be exact because it requires that the basket be held fixed in period 0—Leontief preferences. At the higher level of aggregation, where weights are used, substitution effects are shown to be included in superlative formulas but excluded in the traditional Laspeyres formula (Chapter 16). Similar considerations are discussed in Chapter 21 for the lower level. Whether it is desirable to include such effects depends on the concepts of the index adopted. A pure fixed-base period concept would exclude such effects, while an economic cost-of-living approach (Chapters 18 and 20) would include them. The concepts in Figure 12.1 can be used to address definitional issues such as coverage, valuation, and sampling as well as price measurement issues such as quality adjustment and the inclusion of new goods and establishments.

12.10 It is worthwhile to list the main sources of errors and bias:

- (1) Inappropriate coverage and valuation (Sections C and I);

Figure 12.1. Outline of Sources of Error and Bias



- (2) Sampling error and bias, including
 - (a) Sample design on initiation (Section D), and
 - (b) Effect of missing items and establishments on sampling error (Section E);
- (3) Matched price measurement (Sections F and H), including
 - (a) Response error/bias,
 - (b) Quality adjustment bias,
 - (c) New goods bias, and
 - (d) New establishments bias; and
- (4) Substitution bias and formula bias (Sections G and H), including
 - (a) Upper-level item and establishment substitution,
 - (b) Lower-level item and establishment substitution, and
 - (c) Formula bias.

12.11 It is not possible to judge which sources are the most serious. In some countries and industries, the increasing differentiation of items and rate of technological change make it difficult to maintain a sizable, representative matched sample, and issues of quality adjustment and the use of chained or hedonic indices might be appropriate. In other countries, a limited coverage of economic sectors in which the XMPI is used might be the major concern. Inadequacies in the sampling frame of establishments might also be a concern.

12.12 Although the above outline of sources of errors and bias has been written in the context of surveys of establishments as the source data, much is applicable to administrative sources data and world commodity price data, the subject of Sections H and I, respectively.

12.13 There is no extensive literature on the nature and extent of errors and bias in XMPI measurement. Berndt, Griliches, and Rosett (1993) is a notable exception, though their concern was with producer price indices (PPIs). However, there is substantial literature on errors and bias in consumer price index (CPI) measurement, and Diewert (1998a and 2002c) and Obst (2000) provided a review and extensive reference list. Much of this literature includes problem areas that apply to XMPIs as well as CPIs.

B. Errors and Bias

12.14 In this section, a distinction is made between *error* and *bias*. The distinction is more appropriate to

the discussion of sampling, although the same framework is shown to apply to nonsampling errors and bias. Yet an error or bias can also be discussed in terms of how an existing measure corresponds to some true concept of a XMPI and will vary depending on the concept advocated, which in turn will depend on the use(s) required of the measure. These issues are discussed in turn.

B.1 Sampling error and bias

12.15 Consider the collection of a random *sample* of prices whose overall population average (arithmetic mean) is μ .¹ The *estimator* is the method used for estimating μ from sample data. An appropriate estimator for μ is the mean of a sample drawn using a random design. An *estimate* is the value obtained using a specific sample and method of estimation, let us say \bar{x}_1 , the sample mean. The population mean μ , for example, may be 20, but the arithmetic mean from a random sample of a given size drawn in a specific way may be 19. This difference is *error*, not *bias*; it is simply by chance that a random sample was drawn with, on average, below-average prices. If an infinite number of samples were drawn using sufficiently large samples, the average of the $\bar{x}_1, \bar{x}_2, \bar{x}_3, \dots, \bar{x}_\infty$ sample means would in principle equal μ . The estimator is said to be *unbiased*; if it is not, it is called *biased*. The error caused by \bar{x}_1 being different from $\mu = 20$ did not arise from any systematic under- or overestimation in the way the sample was drawn and the average calculated. If an infinite number of such estimates were drawn and summarized, no error would be found, the estimator not being biased and the discrepancy being part of the usual expected sampling error.²

12.16 It should be stressed that any one sample may give an inaccurate result, even though the method used to draw the sample and calculate the estimate is, on average, unbiased. Improvements in the design of the sample, increases in the sample size, and less variability in the prices (more detailed price specifications for the price basis) will lead to less error, and the extent of such improvements in terms of the sample's probable accuracy is measurable. Note that the accuracy of

¹For simplicity, the discussion is in terms of prices and not price changes.

