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Export and Import Price Indices

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Export and import price indices are essential for assessing the impact of international trade on the domestic economy. Among their most important uses are analyzing developments in the trade balance, measuring foreign prices' contribution to domestic inflation, and deflating nominal values of exports and imports for estimating the volume of gross domestic product. This paper discusses economic concepts for trade price indices at some length. We note the need for reasonably frequent chaining in view of the fluctuation in the conditioning variables of trade price indices. We characterize the effect of the residency orientation of the index on the substitution biases of the commonly used Laspeyres and Paasche formulas, and superlative formulas, which greatly attenuate these biases. Finally, we consider the data sources and methods used to compile them. [JEL C420, C430]

Foreign trade price indices are important indicators for analyzing growth and inflation in an open economy. The price and volume factors comprising the relative changes in exports and imports are required for understanding developments in the goods and services component of the balance of payments current account. They are required for policy analysis and assessing the effects of exchange rate dynamics on the international competitiveness of a country's producers. They are used for escalating the terms of international contracts and measuring and forecasting domestic inflation; for exchange rate analysis; and, bearing on all of the above uses, in estimating GDP volume, the primary summary indicator of economic growth.

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Traditionally, compilers have thought of export and import price indices in the context of the principal administrative source of data used to compile them: customs documents. With only a few exceptions around the world, foreign trade price indices equate the prices of goods exported or imported with the "unit values" of transactions for detailed customs classes of goods.[1] Compilers of export and import price indices obtain the unit value for each detailed commodity class by dividing the aggregate monetary value of export or import transactions in the class by the aggregate quantity shipped. They then average the relative changes in these unit values across classes to construct export and import price indices. The commodity classes come from the Harmonized System of Commodity Classification and Coding (HS). National customs administrations collectively have developed the HS through the World Customs Organization (WCO) and it is used worldwide. The WCO maintains this classification for levying import tariffs and export taxes, but its detail makes it serviceable for statistical uses as well.[2]

To measure price and volume change accurately, compilers should measure prices by the unit values of sufficiently detailed classes of transactions. Using terminology from the most recent draft guidance on Consumer and Producer Price Indices (CPIs and PPIs) we call these ultimate classes "products."[3] We identify a product by a particular set of price-determining characteristics common to the goods and services transactions in that item. If there is only one such product within a customs commodity class, the unit value is a proper price. On the other hand, customs data may be subject to significant undervaluations on declaration forms, particularly when rates of duty are high. Assuming shipping quantities are accurately recorded and consistent with the quantity transacted, undervaluations will bias down otherwise proper unit value prices. Further, missing or erroneously recorded shipping quantities, or shipping quantities that do not closely track quantities transacted, will cause reciprocal errors in the unit value prices for which they are the denominators. These measurement problems are best remedied by better customs administration and compliance. If compliance issues are intractable, however, compilers may have to undertake surveys to circumvent the administrative data issues. Finally, when the characteristics of goods are heterogeneous within a given detailed commodity class, there are multiple products and thus multiple unit value prices within the class. Compilers should measure price change for such a commodity class as an index number of the multiple product prices, not as the change in a single unit value for the class as a whole. For many classes of goods customs documents do not contain enough detail to identify the products needed

[1]Among the countries that are exceptions to extensive use of customs unit values in trade price indices are Australia, Czech Republic (partially), Estonia, Latvia (non-homogenous goods), Mauritius (partially), Singapore, Sweden, United Kingdom (manufactured goods), and United States. These countries instead make substantial use of price surveys of narrowly defined products. See United Nations (2003).

[2]For information on the HS classification, see the World Customs Organization website, *http://www.wcoomd.org/ie/En/Topics_Issues/topics_issues.html.*

[3]On the draft international CPI Manual, see the International Labor Organization website, *http://www.ilo.org/public/english/bureau/stat/guides/cpi/index.htm*, and on the draft international PPI Manual, see the IMF website, *http://www.imf.org/external/np/sta/tegppi/index.htm*.

to compile a price index. Classes of complex goods such as automated machinery are examples where customs detail falls short. For these categories of goods, and all services, compilers need to undertake surveys to identify and track the prices of individual products.

Observing the desired scope concepts is important to the accuracy of the weights as well as the prices of export and import price indices. At the highest level of aggregation, a price index should cover the full scope of the transactions domain of interest. The *System of National Accounts 1993* (*1993 SNA*), compiled by the Commission of the European Communities and others, and the IMF's *Balance of Payments Manual, 5th Edition* (*BPM5*) define this domain as all transactions in goods and services between the residents and nonresidents of a country.[4] Customs data typically cover only exported and imported goods (commodities or merchandise) and the freight and insurance services employed to ship imported goods. They do not cover other internationally traded services. Also, customs data often are limited to transactions that are subject to taxation (e.g., to import tariffs or export taxes) or some form of regulation (e.g., strategic restrictions on exports). They may exclude or at least not fully cover unregulated transactions (e.g., international transactions in free trade zones). Finally, especially when duty rates are high or regulations onerous, customs records on goods may exclude sometimes substantial amounts of smuggling or, as already noted, be subject to significant undervaluations. Thus, although customs data on trade in goods are readily available as a by-product of tax and foreign policy administration, they have detail, scope, and valuation limitations. Compilers need to undertake supplemental statistical collections or surveys to address these limitations in customs data on goods As most services are not covered by customs, compilers have little choice but to undertake surveys for these products.

We have aimed this paper at the reader interested in a compact guide through the statistical standards, economic concepts, index number theory, compilation issues, and dissemination practices affecting export and import price indices. One useful contribution in the first two parts of Section I is our integration of economic index number theory with the prevailing nonresident orientation of the national accounts toward exports and imports. We also emphasize integrating standards and concepts with the procedures price index statisticians must follow in identifying and sustaining measurements on individual products in international trade. The quality of the trade price index system rests most critically on how well compilers identify each included product and track its price. The most important subject for trade statistics in this category is assessing and eliminating the aforementioned unit value bias of customs-source price information for goods.

[4]The international standard for residency is that a unit have a center of economic interest there. (See *1993 SNA,* paragraph 1.28; *BPM5,* paragraph 22.) International guidance operationalizing the concept of center of economic interest in a country ("economic territory") requires that a unit be physically located or established in a country for at least one year. The operational guidance is to be interpreted flexibly, however. See, for example, IMF's *Balance of Payments Compilation Guide,* paragraph 452, and *Manual on Statistics of International Trade in Services* (compiled by the Commission of the European Communities and others), paragraph 3.7.

I. Index Numbers

Index Number Theory

Price index numbers summarize the relative price changes from individual transactions. Price index formulas are functions of the prices p and quantities q of transactions i classified into a given domain D. The *value aggregate* V of the domain is simply the total value of the transactions that fall into it. In prices and quantities, it is

$$V^t = \sum_{i \in D} p_i^t q_i^t. \tag{1}$$

The relative change in the value aggregate over time is

$$\frac{V^t}{V^0} = \frac{\sum_{i \in D} p_i^t q_i^t}{\sum_{i \in D} p_i^0 q_i^0}, \tag{2}$$

where period 0 is a specific period in the past, called the *reference period.* A useful way to think of a price index is that it is the part of relative change in the value aggregate resulting solely from price change. Viewed this way, a price index is the factor P in

$$\frac{V^t}{V^0} = \frac{\sum_{i \in D} p_i^t q_i^t}{\sum_{i \in D} p_i^0 q_i^0} = P^{0,t} Q^{0,t}, \tag{3}$$

where P is a function, or formula, of individual prices and quantities in the reference and comparison periods, and Q is the corresponding volume index. There are many formulas available for P. Irving Fisher (1922) assembled what still is the most extensive inventory of these formulas.

To decide which price index formula is best, Fisher evaluated them against a set of, in his view, desirable axiomatic properties. He was not the first to consider testing index formulas against axioms, but did so in a more systematic and comprehensive way than earlier analysts. His 1922 book thus initiated the axiomatic or test school of thought on index numbers. While Fisher considered a long list of tests or axioms, Eichhorn and Voeller (1976) proved that no index formula can satisfy all of them. We focus here on one consistent subset of Fisher's tests: proportionality, commensurability, time reversal, monotonicity, circularity, and factor reversal. See Box 1 for more on these properties. Fisher and some present-day index number theorists argue that the more of these properties an index satisfies, the better it is. Based on his tests, Fisher preferred what he called the "ideal" index and what now has been named the Fisher Ideal index after him. This section provides further details on this important index formula.

Box 1. The Test or Axiomatic Approach to Assessing Index Numbers

The axiomatic approach to index numbers evaluates different index number formulas based on a set of *tests* or *axioms* proposed by Irving Fisher (1922). These tests can provide reasonable criteria to use for choosing a price index formula. The most important of these are the following.

Proportionality. If all prices change by some common factor, the price index should also change by that common factor. For example, if all prices double, the aggregate price index should double.

Commensurability. The price index should be invariant to changes in the units of measure. For example, if the measure of one good is converted from pounds to kilograms, the index should yield the same result.