²This is *sampling error*, which can be estimated as the differences between upper and lower bounds of a given probability, more usually known as *confidence intervals*. Methods and principles for calculating such bounds are explained in Cochran (1977), Singh and Mangat (1996), and most introductory statistical texts. Moser and Kalton (1971) provided a good account of the different types of errors and their distinction.

such estimates is measured in principle by confidence intervals, that is, probabilistic bounds in which μ is likely to fall. Smaller bounds at a given probability are considered to be more precise estimates. It is in the interest of statistical agencies to design their sample and use estimators in a way that leads to more precise estimates.

12.17 The calculation of such intervals is more straightforward if based on a measure of the variance of price relatives from a random sample design at all stages. The sampling of prices for XMPIs generally do not involve the sampling of establishments and items using probabilistic methods, at least at each stage. Judgmental and cutoff methods are often considered to be more feasible and less resource intensive. Yet it is feasible to develop partial (conditional) measures in which only a single source of variability (stage of sampling) is quantified (see Balk and Kerston, 1986, for a CPI example). Alternative methods for nonprobability samples were discussed in Särndal, Swensson, and Wretman (1992).

12.18 *Efficiency* gains (smaller sampling errors) may be achieved for a given sample size and population variance by using better *sample designs* (methods of selecting the sample) as outlined in Chapter 6. Yet it may be that the actual selection probabilities deviate from those specified in the sample design. Errors arising from such deviations are called *selection errors*.

12.19 Whereas an unbiased estimator may give imprecise results, especially if small samples are used, a biased estimator may give quite precise results. Consider the sampling from only large establishments. Suppose such prices were, on average, less than μ , but assume these major establishments covered a substantial share of the revenue of the industry concerned; then the mean of the estimates from all such possible samples \underline{m} may be quite close to μ , even if smaller establishments had different prices. However, the difference between m and μ would be of a systematic and generally predictable nature. On average, m would exceed μ , the bias³ being $(\mu - m)$.

B.2 Nonsampling error and bias

12.20 The above framework for distinguishing between errors and biases is also pertinent to nonsampling error. If, for example, the prices of items are incorrectly

³Because μ is not known, estimates of sampling error are usually made; they are but one component of the variability of prices around μ .

recorded, a response error results. If such errors are *unsystematic*, then prices are overrecorded in some instances but, counterbalancing this, underrecorded in others. Overall, errors in one direction should cancel out those in the other, and the net error, on average, will be expected to be small. If, however, the establishments selected and kept in the sample are older and produce at higher (quality-adjusted) prices than their newer, high-technology equivalent establishments, then there is a systematic bias. The results are biased in the sense that if an infinite number of similar random samples of older establishments were taken from the population of establishments, the average or expected value of the results would differ from the true population average, and this difference would be the bias. The distinction is important. Increasing the sample size of a biased sample, of older establishments for example, when samples are rebased, reduces the error but not the bias.

12.21 This distinction between errors and bias is for the purpose of *estimation*. When one uses the results from a sample to estimate a population parameter, both error and bias affect the accuracy of the results. Yet there is also a distinction in the statistical literature between types of errors according to their *source*: sampling versus nonsampling (response, nonresponse, processing, etc.) error. Although they are both described as errors, the distinction remains that if their magnitude cannot be estimated from the sample itself, they are biases, and some estimate of μ is required to measure them. If they can be estimated from the sample, they are errors.

B.3 Concepts of a true or good index

12.22 The discussion of errors and bias so far has been in terms of estimating μ as if it were the required measure. This has served the purpose of distinguishing between errors and bias. However, much of this *Manual* has been concerned with the choice of an appropriate index number formula. It is now necessary to consider bias in terms of the difference between the index number formula and methods used to calculate the XMPIs, and some concept of a true index. In Chapter 18, true theoretical indices will be defined from economic theory. The question is, if producers behave as optimizers and switch production toward products with relatively high price increases, which would be the appropriate formula to use? The result will be seen to be a number of *superlative* index number formulas. They do not include the Laspeyres index or the Young index (Chapter 16), which give

unduly low weights to products with relatively high price increases, because no account is taken of substitution effects (see Chapter 18). For industries whose establishments substitute production toward items and products with above-average price increases, Laspeyres is biased downward. An understanding of bias thus requires a concept of a true index. Superlative indices make more reasonable assumptions about the optimizing (substitution) behavior of economic agents than do the Leontief preferences implicit in Laspeyres.

12.23 A good index number formula can be defined by axiomatic criteria as outlined in Chapter 17. The Young and Carli indices, for example, were argued to be biased upward because they failed the time reversal test: The product of the indices between periods 0 and 1 and periods 1 and 0 exceeded unity.

12.24 In XMPI number theory and practice there are quite different conceptual approaches. On the one hand, there is the revenue-maximizing concept of the output export price index and on the other the cost minimizing assumptions of the input import price index. Against these, there is the fixed-basket approach.⁴ An index based on the latter approach would not suffer, in the strictest sense of the concept, from the biases of substitution (formula) or new goods because the concept is one of measuring the prices of a *fixed* basket of goods. However, it may be argued on the grounds of representativeness that the baskets should be updated and substitution effects incorporated.

C. Use, Coverage, and Valuation

12.25 Errors and biases can arise from the inappropriate use of XMPIs, regardless of the methodology used to compile them. Because price changes can vary considerably from product to product, the value of the price index will depend partly on which products or items are included in the index and how the item prices are determined (Chapter 16, Section B.1). In Chapter 4, different uses of XMPIs were mentioned and aligned with different domains and valuation principles. Thus, the discussion of errors and biases starts with a need to decide whether the coverage and valuation practices are appropriate for the purposes required.

12.26 The bias and errors of XMPIs depend on the uses to which they are put so, first, some major uses

are noted, and the domain or coverage of the indices is considered. Second, the principles of valuation are reiterated.

C.1 Uses and coverage

12.27 The input import price index (MPI) is a short-term indicator of inflation. It tracks potential inflation as price pressure builds up for imported goods and services that enter the factory gate. Input PPIs can be disaggregated into MPI and the input price index from resident producers. Similarly, output PPIs can be disaggregated into the export price index (XPI) and the PPI for outputs to domestic markets. Together such indices provide analytical tools to help identify the sources of inflationary pressure and the effects of changes in the term of trade. There may be deficiencies in the coverage of XMPIs. If, for example, an XPI is restricted to the industrial sector, this is a source of error when examining the overall inflation, if price changes for other sectors differ from the industrial sector.

12.28 The XMPIs may be biased when used for national accounts deflation. First, their coverage may be inadequate yet still be used by national accountants. For example, if only manufacturing XMPIs are used to deflate industrial trade flows, and price changes from the missing, quarrying, and construction sectors differ in the aggregate from those of manufacturing, there is a bias. The undercoverage bias is in the use of the index, not necessarily in its construction, although statistical agencies should be sensitive to the needs of users. Second, overcoverage bias means some elements are included in the survey that do not belong to the target population. The bias surfaces if their price changes differ on aggregation from the included ones. Third, the classification of activities for the XMPI should be at an appropriately low level of disaggregation, and the system of classification should be the same as that required for the production and trade accounts under the Commission of the European Communities and others (2008) *System of National Accounts 2008 (SNA 2008)*.

12.29 Highly aggregated XMPIs are used for the macroeconomic analysis of inflation. Certain industries or products with volatile price changes may be excluded. Such indices may be excluded because they introduce substantial sampling error into the aggregate indices, and their exclusion helps with the identification of any underlying “core” trend.

⁴A discussion of the debate can be found in Triplett (2001).

12.30 The preceding discussion has considered the coverage or domain of the index in terms of the activities included. However, such issues also may extend to the geographic scope. The exclusion of establishments in rural areas, for example, may lead to bias if their price changes differ from those in urban areas. Such issues are considered in Sections D and E.