Time Reversal. If prices between periods are reversed, then the price index assumes the reciprocal of its previous value.

Monotonicity. If there are one or more price increases in the current period with no price declines, then the price index should increase.

Circularity. This is a multiperiod transitivity property. The product of the price index change going from period 1 to 2, times the price index change going from period 2 to 3, should equal the price index going directly from period 1 to 3.

Factor Reversal. A price index multiplied by its corresponding quantity index is equal to the ratio of the values for the two comparison periods.

Shortly after Fisher published his inventory of formulas, another school of thought about price indices emerged.[5] Konüs (1924) inferred index number properties from the microeconomic behavior of consumers and began the economic index number school. It subsequently was extended to producers by Fisher and Shell (1972) and Archibald (1977). Among the properties important to the economic school are proportionality, commensurability, and monotonicity. Diewert (1976) derived not only Fisher's "Ideal" index from microeconomic first principles, but a whole class of indices. This class, which Diewert called *superlative,* included other indices studied by Fisher, as well as some that have been introduced since the 1920s. Most notable among the other superlative indices is the Törnqvist index, identified by Fisher in 1922 but named for an economist at the Bank of Finland who wrote about it in 1936.[6] We will consider these two superlative indices after first considering some simple index numbers.

The proportionality, commensurability, and monotonicity axioms shown in Box 1 derive from both the Fisher axiomatic and the economic index number approaches.[7] The time reversal and circularity axioms are consistent with both approaches only if a stringent assumption is made about the underlying economic

[5]Our very brief description of how economic index numbers evolved borrows heavily from Chapter 2 of National Research Council (2002).

[6]See Törnqvist (1936).

[7]See Diewert (2002) on these properties of index numbers.

index.[8] Two additional properties, additivity and consistency in aggregation, are important to many users of index numbers for practical reasons. An *additive* index may be expressed as a sum of weighted components.[9] This is a useful analytical property because the index is the sum of the contributions to change of each of its components. Index formulas that are *consistent in aggregation* produce the same aggregate index regardless of the intermediate aggregations of the basic elements.

Economic index numbers and external trade

Kohli (1978) applied the mathematical duality theory underlying economic index numbers to exports and imports. He posited a production-oriented model in which imports are among the intermediate inputs of the economy's (i.e., the *resident*) enterprise sector and exports are among its outputs. Gross domestic product (GDP) from the production approach is value added—output less intermediate input—plus taxes less subsidies on products. In Kohli's model, exports and imports for a given country are the solutions of a problem maximizing value added, given a country's endowments of primary inputs (e.g., labor and capital services), and the prices of output for domestic uses, output for nonresident uses (exports), intermediate input from domestic sources, and intermediate input from nonresident sources (imports). As elaborated below in this section, we can use the Kohli concept to consider the contribution to change in the value-added price index made by the prices of exported outputs and imported inputs. Diewert (1983) and Diewert and Morrison (1986) used this contribution to change in their approach to study the effects of the terms of trade on the GDP price index (second part of Section II).

On the other hand, export and import price indices most often are used in calculating real net exports to produce a volume index for expenditure on GDP. GDP from the expenditure approach is consumption plus capital formation, plus exports minus imports. We would use the standard national accounts *nonresident* orientation to consider the contribution export and import prices make to change in the price index for expenditure on GDP. In this case, we consider the contribution to change of the prices of expenditures nonresidents make on a country's exported output, net of the contribution made by the prices of their supplies of imported goods and services to the country. It is consistent with the standard national accounts view of imports as a supply of goods and services from, and of exports as a use of goods and services by, the rest of the world (i.e., the *nonresident* enterprise sector).[10] Like the resident approach to export and import

[8]The underlying economic aggregator representing production technology must remain static and *homothetic* over the period of comparison. See Hulten (1973).

[9]National accountants value the additivity property for volume indices, as it associates with a particularly transparent methodological description. One simply deflates the detailed components of value aggregates by the appropriate detailed price indices and adds up the deflated components to get the aggregate volume indicator.

[10]See *1993 SNA* Chapter XIV, Section D.1; Chapter XV, Paragraphs 15.60 (imports as supply from nonresidents) and 15.73 (exports as uses of nonresidents).

price indices, we model this concept in a production framework, except exports are the intermediate *inputs* and imports are the *outputs* of the *nonresident* or rest of the world enterprise sector supplied, respectively, from and to the country in question.[11]

Mathematically, Kohli's resident approach begins with value added as the maximum difference between the value of output and intermediate inputs feasible, given the economy's primary endowments (e.g., labor and capital services) and the prices of outputs and intermediate inputs. Economic theorists call this mathematical relationship between value added, prices, and endowments a *restricted profit function.* We write it

$$V_A^r = v^r(k^r, p_Y^r, p_X, p_Z^r, p_M) = \max\{p_Y^r y + p_X x - p_Z^r z - p_M m:$$
$$(y, x, z, m) \text{ are feasible given } k^r \text{ and resident technology}\}. \quad (4)$$

where V_A = value added; p_Y = prices of outputs for domestic use; p_X = prices of exports; p_Z = prices of intermediate inputs from domestic sources; p_M = prices of imports; y = outputs for domestic use; x = exports; z = intermediate inputs from domestic sources; m = imports; and k = primary inputs. Superscript r refers to the production possibilities of *resident* enterprises; lowercase italic letters as variables (rather than sub- or superscripts) indicate $n \times 1$ vectors of goods and services (except k, which may be of some other dimension), while uppercase italic letters as variables refer to scalars, typically economic aggregates of interest; and the vector k is the set of *conditioning variables* of the value-added function, because it determines the underlying production possibilities of the restricted profit (value-added) maximization problem.

We do not use resident superscripts on export or import prices because the export price for residents is the same as the import price for nonresidents. The reason is that residents and nonresidents are counterparties to the same external trade transaction. Similarly, the import price for residents is the same as the export price for nonresidents. These thus are internationally determined prices.[12] The economic value-added price index comparing prices from period t with period 0 is simply the ratio of the value-added (restricted profit) function at two different price vectors, holding primary input endowments (the *conditioning variables*) fixed:

$$P_{V_A}^{0_t} = \frac{v^r(k^r, p_Y^{ri}, p_X^t, p_Z^{ri}, p_M^t)}{v^r(k^r, p_Y^{r0}, p_X^0, p_Z^{r0}, p_M^0)}. \quad (5)$$

[11]Note that we can choose to view the rest of the world as a consolidation of all other countries into a single entity. Thus, trade between any two countries other than the country in question nets to zero in the consolidation process. We then are left only with the trade between the consolidated rest of the world and the country in question.

[12]They also are treated as such in the *1993 SNA* and the *BPM5,* which set free on board (fob) value at the export frontier as the single valuation and timing principle for recording (accrual of) external trade, comprising the imports (exports) of goods and services of an economic territory from (to) the rest of the world.

Equation (5) is a *Laspeyres perspective economic value-added index* if k^r is equal to its level in period 0 and the value-added function derives from period 0 production possibilities. It is a *Paasche perspective economic value-added price index* if k^r is equal to its level in period t and the export function derives from period t production possibilities.

To focus on the external trade parts of value added, Kohli then uses the Hotelling (1932)-Shephard (1953) lemma to derive export and import functions via differentiation of the value-added function as

$$X = p_X{}'\nabla_x v^r(k^r, p_Y^r, p_X, p_Z^r, p_M)$$
$$M = -p_M{}'\nabla_m v^r(k^r, p_Y^r, p_X, p_Z^r, p_M), \quad (6)$$

where X = the value of exports and M = the value of imports.

Like the value-added function, if we scale all prices by a given factor, the export and the import functions also will be scaled by that factor. We could set up economic export and import price indices using ratios of functions (6) analogous to the way we set up the value-added price index (5). Such indices, which condition on primary input endowments only, would satisfy Fisher's proportionality test in *all* prices.

Such ratios are not, however, price indices for exports or imports themselves, because they do not decompose exports only or imports only into price and volume factors. The "index" ratio for exports using the above import function, for example, does not satisfy Fisher's proportionality test in export prices *alone.* Ratios of the export and import functions evaluated in the prices of period t and period 0 thus give the *contribution to change* of the prices of externally traded goods and services for the value-added (or GDP by production) price index (5).[13] Kohli's resident production theory of export and import price indices therefore must be reexpressed along the lines presented in Alterman, Diewert, and Feenstra (1999) to explain the typical export and import price indices that customs and statistical offices produce around the world.

Before considering an approach focused more explicitly on economic export and import price indices, it will be helpful to revisit the above analysis from the nonresident point of view. Let superscript *nr* refer to the rest of the world and replace superscript *r* with superscript *nr* in the above equations. Notice that from the resident view, the resultant of the rest of the world's export function is the imports of the country in question. Thus, the supply view of imports given in the expenditure approach to GDP determines imports to a country with the export function of the rest of the world. Similarly, the uses view of exports in the expenditure approach to GDP determines exports by the import function of the rest of the world.

[13]The Kohli export supply and import demand functions are based on optimization of output, intermediate input, exports, and imports simultaneously given domestic output, domestic input, export, and import prices, as well as the endowment conditioning variables. Thus, index numbers formed with them summarize movements in all prices, not just those of exports or import alone. See our discussion of the Diewert and Morrison (1986) terms of trade indicator in the second part of Section II.

Economic index numbers for exports and imports

To focus on exports from the resident (Kohli) point of view, let observed exports be the maximum value of exports feasible given output for domestic uses, consumption of intermediate goods and services from both domestic and imported sources, and primary endowments, given the prices of exports. We can define directly a function producing this resultant as

$$X = v_X^r\left(k^r, y^r, z^r, m^r; p_X\right) = \max_x \left\{ \begin{array}{l} p_X x\colon \left(y^r, x, z^r, m^r\right) \\ \text{are feasible given } k^r \text{ and resident technology} \end{array} \right\}. \quad (7)$$

Notice that *k, y, z,* and *m* are the *conditioning variables* of the problem defining the resident export function. Similarly, we can define an import function as the minimum value of imports feasible given a level of output for domestic uses, exports, consumption of intermediate input from domestic sources, and primary endowments, given the prices of imports as

$$M = v_M^r\left(k^r, y^r, x^r, z^r; p_M\right) = \min_m \left\{ \begin{array}{l} p_M m\colon \left(y^r, x^r, z^r, m\right) \\ \text{are feasible given } k^r \text{ and resident technology} \end{array} \right\}. \quad (8)$$

Notice that *k, y, x,* and *z* are the *conditioning variables* of the problem defining the import function.

The economic export price index is then

$$P_X^{r,0t} = \frac{v_X^r\left(k^r, y^r, z^r, m^r; p_X^t\right)}{v_X^r\left(k^r, y^r, z^r, m^r; p_X^0\right)}, \quad (9)$$

and the economic import price index is

$$P_M^{r,0t} = \frac{v_M^r\left(k^r, y^r, x^r, z^r; p_M^t\right)}{v_M^r\left(k^r, y^r, x^r, z^r; p_M^0\right)}, \quad (10)$$

where, again, the *r* superscript denotes the *resident* orientation. As with the value-added price index (5), both are ratios of functions evaluated at different price vectors holding fixed the respective sets of conditioning variables. Equation (9) is a *Laspeyres perspective economic export price index* if (k^r, y^r, z^r, m^r) is set to its level in period 0 and the export function derives from period 0 production possibilities. It is a *Paasche perspective economic export price index* if (k^r, y^r, z^r, m^r) is set to its level in period *t* and the export function derives from period *t* possibilities. Equation (10) is a *Laspeyres perspective economic import price index* if (k^r, y^r, x^r, z^r) is set to its level in period 0 and the import function derives from period 0 production possibilities. It is a *Paasche perspective economic import price index* if (k^r, y^r, x^r, z^r) is set to its level in period *t* and the import function derives from period *t* production possibilities.

V_X^r is homogeneous degree one and increasing in export prices by definition (7). The economic export price index thus satisfies Fisher's proportionality and monotonicity tests. It also satisfies the commensurability test. We can say the same for the economic import price index. In the resident production view, then, X is the result of a maximization problem, and the resident-view export price index thus has the characteristics of an output price index. M is the result of a minimization problem, and the resident-view import price index thus has the characteristics of an input price index.

If we change the superscript in the above expressions defining the export and import functions from r to nr, we express the problem from the point of view of the rest of the world. As noted earlier, the rest of the world's import (export) function then determines domestic exports (imports):

$$\begin{aligned} X &= v_M^{nr}(k^{nr}, y^{nr}, x^{nr} \equiv m^r, z^{nr}; p_X) \\ &= \min_m \left\{ \begin{matrix} p_X m: (y^{nr}, x^{nr}, z^{nr}, m) \\ \text{are feasible given } k^{nr} \text{ and nonresident technology} \end{matrix} \right\}. \end{aligned} \tag{11}$$

$$\begin{aligned} M &= v_X^{nr}(k^{nr}, y^{nr}, z^{nr}, m^{nr} \equiv x^r; p_M) \\ &= \max_x \left\{ \begin{matrix} p_M x: (y^{nr}, x, z^{nr}, m^{nr}) \\ \text{are feasible given } k^{nr} \text{ and nonresident technology} \end{matrix} \right\}. \end{aligned} \tag{12}$$

The *conditioning variables* of the export function from the nonresident perspective are k^{nr}, y^{nr}, $x^{nr} \equiv m^r$ and z^{nr}, while the conditioning variables of the import function from the nonresident perspective are k^{nr}, y^{nr}, z^{nr}, and $m^{nr} \equiv x^r$.

With the *nonresident* export and import functions, we define the following price indices for external trade, holding the conditioning variables constant and comparing, respectively, export and import prices between periods:

$$P_X^{nr,0t} = \frac{v_M^{nr}(k^{nr}, y^{nr}, x^{nr} \equiv m^r, z^{nr}; p_X^t)}{v_M^{nr}(k^{nr}, y^{nr}, x^{nr} \equiv m^r, z^{nr}; p_X^0)} \tag{13}$$

$$P_M^{nr,0t} = \frac{v_X^{nr}(k^{nr}, y^{nr}, z^{nr}, m^{nr} \equiv x^r; p_M^t)}{v_X^{nr}(k^{nr}, y^{nr}, z^{nr}, m^{nr} \equiv x^r; p_M^0)}. \tag{14}$$

Again, the *nr* superscript denotes *nonresident* orientation. As noted earlier, these indices apply to exports and imports as expenditure on GDP rather than as components of value added. In effect, the export (import) price index of a country from the nonresident approach is the import (export) price index for the rest of the world. Equation (13) is a *Laspeyres perspective economic export price index* if (k^{nr}, y^{nr}, $x^{nr} \equiv m^r$, z^{nr}) is set to its level in period 0 and the export function derives from period 0 production possibilities. It is a *Paasche perspective economic export price index* if (k^{nr}, y^{nr}, $x^{nr} \equiv m^r$, z^{nr}) is set to its level in period t and the export function derives from period t production possibilities. Equation (14) is a *Laspeyres perspective economic import price index* if (k^{nr}, y^{nr}, z^{nr}, $m^{nr} \equiv x^r$) is set to its level in period 0 and the import function derives from period 0 production possibilities. It is a *Paasche perspective economic import price index* if (k^{nr}, y^{nr}, z^{nr}, $m^{nr} \equiv x^r$) is set to its level in period t and the import function derives from period t production possibilities.

These economic indices also satisfy three of the Fisher tests: proportionality, monotonicity, and commensurability. However, the export price index now has the properties of an input price index, since it is a ratio of functions derived from minimizations; and the import price index has the properties of an output price index, since it is a ratio of functions derived from maximizations. The conceptual input/output status is important in determining the bias of the simple indices statistical offices usually compute and publish, as discussed in the next section on index formulas.

To segue to the specialized topic of index formulas in the next sections, we will revert to the simpler notation of the beginning of this section, where we discussed price indices in terms of decomposing value aggregates into price and volume factors. In the *resident* (Kohli) view, equation (1) translates to

$$V = \sum_i p_i q_i \approx X = \sum_i p_{Xi} x_i = v_X^r(k^r, y^r, z^r, m^r; p_X) \qquad \text{[exports]}$$

or

$$V = \sum_i p_i q_i \approx M = \sum_i p_{Mi} m_i = v_M^r(k^r, y^r, x^r, z^r; p_M) \qquad \text{[imports].}$$

In the *nonresident* (standard national accounts) view, equation (1) translates to

$$V = \sum_i p_i q_i \approx X = \sum_i p_{Xi} x_i = v_M^{nr}(k^{nr}, y^{nr}, x^{nr} \equiv m^r, z^{nr}; p_X) \qquad \text{[exports]}$$

or

$$V = \sum_i p_i q_i \approx M = \sum_i p_{Mk} m_i = v_X^{nr}(k^{nr}, y^{nr}, z^{nr}, m^{nr} \equiv x^r; p_M) \qquad \text{[imports].}$$

Our task is to find feasible ways to decompose these export and import value aggregates into price and (implicit) volume components, consistent with the *resident* export and import concepts (9) and (10), or *nonresident* concepts (13) and (14).

Simple Formulas

The Laspeyres index formula is written alternatively as

$$P_L^{0t} = \frac{\sum_{i=1}^{n} p_i^t q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0} \qquad (15)$$

or

$$P_L^{0t} = \sum_{i=1}^{n} s_i^0 \left(\frac{p_i^t}{p_i^0} \right), \tag{16}$$

where $s_i^0 = \dfrac{p_i^0 q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0}$.

The Laspeyres index keeps the quantities (q) fixed in the reference period (0) to compare the levels of prices (p) between the reference period and the present (t). For exports (imports), it is the ratio of what it costs today for nonresidents (residents) to purchase the same set of goods and services produced by residents (nonresidents) that they purchased in the reference period. From equation (2), the Laspeyres price index can be restated as a reference-period weighted average of the price relatives of the elementary goods and services in the scope of the index.