C.2 Valuation

12.31 In Chapters 4, 15, and 20, valuation issues are outlined. The appropriate valuation principle to adopt depended on the use of the XMPI. A resident producer's perspective was identified as appropriate for the use of terms of trade measurement, transmission of inflation, and productivity analysis. The valuation of an (output) XPI from a resident producer's perspective involves valuing output at basic prices with any value-added tax or similar deductible tax, invoiced to the purchaser, excluded. Such tax revenues go to the government and should be excluded because they are not part of the establishment's receipts. Transport charges and trade margins invoiced separately by the producer should also be excluded. An (input) MPI from a resident producer's perspective should value intermediate inputs with nondeductible taxes included, because they are part of the actual costs paid by the establishment. For MPIs, changes in the tax procedures—say, owing to a switch to import duties on intermediate inputs, for example—can lead to bias. In such instances, ex-tax or ex-duty indices might be produced. In any event, it is necessary to ensure that establishments treat indirect taxes in a consistently appropriate way, especially when such tax rates fluctuate. A nonresident producer's perspective requires that exports are valued at purchaser's prices and imports at basic prices. However, there are pros and cons to the consistent use of purchaser's prices and basic prices for supply and use tables in volume terms, as discussed in Chapter 4 and Chapter 15 of the *2008 SNA*. Even with these principles established and a purpose in mind, if data are from customs sources, imports are valued c.i.f. (i.e., they include the cost of carriage, insurance, and freight) at the point of entry into the importing economy and exports are valued f.o.b (free on board) at the point of exit from the exporter's economy. As outlined in Chapter 4, neither of these may meet the analytical needs for the purposes outlined above.

D. Sampling Error and Bias on Initiation

12.32 In Chapter 6, appropriate approaches to sample design were outlined. The starting point for potential bias in sample design is an inadequate

sampling frame. It is one of the most pernicious sources of error because the inadequacies of a sampling frame are not immediately apparent to users. Yet a sampling frame biased to particular sizes of establishments or industrial sectors will yield a biased sample irrespective of the probity of the sample selection. Because sampling is generally in three stages—the sampling of products, establishments producing those products, and the items within such establishments—a sampling frame is required for products, establishments, and items within establishments. The sampling frame for items within establishments relies on the establishment producing data on the revenues, quantities, and prices (or revenue per unit of output) for the items produced. Bias may arise here, perhaps because some components produced are priced and recorded elsewhere, say at the head office. The sampling of establishments requires a procedure to identify exporters and importers. In some countries, licensing bodies or trade associations may provide systematic files. Alternatively, if the customs documents identify the exporter or importer and this information can then be matched to a directory of businesses, then this is likely to provide a more reliable frame, which may also take account of the value of exports and imports for stratification. In some categories, such as imports of cigarettes, there may be many, possibly illegal, importers not covered by such identification procedures. The sampling frame for products can be taken from disaggregated Harmonized System of Commodity Classification Coding (HS) categories customized to the needs of the country. Exports, unlike imports, are usually concentrated in a relatively small number of classification categories particular to the economy of the country concerned. It should be kept in mind that even when purposive sampling is used, there is an implicit frame from which the respondent selects items. It should be clear to the respondent what the frame should be.

12.33 The selection of the sample of establishments from the sampling frame should be random or, failing that, purposive. In the latter case, the aim should be to include major items whose price changes are likely to represent overall price changes. Chapter 6 provided a fairly detailed account of the principles and practice of sample selection and the biases that may ensue. The distinction has already been drawn between *bias* and *sampling error*, and the possibility has been raised that unbiased selection will be accompanied by estimates with substantial error, owing to high variability in the price (change) data and relatively low sample sizes.

E. Sampling Error and Bias: The Dynamic Universe

12.34 Chapters 8 and 9 also considered sampling issues. Under the matched-models method, prices will be missing in a period if the item is temporarily or permanently out of production. If overall imputations are used to replace the missing prices, the sample size is being effectively reduced and the sampling error increased. In a comparison between prices in period 0 and period t , imputation procedures (Chapter 8) ignore the prices in period 0 of items whose prices are missing in period t . If such old prices of items no longer produced differ from other prices in period 0, there is a bias owing to their exclusion. Similarly, new items produced after period 0, and thus not part of the matched sample, are ignored; if their prices in period t differ, on average, from the prices of matched items in period t , there is a bias. Sampling error and bias, therefore, may arise owing to the exclusion of prices introduced after initiation and dropped when they go missing. The need for the sample to be representative of the dynamic universe is over and above any errors and bias in the sample design on initiation.