The Paasche index formula is written alternatively as

$$P_P^{0t} = \frac{\sum_{i=1}^{n} p_i^t q_i^t}{\sum_{i=1}^{n} p_i^0 q_i^t} \tag{17}$$

or

$$P_P^{0t} = \frac{1}{\sum_{i=1}^{n} s_i^t \left(\frac{p_i^0}{p_i^t} \right)}, \tag{18}$$

where $s_i^t = \dfrac{p_i^t q_i^t}{\sum_{i=1}^{n} p_i^t q_i^t}$.

The Paasche index fixes quantities at their levels in the comparison period (t). By implication, the quantities change from period to period, unlike a Laspeyres index. In its simplest form the Paasche index is, in the case of imports for example, the ratio of what today's purchases abroad cost compared with what they would have cost in a specific previous period. This also can be viewed as the current value of the current basket relative to what is often (and logically) called its *constant price* value. The Paasche price index can be restated as a current-period *weighted harmonic mean* of price relatives, as shown in equation (18).[14]

[14]The harmonic mean of a vector x with weights s is $\mu_h = \left(\sum_t s_i (x_i)^{-1} \right)^{-1}$, where $\sum_i s_i = 1$.

The Laspeyres and Paasche indices fix the quantities transacted at their levels from only one of the two periods compared. Unlike economic export and import price indices (9), (10), (13), and (14), they do not admit the possibility that economic agents may change those quantities in response to changes in relative prices. They thus are subject to *substitution bias*. The direction of this bias depends on whether the price index is for uses of goods and services, such as exports from the nonresident view, or for supplies of goods and services, such as imports from the nonresident view.

To assess substitution bias of uses price indices from the nonresident view, we compare economic export price indices based on equation (13) with the respective Laspeyres and Paasche approximations. (Alternatively, we may compare the "resident view" Laspeyres and Paasche perspective economic import price indices based on equation (10) with its Laspeyres and Paasche approximations.) Moreover, we are orienting the economic index from the "Laspeyres perspective" when assessing the substitution bias of the Laspeyres index. This means that (k^{nr}, y^{nr}, $x^{nr} = m^r$, z^{nr}) and the technology underlying the export function reference period 0 in equation (13). (Alternatively, (k^r, y^r, z^r, m^r) and the technology underlying the import function reference period 0 in equation (10).) Further, we are orienting the economic index from the "Paasche perspective" when assessing the substitution bias of the Paasche index. This means that (k^{nr}, y^{nr}, z^{nr}, $m^{nr} = x^r$), and the technology underlying the import function, reference period t in equation (13). (Alternatively, (k^r, y^r, x^r, z^r) and the technology underlying the export function reference period t in equation (10).)

Laspeyres price indices for uses aggregates have upward substitution bias, while Paasche price indices for these aggregates have downward substitution bias. The reasoning supporting the direction of substitution bias relies on microeconomics. We analyze aggregates for uses as composed of the expenditures of cost-minimizing (nonresident) economic agents. When confronted with a price change, agents seek a new combination of goods and services consistent with a given set of conditioning variables. The combination they choose will cost no more than the old set of goods and services would at the new prices. The old combination will be chosen only if all other possibilities, holding the conditioning variables constant, cost more than the old combination at the new prices. Since there are almost always new combinations of products feasible for the given conditioning variables and costing less at the new prices, staying with the old is not likely. Thus, the numerator of the Laspeyres index, which is the cost of the old set of goods at the new prices, is too high. The Laspeyres *uses* price index thus is too high. By the same reasoning, the denominator of the Paasche index, which is the cost of the new set of goods at the old prices, also is too high. The Paasche *uses* price index thus is too low.

To assess substitution bias of supply price indices from the "nonresident view," we compare the economic import price index (14) with its Laspeyres and Paasche approximations. (Alternatively, we may compare the "resident view" economic export price index (9) with its Laspeyres and Paasche approximations.) Moreover, we are orienting the economic index from the "Laspeyres perspective" when assessing the substitution bias of the Laspeyres index. This means that (k^{nr}, y^{nr}, z^{nr}, $m^{nr} = x^r$) and the technology underlying the import function reference period 0 in equation (14). (Alternatively, (k^r, y^r, x^r, z^r) and the technology underlying the export function reference period 1 in equation (9).) Further, we are orienting the economic index from the "Paasche perspective" when assessing the substitution bias of the Paasche index. This means that (k^{nr}, y^{nr}, $x^{nr} = m^r$, z^{nr}), and the technology underlying the import function, reference period t in equation (14). (Alternatively, (k^r, y^r, z^r, m^r) and the technology underlying the export function reference period t in equation (9).)

By reasoning similar to that for the uses price indices, the Laspeyres price indices for supply aggregates have downward substitution bias, while Paasche indices for these aggregates have upward substitution bias. In this case we are comparing the "nonresident view" economic import price index (14) with its Laspeyres and Paasche approximations. (Alternatively, we may also compare in this context the "resident view" economic export price index (9) with its Laspeyres and Paasche approximations.) Again, microeconomics lies at the heart of the argument. We analyze supply aggregates as composed of the transactions of (nonresident) economic agents using given inputs to maximize the value of output supplied (to residents). When confronted with a price change, agents seek a new combination of products to supply that is feasible with their given set of inputs. The combination they choose will yield as least as much in revenue as would supplying the old set of products at the new prices. They will choose the old combination only if all other possibilities requiring the same inputs to produce yield less revenue than the old combination at the new prices. There almost always are new combinations of products needing no more inputs than the old combination and yielding more revenue at the new prices. Staying with the old combination is unlikely. Thus, the numerator of the Laspeyres index, which is the value of the old set of goods at the new prices, is too low. The Laspeyres supply price index thus is too low. By the same reasoning, the denominator of the Paasche index, which is the value of the new set of goods at the old prices, is too low. The Paasche supply price index thus is too high.

Thus, depending on the orientation from which we choose to interpret export and import price indices, the implied substitution biases of Laspeyres and Paasche export and import price indices *are in opposite directions.* It is important in understanding this outcome that substitution bias does not involve the difference between the "Laspeyres perspective" and "Paasche perspective" economic indices themselves. The results pertain only to the relationships between the Laspeyres and Paasche perspective *economic* indices and their corresponding Laspeyres and Paasche *approximations.* Economic indices from the two "perspectives" have no particular relationship to one another, unless (a) technology is static and (b) the shares of products in the index are independent of all the conditioning variables in the export or import function on which the index is based. In the latter case, the export and import functions are *homothetic* and the Laspeyres perspective and Paasche perspective economic indices for a given aggregate are identically equal for a *given technology.* Because these assumptions rarely hold in real data, the simple Laspeyres and simple Paasche indices often are related to one another differently than would be predicted by their substitution biases alone. For example, although the Laspeyres uses price indices have upward substitution bias they may not necessarily lie above the corresponding Paasche uses indices, which have downward substitution bias. The reason is that the Laspeyres perspective *economic* index may lie well below the Paasche perspective *economic* index. Change in nonprice variables can more than offset the substitution effects from the price changes, unless, as noted, the underlying economic export or import functions are homothetic. Moreover, even if homotheticity holds, technology change also may offset the effects of substitution bias in the Laspeyres-Paasche index relationship.

The geometric mean price index maintains that substitution takes place across products with unitary elasticity in response to changes in relative prices. For most goods and services, this is more realistic than the Laspeyres and Paasche index assumption that no substitution takes place. The geometric mean formula is written from the Laspeyres perspective as

$$P_{GL}^{0t} = \prod_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right)^{s_i^0} \tag{19}$$

or the Paasche perspective as

$$P_{GP}^{0t} = \prod_{i=1}^{n} \left(\frac{p_i^t}{p_i^0} \right)^{s_i^t}, \tag{20}$$

where

$$s_i^t = \frac{p_i^t q_i^t}{\sum_{i \in D} p_i^t q_i^t}.$$

How do the simple indices stack up against Fisher's axioms or tests? All of the simple indices pass the proportionality and commensurability tests. All of the simple indices fail the time reversal and factor reversal test. The Laspeyres and Laspeyres geometric indices pass the monotonicity test, but the Paasche and Paasche geometric do not. The Laspeyres and Laspeyres geometric indices satisfy the circularity test, but the Paasche and Paasche geometric do not. Of the group, the Laspeyres and Laspeyres geometric satisfy four of the six axioms, while the Paasche and Paasche geometric satisfy two, so the Laspeyres-type simple indices rank first. Considering our two supplemental properties, only the Laspeyres index is strictly additive in prices.[15] The simple indices all are exactly consistent in aggregation.