12.35 As the sample of establishments and items deteriorates, rebasing the index—to update the weights and sample of establishments and items or the rotation of sample items—becomes increasingly desirable. However, rebasing involves costly and irregular procedures and, for some industries, more immediate steps are required. Rebasing and sample rotation are used to improve the sampling of establishments and items. Strategies for dealing with missing establishments and missing prices also have an effect on the sampling of establishments and items. Such strategies involve introducing *replacement* establishments and items that replenish the sample in a more limited way than do rebasing and sample rotation. Quality adjustments to prices are required if the replacement establishment or item differs from the missing ones, although this is the concern of price measurement bias in Section F. New establishments and goods may also need to be incorporated into the sample to avoid sampling bias. There is a need in such instances to *augment* the sample. Such augmentation may require a change to the weighting system and, as discussed in Chapter 9, should be undertaken only when the incorporation of major new establishments or goods is considered necessary. Thus, bias in sampling owing to differences between the dynamic universe and the static one on initiation may, to some

extent, be mitigated by sample replacement and augmentation (Chapter 9).

12.36 Circumstances may arise in which there is a serious sample deterioration owing to missing items as differentiated items rapidly turn over. In such cases, hedonic indices or chaining based on resampling the universe each month was advised in Chapter 8, Section G.

F. Price Measurement: Response Error and Bias, Quality Change, and New Goods

F.1 Response error and bias

12.37 Errors may happen if the reporting or recording of prices is inaccurate. If the errors occur in a systematic manner, there will be bias. The item descriptions that define the price basis should be as tightly specified as is reasonably possible, so that the prices of like items are compared with like. Allowing newer models to be automatically considered comparable in quality introduces an upward bias if quality is improving. Similar considerations apply to improvements in the quality of the service that accompanies an item. The period to which the prices relate should be clearly indicated, especially where prices vary over the month in question and some average price is required (Chapter 7). Errors in valuation can be reduced by clear statements of the basis of valuation and discussions with respondents if the valuation principles of their accounting systems differ from the valuation required. This is of particular importance when there are changes in tax rates or systems. Diagnostic checks for extremely unusual price changes should be part of an automated quality assurance system, and extreme values should be checked with the respondent and not automatically deleted. For example, a change in the currency in which the price is quoted, or from transaction to list price, can lead to unusual price changes that, on detection, can be remedied. Price collectors should visit establishments on initiation and then periodically as part of a quality assurance auditing program (see Chapter 13).

12.38 For unit value indices from customs data, information on the customs declarations may be inaccurate (Chapter 2). The information on quantities shipped may be in the wrong units or simply missing. Such data should be validated by recourse to the establishment or some independent data source such as world commodity prices.

F.2 Quality change bias

12.39 Bias can arise, as discussed in Section E, because newly introduced items do not form part of the matched sample, and their (quality-adjusted) prices may differ from those in the matched sample. This *sampling* bias from items of improved quality and new goods was the subject of Section E. It was also noted that statistical agencies may deplete the sample by using imputation or use replacements to replenish the sample. The concern here is with the validity of such approaches for price measurement, not their effects on sampling bias.

12.40 In Chapter 8, a host of explicit and implicit quality adjustment methods were outlined. From a practical perspective, the quality change problem involves trying to measure price changes for a product that exhibited a quality change. The old item is no longer produced, but a replacement one or alternative is there. If the effect of quality on price is, on average, either improving or deteriorating, then a bias will result if the items are compared as if they were of the same quality, when they are not. An explicit quality adjustment may be made to the price of either of the items to make them comparable. A number of methods for such explicit adjustments were outlined in Chapter 8, including expert judgment, quantity adjustment, option and production costs, and hedonic price adjustments. If the adjustments are inappropriate, there will be errors and, if the adjustments are inappropriate in a systematic direction, there will be a bias. For example, using quantity adjustments to price very small lots of output, for which customers pay more per unit for their convenience, would yield a biased estimate of the price adjustment owing to quality change (Chapter 8, Section E.2).