Superlative Formulas

In our discussion of substitution bias, we introduced the microeconomic notions of cost minimizing users of products and output maximizing producers. Superlative index formulas can reflect the substitution behavior of economic agents to a very close approximation, closer than the Paasche, Laspeyres, or their geometric mean

[15]However, the other basic indices are additive up to a monotonic transformation. The Paasche index is additive in the transformation $1/x$ and the geometric indices are additive in the transformation $\ln x$.

counterparts. These indices use weight information from both the reference and comparison periods, rather than from one or the other. Because they are symmetric, they satisfy the time reversal test, unlike the Laspeyres and Paasche. The best known is the Fisher Ideal index, which is the geometric mean (square root) of the Laspeyres and Paasche indices:

$$P_P^{0t} = \left(P_L^{0t} P_P^{0t}\right)^{\frac{1}{2}}. \tag{21}$$

Results from Diewert (1976) can be used to show that if the export ((9) or (13)) or import ((10) or (14)) function is approximated with a quadratic function homogeneous in the prices of, respectively, exports or imports, the Fisher Ideal export or import price index is exact for this approximation.[16] A quadratic export or import function is said to be *flexible,* because it can differentially approximate a twice differentiable homogeneous function to the second order when prices and quantities are not too different. Since the Fisher Ideal index is exact for a flexible functional form for the export or import function, it is said to be *superlative.*

Another well-known superlative index is the Törnqvist index, which is

$$P_T^{0t} = \prod_{i=1}^{n} \left(\frac{p_i^t}{p_i^0}\right)^{s_i^{0t}} = \left(P_{GL}^{0t} P_{GP}^{0t}\right)^{\frac{1}{2}}, \tag{22}$$

where $s_i^{0t} = \frac{1}{2}\left(\frac{p_i^0 q_i^0}{\sum_i p_i^0 q_i^0} + \frac{p_i^t q_i^t}{\sum_i p_i^t q_i^t}\right).$

The Törnqvist index thus is equal to the geometric average of the Laspeyres and Paasche perspective geometric mean indices of equations (19) and (20). Results from Diewert (1976) can be used to show that if the export ((9) or (13)) or import ((10) or (14)) function is approximated with the Christensen, Jorgenson, and Lau (1973) translog function, the Törnqvist export or import price index is exact for the approximation.[17] Since, like the homogeneous quadratic function, the translog function is *flexible,* the Törnqvist price index, like the Fisher Ideal, is *superlative.*

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[16]The homogeneous quadratic aggregator function is

$$f(p) = \sqrt{p'Ap}.$$

When used to approximate the export or import function, the matrix of coefficients A is effectively a certain function of all the arguments of the export or import functions other than, respectively, export prices or import prices p.

[17]The translog aggregator function is

$$t(p) = \exp(\alpha + \beta' \ln p + \ln p' \Lambda \ln p).$$

When used to approximate the export or import function, the scalar parameter α, the vector parameter β, and the matrix parameter Λ are effectively certain functions of all the arguments of the export or import functions other than, respectively, export prices or import prices p. To maintain homogeneity in prices like the underlying export or import functions, $\beta'\mathbf{1} = 1$ and $\mathbf{1}'\Lambda\mathbf{1} = 0$, where $\mathbf{1}$ is a vector of ones with the same dimension as p.

The Fisher Ideal index formula satisfies five of the six index tests, failing only circularity, earning Fisher's "Ideal" moniker. The Törnqvist index passes four of the six tests, failing circularity and monotonicity. Besides having good axiomatic properties, as noted at the start of this section, superlative indices also better reflect economic behavior when relative prices between products are changing. Unlike the Laspeyres index, the Fisher and Törnqvist indices are not additive, nor exactly consistent in aggregation. The superlative indices are consistent in aggregation to a close approximation, however.[18]

Fixed-Base and Chained Indices

Fixed-base indices have a common point of comparison to which the prices of all goods and services in the domain of the index relate. Thus, the index is a function of direct relative price comparisons between the current period and the single period of reference. *Chained indices* are the result of linking several, differently based series. If the frequency of linking is every period, a chained index is the product of a series of short-term, month-to-month, quarter-to-quarter, or year-to-year indices, according to the periodicity of the index.

The Laspeyres index formula often is used in foreign trade indices because, it is argued, users understand this index more easily than other indices. The idea underlying the Laspeyres index, which compares the current value of a fixed "market basket" of imported or exported goods and services with its value in a past period, certainly is straightforward to convey. The problem with holding the base fixed for extended periods, however, is that the index gets out of date and loses relevance. Its weights and products become uncharacteristic of current transactions. Consequently, if the product shares for transactions covered by the domain of the index change markedly over short intervals of time, more frequent chaining is advisable. This is almost universally the case for external trade in goods and services. This is straightforward not only empirically, but from examination of the relevant aggregator functions for the economic export and import price indices. The export aggregator functions (9) and (13) and the import aggregators (10) and (14) have a number of conditioning arguments besides the prices of, respectively, exports and imports. We expect these variables—endowments, domestic or foreign output, domestic or foreign intermediate consumption, and imports or exports—to change over time and to have a significant impact on the weights of export and import price indices.

In general, then, compilers can chain when they have new information about the weights or shares at some level of aggregation in the index.[19] Hence, it is not a matter of deciding to chain an index, but whether and how frequently new information becomes available for the weights to enable chaining. If the weighting information is available at frequent intervals, chaining can occur more often than

[18]See Diewert (1978).

[19]We also chain when we replace or supplement the sample of products whose prices are followed within each elementary aggregate. In a probabilistic sense, this is the same as changing the weights of products by sampling from a more recent and differently composed population of transactions.

when it is available at intervals of several years. Some countries chain certain indices such as the CPI at intervals as lengthy as a decade. They chain infrequently because the information on shares of household expenditure can be expensive and time-consuming to obtain. The responsible agency can publish and make official a version of the CPI incorporating the new weighting information only well after the reference period of the weights. If, as with the CPI, the index is not revised to incorporate slow-arriving weighting information, there is little alternative to the fixed-base Laspeyres index. This, however, is not such an important argument for the Laspeyres index in the case of international trade price indices. The available source information for the shares often is as current as the information on the prices and frequent chaining thus is viable.

In a given link for a chain index, the expenditure shares are for the previous period (Laspeyres-type, equations 16 and 19) or the current period (Paasche-type, equations 18 and 20), or both (Fisher Ideal and Törnqvist, equations 21 and 22). The chain Laspeyres index can be written as

$$P_L^{t-1,t} = \sum_{i=1}^{n} s_i^{t-1}\left(\frac{p_i^t}{p_i^{t-1}}\right) \tag{23}$$

$$P_{LC}^{0t} = P_L^{01} \times P_L^{12} \times P_L^{23} \times \cdots \times P_L^{t-1,t} = \prod_{\tau=1}^{t} P_{LC}^{\tau-1,\tau}, \tag{24}$$

and the chain Paasche index can be written as

$$P_P^{t-1,t} = \frac{1}{\sum_{i=1}^{n} s_i^{t}\left(\frac{p_i^{t-1}}{p_i^{t}}\right)} \tag{25}$$

$$P_{PC}^{0t} = P_P^{01} \times P_P^{12} \times P_P^{23} \times \cdots \times P_P^{t-1,t} = \prod_{\tau=1}^{t} P_{PC}^{\tau-1,\tau}. \tag{26}$$

The chain geometric Lapeyres and Paasche indices are constructed similarly as a product of short-term index links with updated weights computed using the geometric formulas instead of the Laspeyres and Paasche.

In general, the chain Laspeyres index has less upward substitution bias than the fixed-based version and the chain Paasche has less downward bias than the fixed-base version. Thus, the difference between the two chained measures usually is smaller than for the fixed-base versions.[20] The chain Fisher is the geometric mean of the chain Laspeyres and chain Paasche indices. Similarly, the chain

[20]With a cautionary proviso to be discussed in Section III: chaining the Laspeyres and Paasche indices at too high a frequency can lead to unacceptable amounts of "chain drift," under which the chained index deviates by too wide a margin from the fixed-base index as a result of, for example, random measurement error in the prices and/or weights. Schultz (1983) established that correlation of a given sign between prices and quantities will produce a bias of the opposite sign in any fixed-basket index, such as the Laspeyres, when it is chained, particularly if prices "bounce" rather than follow a smooth trend. See, for example,

Törnqvist is the geometric mean of the chain geometric Laspeyres and chain geometric Paasche indices, respectively:

$$P_{FC}^{0t} = \left(P_{LC}^{0t} P_{PC}^{0t}\right)^{\frac{1}{2}} = \prod_{\tau=1}^{t} \left(P_{L}^{\tau-1,\tau} P_{P}^{\tau-1,\tau}\right)^{\frac{1}{2}} \tag{27}$$

$$P_{TC}^{0t} = \left(P_{GLC}^{0t} P_{GPC}^{0t}\right)^{\frac{1}{2}} = \prod_{\tau=1}^{t} \left(P_{GL}^{\tau-1,\tau} P_{GP}^{\tau-1,\tau}\right)^{\frac{1}{2}}. \tag{28}$$

Chained indices are not additive in aggregation when comparisons are made across linking periods, nor are they transitive (they do not pass the circularity test).