12.41 There are also implicit approaches to quality adjustment. These include the overlap approach, overall and targeted mean imputation, class mean imputation, comparable substitution, spliced to show no price change, and the carry-forward approach. Imputations, whereby the price changes of missing items are assumed to be the same as those of the overall sample or some targeted group of items, are widely used. Yet such approaches increase error through the drop in effective sample size and may lead to bias if the items being dropped are at stages in their life cycle where their pricing differs from that of other items. Such bias is usually taken to overestimate price changes (Chapter 8, Section D).

12.42 The choice of appropriate quality adjustment procedure was argued in Chapter 8 to vary among

industries to meet their particular features. There are some products, such as consumer durables, materials, and high-technology electronic products, in which the quality change is believed to be significant. If such products have a significant weight in the index, overall bias may arise if such changes are ignored or the effects of quality change on price are mismeasured. Whichever of the methods are used, an assumption is being made about the extent to which any price change taking place is due to quality; bias will ensue if the assumption is not valid.

12.43 The problem of quality change is more serious for unit value indices based on customs data. In this case any changes in the mix of the qualities shipped between periods leads to bias in the index. For example, two models of a make of automobile may be imported from a company. If the proportion shipped of the more expensive model increases between the two periods compared, the unit value index will overstate the price change (Chapter 2).

F.3 New-goods bias

12.44 Over time, new goods (and services) will appear. These may be quite different from what is currently produced. An index that does not adequately allow for the effect on prices of new goods may be biased. Introducing new goods into an index is problematic. First, there will be no data on weights. Second, there is no base-period price to compare the new price with. Even if the new good is linked into the index, there is no (reservation) price in the period preceding its introduction to compare with its price on introduction. Including the new good on rebasing will miss the price changes in the product's initial period of introduction, and it is in such periods that the unusual price changes are expected if the new good delivers something better for a given or lower price. Similar considerations apply to new establishments (Section G.4). New-goods and new-establishment bias is assumed to overstate price changes, on average.

F.4 Temporarily missing bias

12.45 The availability of some items, such as fruits and vegetables imported for canning, fluctuates with the seasons. A number of methods are available to impute such prices during their missing periods. Bias has been shown to arise if inappropriate imputation approaches are used. Indeed, if seasonal items constitute a large proportion of revenue, it is difficult to give meaning to month-on-month indices, although comparisons

between a month and its counterpart in the next year will generally be meaningful (see Chapter 23).

G. Substitution Bias

12.46 Given the domain of an index and the valuation principles, the value of the revenue accruing to the establishment can be compared over two periods, say, 0 and 1. It is shown in Chapter 16 that the change in such values between periods 0 and 1 can be broken down into two components: the overall price and overall quantity change. An index number formula is required to provide an overall, summary measure of the price change. In practice, this may be undertaken in two stages. At the higher level, a weighted average of price changes (or change in the weighted average of prices) is compiled with information on revenues (quantities) serving as weights. At the lower level, the summary index number formulas do not use revenue or quantity weight, and use only price information to measure the elementary aggregate indices of average price changes (or changes in average prices). It is recognized that in many industries weights are available at the lowest item level and the lower-level problem does not exist. Five approaches are used in Chapters 16 through 18 to consider an appropriate formula at the higher level; a similar analysis is undertaken for lower-level elementary aggregate indices in Chapter 21.

G.1 Upper-level substitution bias

12.47 Different formulas for aggregation have different properties. At the upper-weighted level, substantial research from the axiomatic, stochastic, Divisia, fixed-base, and economic approach has led to an understanding of the bias implicit in particular formulas. Chapters 16 through 18 discuss such bias in some detail. The Laspeyres formula is generally considered to be used for XMPI construction for the practical reason that it does not require any current-period quantity information. It is also recognized that the appropriate deflator that generates estimates of output at constant prices is a Paasche one (Chapter 19). Thus, if estimates of a series of output (including that aimed at the export market) at constant prices is required, the use of the Laspeyres deflator will result in bias. In practice, for a price comparison between periods 0 and t , period 0 revenue weights are not available and a Young index is used, which weights period 0 to t price changes by an earlier period b revenue shares. Chapter 16 finds this index to be biased. Superlative index number formulas, in particular the Fisher and Törnqvist indices, have good axiomatic properties and can also be justified using

the fixed-base, stochastic, and economic approaches. Indeed, Laspeyres can be shown to suffer from *substitution* bias if particular patterns of economic behavior are assumed. For example, producers may seek to maximize revenue from a given technology, and inputs may shift production to items with above-average relative price increases. The Laspeyres formula, in holding quantities constant in the base period, does not incorporate such effects in its weighting, giving unduly low weights to items with above-average price increases. Therefore, it suffers from a downward bias. It can be similarly argued that the fixed, current-period weighted Paasche index suffers from an upward bias, whereas the Fisher index is a symmetric mean of the two, falling within these bounds. Calculating the Fisher index retrospectively on a trailing basis will give insights into upper-level substitution bias.

12.48 The extent of the bias depends on the extent of the substitution effect. The Laspeyres index is appropriate if there is no substitution. However, the economic model assumes that the technology of production is the same for the two periods being compared. If, for example, the factory changes its technology to produce the same item at a lower cost, the assumptions that dictate the nature and extent of the bias break down.

G.2 Lower-level substitution bias

12.49 In some countries or industries, elementary aggregate indices at the lower level of aggregation that use only price information are constructed. The prices are aggregated over what should be the same item. In practice, however, item specifications may be quite loose and the price variation between items being aggregated quite substantial.

12.50 The axiomatic (test), stochastic, and economic approaches can also be applied to the choice of formula on this lower level (Chapter 21). The Carli index, as an arithmetic mean of price changes, performed badly on axiomatic grounds and is not recommended. The Dutot index, as a ratio of arithmetic means, was shown to be influenced by the units of measurements used for price changes and is not advised when items do not meet tight quality specifications. The Jevons index, as the geometric mean of price changes (and equivalently, the ratio of geometric means of prices), performed well when tested by the axiomatic approach and, assuming sampling proportionate to stable—unitary elasticity—revenue share, incorporates a substitution effect. But the substitution effect goes the opposite way of that predicted by

the aforementioned economic model. For a consumer price index, the economic model is one of consumers substituting *away* from items with above-average price increases so more of the relatively cheaper items are purchased. Constant revenue shares is an appropriate assumption in these circumstances. However, producer theory requires producers to substitute *toward* items with above-average price increases, and assumptions of equal revenues are not tenable. Chapter 21 details a number of formulas with quite different properties. However, it concludes that because the axiomatic, stochastic, fixed-base, and economic approaches, as noted in Section G.1, find superlative index numbers to be superior (Chapters 16 to 18), a more appropriate course of action is to attempt to use such formulas at the lower level, rather than replicate their effects using only price data, a task to which they are unsuited. Respondents should be asked to provide revenue or quantity data as well as price data. Failing that, appropriate index number formulas are advocated depending on the expected nature of the substitution bias.

G.3 New-establishment (substitution) bias

12.51 The need to include new establishments in the sample has already been referred to in Section E. Products produced by new establishments may not only have different (usually lower) prices, arguing for their inclusion in the sample, but gain increasing acceptance as purchasers substitute goods from new establishments for goods from old establishments. Their exclusion may overstate price changes owing to substitution bias.

G.4 Formulas bias

12.52 Formulas bias can arise because of the properties of the index number formulas used. For example, as explained in Chapter 21, the Carli index number formula, the unweighted arithmetic mean of price ratios, fails the time reversal test. The product of a Carli index between periods 0 and 1, and between periods 1 and 0, exceeds unity; it is upward biased. In Chapter 17 desirable properties or *axioms* are outlined for index numbers, and the failure of some of these properties is such that the use of such formulas can be regarded as leading to bias. In some cases, a formula that is otherwise generally accepted may be biased when applied to data with particular characteristics. For example, Chapters 20 and 23 show how a chain price index can drift when applied to volatile data such as highly seasonal data.