II. Constructing Price Indices for Exports and Imports

Export and Import Price Indices

The main steps for compiling export and import price indices are no different than for other major price indices such as the CPI and PPI. The basic element of information is the *transaction,* whose dimensions are a price and a quantity and a complete description or set of characteristics. Index compilation begins with *recording* the *prices* (as well as characteristics and, preferably, quantity transacted) for individual transactions in goods and services. The transactions are dated and grouped in time according to the periodicity of the index, usually one month. There are three major stages to compiling a price index.

- The *first stage* is to compute *unit values* for detailed products, which are termed *products* (or *varieties* or *item specifications*), by averaging prices across *transactions. Products are the smallest entities on which prices are measured from period to period.* Because of the often large number of transactions for each product, price indices for them usually (but not always) are based on samples of transactions. Because there typically are so many products, however, the transaction sample for a product may comprise as few as a single observation. In this case, the estimator for the product unit value is the price quote for this single sampled transaction.
- The *second stage* is to compute *indices* for the *elementary aggregates* (or *basic headings* or *item groups* or simply *items*) from information on the relative change in the prices (unit values) of the products. *Elementary aggregates are the smallest entities for which price index estimates are to be made.* Because of the very large number of varieties of detailed types of products in transactions, price

Feenstra and Shapiro (2003) and Triplett (2003). We cannot be completely intolerant of drift, however. Note that indices *empirically* satisfying the circularity property along one historical price path are not subject to chain drift by definition. On the other hand, a sufficient but not necessary condition for this is Hulten's (1973) result that having a path-independent (circular along any conceivable historical path) Divisia (e.g., infinitesimally chained) index is equivalent to having an underlying aggregator (export or import function) that is static and homothetic (in exports or imports). The unreasonableness of the latter conditions in describing the real world of international trade argues for some tolerance for chain drift.

indices for them usually are based on samples of products rather than a complete enumeration.

- The *third stage* is to compute *indices* for the *upper aggregates* by combining the indices for the elementary aggregates.

Transactions, products, and unit values

In any price index it is necessary to establish an unambiguous way of identifying each product. This is done by observing the *price-determining characteristics* of transactions in each class of goods and services. A price-determining characteristic must significantly explain variations in the price observed for a given transaction in a certain type of good or service within a reasonably short period, such as a month. A characteristic having no cross-sectional impact on price is irrelevant for defining a product. By this "price explanatory power" criterion, *we will have successfully enumerated the price-determining characteristics if there is very little variability in the prices of the transactions with that specific set of characteristics.*

Examples of price-determining characteristics include mode of shipment, size, weight, dimensions, and terms of transaction. Such characteristics may include class and quality of wheat, clock speed and word size of a microprocessor, horsepower and interior volume of a car, or whether a milling machine has an interface with a computerized control.

For a given product properly defined according to particular values of its price-determining characteristics, it is possible to observe multiple transactions. For example, we might consider an export product within the class of magnetic disk drives with characteristics of capacity, seek time, revolutions per minute (RPM), and interface, as follows:

Product code = 8471705095
Description = Magnetic disk drive unit
Capacity = 60 gigabytes
Seek time = 4 milliseconds
RPM = 7,200
Interface = USB2
Source = Malaysia
Destination = Russia.

There may be 150 transactions fitting this description. A compiler who measured all such transactions in a given month ideally would determine the price of this product as the quantity weighted average or *unit value* of these transactions.

Prices for products are obtained as unit values by dividing the total value of import or export transactions in the product by the sum of the corresponding quantities. Let $p_{\tau i}^t$ be the price in period t of the τth transaction in the ith product and let $q_{\tau i}^t$ be the corresponding quantity transacted. Then the price and quantity of the ith product is

$$p_i^t = \frac{\sum_{\tau \in \{i\}} p_{\tau i}^t q_{\tau i}^t}{\sum_{\tau \in \{i\}} q_{\tau i}^t} \tag{29}$$

$$q_i^t = \sum_{\tau \in \{i\}} q_{\tau i}^t . \tag{30}$$

Equations (29) and (30) are the price and quantity arguments that appear in the index number formulas of the section on index numbers. If, as we would expect, there is little or no variation in price across transactions within product *i,* then the unit value (29) is essentially invariant to its transaction quantity weights:

$$\frac{q_{\tau i}^t}{\sum_{\tau \in \{i\}} q_{\tau i}^t},$$

and the unit value can be estimated accurately by the unweighted average of prices of transactions in the product or, if the variance in prices is sufficiently low, by the price of any one of the transactions τ.

Price indices for elementary aggregates

The elementary aggregates are the basic index building blocks from which compilers produce price indices. They are defined principally by the purposes for which detailed index information will be used. For example, customs authorities may want to forecast tax revenue taking into account trends in the prices of specific product categories. In this case, the customs classification of products in international trade is at least one of the defining criteria of an elementary aggregate. In addition, national accountants will need price indices for detailed product classes to track the supply and use of goods and services. Here, the national product classification is a defining criterion. Marketing analysts will want to know price trends by product and by source (imports) or destination (exports) country. To accommodate this use, the elementary aggregate is defined not only by product but also by source or destination country.

In certain cases, the elementary aggregate is defined by statistical requirements at such a detailed level that it contains a single product. Some agricultural products and mineral ores may fall into this category. The price index for such an elementary aggregate is simply the ratio of the dated unit values of the single product comprising it:

$$R_{jk}^{0,t} = \frac{p_i^t}{p_i^0}, \tag{31}$$

where $i \in$ the elementary aggregate $\{jk\}$, with j = product code and k = country code.

More commonly, there will be multiple products within an elementary aggregate. This being the case, the price index for the elementary aggregate would be calculated in principle exactly as in the section on index numbers. The weight for each of the products in this calculation would be its value share in the elementary aggregate. Formulas such as the Laspeyres (16), Paasche (18), geometric Laspeyres (19), geometric Paasche (20), Fisher Ideal (21), or Törnqvist (22) and their chain versions (23)–(29) thus would be used to calculate the price index for the elementary aggregate $R_{jk}^{0,t}$.

However, while compilers usually know the share weights of elementary aggregates in total exports or imports, they usually do not know the shares of products within an elementary aggregate. The source data for products come from *sample surveys.* As discussed in Section IV, these surveys determine the products when survey statisticians probabilistically select the sample of export or import transactions from the reporter. The mere presence of products in the sample thus probabilistically represents their weight in the elementary aggregate. The price index estimator for the elementary aggregate usually is constructed as one of several types of unweighted averages of relative price change for the sampled elementary aggregates. These averages are broadly similar to the price indices discussed in Section II, except that all the price relatives for the products are equally weighted. As estimators of the weighted price indices over all products in the aggregate these unweighted aggregators can have good statistical properties. If the average of these unweighted elementary aggregator indices is taken from many samples, the result may converge toward a particular price index with the correct share weights under certain conditions.

The basic elementary aggregate formulas are the Carli or average of price relatives index, the Dutot or ratio of price averages index, and the Jevons or geometric mean of price relatives index. The expressions for these indices are as follows:

Carli

$$\hat{R}_{Cjk}^{0,t} = \frac{1}{n_{jk}^{0,t}} \sum_{i \text{ in agg.} jk} \frac{p_i^t}{p_i^0} \tag{32}$$

Dutot

$$\hat{R}_{Djk}^{0,t} = \frac{\frac{1}{n_{jk}^{0,t}} \sum_{i \text{ in agg.} jk} p_i^t}{\frac{1}{n_{jk}^{0,t}} \sum_{i \text{ in agg.} jk} p_i^0} \tag{33}$$

Jevons

$$\hat{R}_{Jjk}^{0,t} = \left[\prod_{i \text{ in agg.} jk} \frac{p_i^t}{p_i^0} \right]^{\frac{1}{n_{jk}^{0,t}}}. \tag{34}$$

Notice that under the geometric averaging of the Jevons index, the ratio of geometric averages of prices is the same as the geometric average of price relatives. This does not obtain under the arithmetic averaging of the Carli and Dutot indices.

A less well known option for the elementary aggregate index formula is the

Harmonic

$$\hat{R}^{0,t}_{Hjk} = \left[\frac{1}{n^{0,t}_{jk}} \sum_{l \text{ in agg. } jk} \left(\frac{p^{t}_{jkl}}{p^{0}_{jkl}} \right)^{-1} \right]^{-1}. \tag{35}$$

From the Carli (32) and the Harmonic (35) formulas, a last option for the elementary aggregator is the

Carruthers-Sellwood-Ward-Dalén (CSWD)

$$\hat{R}^{0,t}_{CSWD,jk} = \left[\hat{R}^{0,t}_{C,jk} \hat{R}^{0,t}_{H,jk} \right]^{\frac{1}{2}}. \tag{36}$$

The Carli index mimics the Laspeyres, the Harmonic index[21] mimics the Paasche, the Jevons mimics the geometric and Törnqvist, and the CSWD[22] mimics the Fisher Ideal. As with the Laspeyres (16) and Paasche (18) indices, the Carli (32) and Harmonic (35) indices will be subject to substitution bias as discussed in Section II. High substitution effects have been found within elementary aggregates by empirical studies of selected goods and services. Because it allows for a specific level of product substitution, the Jevons index has found favor as the preferred elementary aggregator for the majority of products.

Because of the large turnover in the product varieties within elementary aggregates of foreign trade data, compilers routinely chain elementary aggregate indices. The Dutot (33) and Jevons (34) indices satisfy Fisher's circularity property. They are invariant in a specific sense, whether computed in fixed-base or chained form even when the items in an elementary aggregate are subject to seasonal availability or temporary supply interruptions.

On the other hand, Schultz (1983) has shown that the Carli (32) and Harmonic (35) indices are biased when they are chained. The bias worsens when there is (a) a high variance in relative price changes and (b) the normally expected correlation between changes in prices and quantities. Both indices "drift" compared with their unchained, fixed-base counterparts. In other words, they violate the circularity property by a margin that widens significantly over time under conditions (a) and (b).[23] Seasonal and temporarily unavailable items only worsen the drift problem.

The CSWD index (36), however, reduces the bias of the Carli and Harmonic indices comprising it. The biases of the Carli and Harmonic aggregators were shown by Schultz (1983) to be in opposite directions. Diewert (2002, p. 54) has shown that the CSWD aggregator closely approximates the Jevons elementary aggregator when period-to-period price changes are small, and that the Jevons satisfies the circularity property, protecting it from chain "drift." Balk (2002) demonstrates that under

[21]Coggeshall (1887) seems to have been the first to consider this formula in a price index.

[22]Carruthers, Sellwood, and Ward (1980), and Dalén (1992).

[23]It is not a foregone conclusion that a good price index should satisfy circularity exactly, however. For example, chaining by itself sacrifices circularity as already noted. See note 20.

certain probability sampling schemes, the expected value of the CSWD index converges to the Fisher Ideal.

Price indices for upper aggregates

Formulas such as the Laspeyres (16), Paasche (18), geometric Laspeyres (19), geometric Paasche (20), Fisher Ideal (21), or Törnqvist (22) are used to calculate the price index for the upper index aggregates. Instead of price ratios, the upper aggregate indices would contain elementary aggregate price indices as arguments, as in the following:

$$P_L^{0t} = \sum_k \sum_j s_{jk}^0 \hat{R}_{jk}^{0,t} \qquad \text{[Laspeyres, reference equation (16)]} \qquad (37)$$

$$P_P^{0t} = \frac{1}{\sum_k \sum_j s_{jk}^t \left(\hat{R}_{jk}^{0,t}\right)^{-1}} \qquad \text{[Paasche, reference equation (18)]} \qquad (38)$$

$$P_{GL}^{0t} = \prod_k \prod_j \left(\hat{R}_{jk}^{0,t}\right)^{s_{jk}^0} \qquad \text{[Geometric Laspeyres, reference equation (19)]} \qquad (39)$$

$$P_{GP}^{0t} = \prod_k \prod_j \left(\hat{R}_{jk}^{0,t}\right)^{s_{jk}^t} \qquad \text{[Geometric Paasche, reference equation (20)]} \qquad (40)$$

$$P_F^{0t} = \left(P_L^{0t} P_P^{0t}\right)^{\frac{1}{2}} \qquad \text{[Fisher Ideal, reference equation (21)]}$$

$$P_T^{0t} = \left(P_{GL}^{0t} P_{GP}^{0t}\right)^{\frac{1}{2}} \qquad \text{[Törnqvist, reference equation (22)].}$$

Relative trade prices by product and source or destination country may change significantly over annual periods. Since this is the rule rather than exception, the Fisher Ideal or Törnqvist chained indices would be more accurate measures of the relative change in prices for upper aggregates than the Laspeyres-type or Paasche-type chained indices. The short-term biases of the latter indices tend to compound over time. Further, as a rule the value shares of elementary aggregates within exports and imports also change significantly over annual periods. Because of this, annual chaining is recommended rather than adjusting the weights over longer durations.

Terms of Trade

Broadly speaking, terms of trade are a measure of the degree to which a country gets favorable transaction terms (prices) for its exports relative to its imports. It generally involves some notion of the purchasing power of income. There are a number of terms of trade concepts and no consensus on which is definitive. Without going deeply into the details, we briefly consider a selection of common alternatives to demonstrate how export and import price indices may figure into compiling the terms of trade.

The *simple terms of trade index* (TT^t_{Simple}) is calculated by dividing a price index (or unit-value index proxy) for exports by a price index (or unit-value index proxy) for imports:

$$TT^t_{Simple} = \frac{P^{0,t}_X}{P^{0,t}_M}, \tag{41}$$

where $P^{0,t}_X$ and $P^{0,t}_M$ are the price indices for, respectively, exports (X) and imports (M). This indicator appears in the IMF's *International Financial Statistics,* for example.

The dual *relative volume index* (TT^t_{Vol}) is the ratio of an index of the quantity of commodity imports to an index of the quantity of commodity exports, where the quantity index of exports (imports) is the ratio of the value of exports (imports) to the unit-value index of exports (imports):

$$TT^{0,t}_{Vol} = \frac{\dfrac{M^t/M^0}{P^{0,t}_M}}{\dfrac{X^t/X^0}{P^{0,t}_X}}, \tag{42}$$

which can be rewritten as

$$TT^{0,t}_{Vol} = \frac{M^t/M^0}{X^t/X^0} \times TT^{0,t}_{Simple}. \tag{43}$$

The *income terms of trade index* measures the quantity of imports a country can purchase with its exports. It is equivalent to the country's purchasing power of exports, or its capacity to import.

$$TT^{0,t}_{Income} = \frac{X^t/X^0}{P^{0,t}_M} = \frac{P^{0,t}_X \times Q^{0,t}_X}{P^{0,t}_M} = \frac{P^{0,t}_X}{P^{0,t}_M} \times Q^{0,t}_X, \tag{44}$$

where $Q^{0,t}_X$ is the volume index for exports. Equation (30) can be rewritten as

$$TT^{0,t}_{Income} = Q^{0,t}_X \times TT^{0,t}_{Simple}. \tag{45}$$

The *1993 SNA* (paragraphs 151 to 156 of Chapter XVI) defines the trading gains or losses, TT_{SNA}, of a country as the difference between the "real" trade balance and the trade balance at constant prices:

$$TT^{0,t}_{SNA} = \frac{X_t - M_t}{P^{0,t}} - \left[\frac{X_t}{P^{0,t}_X} - \frac{M_t}{P^{0,t}_M}\right], \tag{46}$$

where X = exports at current prices; M = imports at current prices; and $P^{0,t}$ = a price index based on some selected numeraire.

The *1993 SNA* recognizes no single choice as optimal in all circumstances for the general price index $P^{0,t}$ with which to deflate the current trade balance. There are three broad choices for this index. The first is a trade price index such as the import price index, the export price index, or a combination of the two. The second is a general price index not derived from foreign trade (e.g., the CPI or the price index for gross domestic final expenditure, comprising consumption and capital formation). The GDP deflator is a third choice, which combines both domestic (consumption and capital formation) and foreign (net exports) price information.

The Diewert (1983) and Diewert and Morrison (1986) terms of trade measure recalls the *1993 SNA* trading gains indicator (46) as well as the simple terms of trade index (41). Diewert and Morrison build on the Kohli (1978) model to produce a terms of trade indicator having a specific and natural interpretation linked to the production approach (value-added) GDP deflator. It decomposes the value-added deflator into two multiplicative factors. The first factor measures the contribution to change in the deflator arising from changes in the prices of output for domestic uses and intermediate consumption from domestic sources. The second factor measures the contribution to change in the GDP deflator of changes in exports (domestically produced but used by nonresidents) and imports (domestically used but produced by nonresidents). Hence,

$$P_{GDP}^{0,t} = \frac{tx^t}{tx^0} \frac{\left(P_Y^{0,t}\right)^{\frac{1}{2}\left(\frac{Y^0}{GDP^0}+\frac{Y^t}{GDP^t}\right)}}{\left(P_Z^{0,t}\right)^{\frac{1}{2}\left(\frac{Z^0}{GDP^0}+\frac{Z^t}{GDP^t}\right)}} \times TT_{DM}^{0,t},$$

where $\frac{tx^t}{tx^0}$ = the relative change in one plus the rate of taxes less subsidies on products as a percentage of value added[24]; $P_Y^{0,t}$ = the price index of domestic output for resident uses; $P_Z^{0,t}$ = the price index of intermediate input from resident sources; $Y^t = p_Y^t y^t$ = the value of output for resident uses (i.e., excluding exports); $Z^t = p_Z^t z^t$ = the value of intermediate consumption from resident sources (i.e., excluding imports);

$$GDP = \tau[(Y + X) - (Z + M)];$$

and

$$TT_{DM}^{0,t} = \frac{\left(P_X^{0,t}\right)^{\frac{1}{2}\left(\frac{X^0}{GDP^0}+\frac{X^t}{GDP^t}\right)}}{\left(P_M^{0,t}\right)^{\frac{1}{2}\left(\frac{M^0}{GDP^0}+\frac{M^t}{GDP^t}\right)}}. \tag{47}$$

[24]Value added is the difference between output at *basic prices,* which exclude taxes on products and include subsidies on products, and intermediate consumption at *purchasers' prices,* which include taxes on products and exclude subsidies on products. GDP is value added plus taxes less subsidies on (output and imported) products, or the product of one plus the rate of net taxes on products as a percentage of value added, τ. Including the relative change in τ in the price index for GDP ensures that net taxes on products will not affect the volume index for GDP via the production approach.