H. Administrative Data

12.53 Chapter 5 outlined alternative data sources including the use of administrative data, that is, data taken from other administrative sources derived to serve other purposes, but useful for XMPI compilation. The primary source for such data is customs data. Such data must also be evaluated in terms of its sources of errors and bias. In particular, as discussed in Chapter 2, there is likely to be a problem with making matched price comparisons owing to the reliance on unit values. XMPIs compiled from customs data use unit values as the “prices” of goods exported and imported. The unit value is calculated for detailed headings of the HS. Yet there is scope for variation in the mix of what is imported and exported in each month, and the product descriptions on customs documents may be insufficient to even identify the change in mix. For example, a change in the quantity of higher-priced items in a load from one month to the next may be misrepresented as an increase in prices. Of critical importance is the variation in prices over the items in the customs specification. If there is no variation, the goods are homogeneous and unit values are appropriate. Many times, this will not be the case.

12.54 There may be problems of coverage. Much of the internationally traded service industry and transactions between countries (or trading zones within countries) with whom the country has a free-trade agreements may not be covered. Such coverage problems primarily arise if administrative customs data are used as the sole source of data. However, such coverage problems can be ameliorated by use of establishment-based survey data, though sampling and nonresponse issues may arise.

12.55 There is also a problem with regard to valuation. Customs data value imports usually with freight and insurance included as they cross the importing country’s frontier, but exports, while recording values f.o.b., are valued as they leave the exporting country rather than when they arrive at the importing country. The requirement, as outlined in Chapters 4 and 15, is for the valuation to take place when there is a change of ownership with the precise principle for valuation being related to the use of the XMPIs and whether a resident’s or nonresident’s perspective is adopted.

12.56 Even if the contents of each load are homogeneous within an HS, there may be response bias, owing to a tendency in product groups for which tariff duties are high to undervalue specific imports and exports.

Many high-value goods are built to customers' specifications and will not be found in subsequent months for accurate price comparisons.

I. World Commodity Prices

12.57 Data on import and export price changes may be drawn from world commodity price indices on the assumption that the market for such prices is sufficiently competitive that world price changes, at least, are similar to those of the compiling country. Thus, it may be recognized that prices in the importing country are above world trade levels, say owing to higher transport costs from the countries of origin. What is assumed, however, is that price changes will be similar.

12.58 The use of world commodity price indices as a data source has some appeal. They are generally readily and freely available, and this is usually on a timely basis. They are more suitable for imports (and exports) of homogeneous commodities purchased (produced) by many small importers (or resident producers). A number of potential sources of error should be noted.

12.59 First is the coverage of the data. The compiling organization, usually a trade association, should be contacted to ensure that the data cover all exports and imports and, if not, whether the price indices relating to the excluded trade flows are likely to differ from the included ones and, more particularly, whether they are likely to differ from the price changes of the compiling country. It may be the case that separate indices are available for separate regions (or even countries); if so, commodity price indices for regions with similar expected price changes should be sought.

12.60 Second is the definition of the price series. It is necessary to establish that the commodity, or the mix of commodities, covered by the index relates to

those traded by the compiling country. Different commodities may be imported or exported at different levels of quality and have different physical or financial "treatments" to, say, preserve or insure their contents during a possibly long transportation. Transport costs can be estimated to identify whether, for example, they are likely to have different changes for imports to the compiling country than the world at large and, if so, adjustments can be made.

12.61 Third is the aggregation procedure. In Chapters 16 to 21, alternative index number formulas for aggregating price changes are outlined. Some of the formulas are shown to have better properties than others, and some are shown to have demonstrable bias. It is important to ascertain whether the formulas used for world trade price indices are subject to such biases.

12.62 Fourth, there is a specific concern here that world commodity price indices act as import price indices.

12.63 A more reliable data source than world trade price indices will usually be the resident distributor, because such data require no assumption of invariance of price changes for the country purchasing (producing) the commodities. However, if there are problems obtaining data from such distributors, or if the data are in doubt, world commodities indices, at the very least, provide a benchmark against which to evaluate data from domestic businesses.

12.64 The sections above are merely an overview of the sources of error and bias and are not intended to be either exhaustive or detailed accounts. The detail is to be found in the individual chapters concerned. The multiplicity of such sources argues for statistical agencies undertaking audits of their strengths and weaknesses and formulating strategies to counter such errors and bias in a cost-effective manner.