This terms of trade index thus is the contribution to change factor for net exports within a Törnqvist GDP price index that is superlative for the economic value-added price index (5).

Two points are worthy of note. First, the weights of TT_{DM} do not add up to one. It is thus not proportional to a simple scaling of the prices of exports or inversely proportional to a scaling of the prices of imports. Second, it will not be invariant to an equal scaling of export and import prices unless the balance of trade is zero. It will increase with an equiproportional scaling of export and import prices when the trade balance is positive and decrease when the trade balance is negative. See Kohli (1990, 1991, 2002) for further details on, and other versions of, this approach to the terms of trade.

III. Data Sources

Data used to compile foreign trade indices usually are derived from administrative sources or survey sources. Administrative sources include the customs administration, which usually stores the contents of clearance documents in a database; the international transactions recording system; and specific agencies providing data on services. Survey sources include export and import price surveys, producer price surveys, and consumer price surveys.

Customs data are the most commonly used administrative source for the compilation of foreign trade indices. In most countries, a customs declaration is required for merchandise imports and exports, whether or not these goods are subject to customs duties (but there are important exceptions to this). In principle, a customs declaration identifies the importer or exporter, the product code, the value of the shipment, the number of units involved and other appropriate measures of the good's physical dimensions, duties paid, the country of origin or destination, the port of entry or exit, the mode of transport, the costs of transport, and the costs of insurance and freight. Customs, the statistical office, or another agency processes copies of the customs documents to compile statistics on foreign trade. Another administrative source is the international transactions recording system (ITRS) used by most countries to administer current or former foreign exchange regulations. The ITRS records all transactions between residents and nonresidents in which banks serve as intermediaries. A third data source are other agencies regulating service activities, such as the country's ministry or department of transportation database, which can be a source of information on international transportation exports, and the ministry or department of tourism database, which provides data for exports of travel and tourism goods and services purchased by international visitors during their stay in the country. The ministry of finance or treasury can be a significant source of information. International trade within a customs union may be covered by requiring additional information itemizing goods and services purchases by source country and sales by destination country on value-added tax returns, for example.

When customs or other administrative sources are inadequate for identifying products and tracking their prices, surveys are used to fill this gap. The surveys can be a collection directed specifically at prices for foreign trade or an extract from another survey, such as for the PPI. In the first case compilers select export and import samples of establishments from comprehensive lists, or *frames,* of establishments engaged in external trade by type of item transacted. For goods these frames are assembled most often from tariff and export declaration documents. If the frame has an appropriate measure of the size of each unit (exports or a close correlate for exports and imports or a close correlate for imports) compilers select establishments with probability proportional to size. Instead of probability selections, compilers may select so-called cutoff samples of establishments representing the top, say, 50 to 75 percent of the value of trade within a stratum. Compilers then survey the selected establishments to select a set of transaction and product characteristics whose price is to be recorded at the periodicity of the index. Among the transaction characteristics would be the date of export as a best convention for the desired change of ownership accrual principle.

Besides surveys specially designed for international trade, PPI surveys may be a source of data for export price indices. PPI coverage of international trade usually is not comprehensive because at the current state of the art PPIs do not cover most services, including wholesale distribution. Producers directly involved in export and import trade often specialize in international wholesale distribution. On the other hand, PPIs generally do represent producers specialized in nondistributive activities such as mining, manufacturing, and energy production. To the extent these establishments engage in transactions directly with nonresident buyers to sell their output, the PPI price sample can be a source of prices and weights for the export price index, provided exports are separately identified. The CPI is a third source of data to the extent that it covers household purchases of goods and services abroad as a result of recreational tourism.[25] Such expenses usually would be measured via the passenger debarkation documents collected by customs at ports, border crossings, and international airports. Cross-border shopping is thought to be an important component of household consumption in countries too small to have an advanced retail distribution industry, but are a short distance from larger countries that do possess such an industry. It also may be important when there are large consumption tax rate or exchange rate differences making shopping abroad worth the travel expense.

IV. Setting Up a System to Compile Foreign Trade Price Indices

Determining Elementary Aggregates and Their Weights

The customs and ITRS sources of data for weights will not necessarily closely comply with the change of ownership accrual principle. Customs accrues import goods when they enter a country at cost-insurance-freight (cif) prices and export goods when they leave a country at free on board (fob) prices. The ITRS accrues import goods and services when payments to nonresidents are recorded and export

[25]It's worth mentioning that only a few countries currently attempt to collect prices for the imports generated by this cross-border shopping because it would involve collecting prices from nonresident retailers or establishing data-sharing agreements with the statistical offices of neighboring countries.

goods and services when receipts from nonresidents are recorded. The *1993 SNA* and *BPM5* convention on the change of ownership principle accrues both export and import goods trade on various dates, depending on the specifics of the agreements between the transacting parties, if available. In lieu of this, the convention for imports is to use the date items cross the *importing* country's frontier at fob prices, which are exclusive of separately invoiced insurance and freight. Customs imports conform, of course, with this timing convention, though insurance and freight often are not separately identified. In lieu of contract specifics allowing a single accrual date to be established, the convention for exports is to use customs export data, which conform with the fob valuation principle, but record on the date of departure from the *source* economic territory rather than the date of entry into the *destination* economic territory. This different treatment of accrual dates for goods trade inherent in national customs data inevitably opens up discrepancies between the statistics of trading partners the single accrual date principle would avoid by definition. Compilers do what they can to keep discrepancies to a minimum by selecting transactions where trading partner discrepancies are likely to be large.[26] Service imports are recorded when delivered to residents by the nonresident supplier, and service exports when delivered to nonresidents by the resident supplier. Thus, to the extent possible, the balance of payments should be the principal source of data on weights, because adjustments are made to the source information in order to compile goods and services trade on a change of ownership basis.

Unfortunately, the balance of payments information on goods and services exports and imports may lack the detail required to calculate weights for elementary aggregates at the highest level of product and destination/source detail identified in customs and service trade survey data. A reasonable approach to this problem is to allocate the available balance of payments product aggregates to detailed HS and Central Product Classification (CPC) categories crossed with destination/source by using customs and service trade survey data. Consistency between the coverage of export and import price indices and the balance of payments goods and services aggregates thereby will be assured.

Determining the Sample of Products

Goods: testing customs elementary aggregates for multiple products

The first phase in setting up a compilation system for export and import goods price indices is to identify the products whose prices will be tracked by the index. The logic of this process is to begin with evaluating the data already available from

[26]Compilers seek contract specifics for large value transactions such as ships and aircraft to establish the change of ownership date wherever possible, but, as noted, generally do not seek such information for most other goods trade. The errors introduced by using unadjusted customs data are thought to be mitigated by the presumably short time most goods spend in transit. There are other exceptions requiring special handling, however, such as oil and mineral shipments, which may sit in transit inventory for some time to take advantage of price movements or because transit time is irreducibly long compared with a relatively short, say, one-month, reference period.

customs sources. The objective is to test whether each elementary aggregate of goods defined by the detailed customs commodity code and destination or source country comprises a single product. If so, because the unit value can be used as a price, a price relative can be formed directly from successive observations on it, and no further collections are required, assuming customs timing errors are not too severe relative to the change of ownership principle. If not, additional surveys will be required to identify the underlying products within those commodity codes. To evaluate the fitness of customs unit values as the basis for elementary aggregate price indices, we consider two suites of testing protocols.

Price dispersion test

Our definition of a product is based fundamentally on the price dispersion of all transactions falling within the group defined by the item. We can consider a given domain of export or import transactions defined by a particular set of commodity and transaction characteristics to be a product if there is very little price dispersion within the domain at any given point in time. An elementary aggregate defined by a customs commodity class crossed with a destination/source country may satisfy this condition. In this case, there is one product in the elementary aggregate, and the unit value that can be derived from customs information may be considered a reasonable estimator of the desired unit-value estimate for the product. In the presence of some price dispersion in the elementary aggregate, a further test would require additional information on the price-determining characteristics of the transactions in the customs elementary aggregate, if available (in the form of text notes included in the customs documents, for example). If there is no variation in any of these characteristics, we would tend to accept that there is a single product in the aggregate. If, however, there is significant variation in the price-determining characteristics, we would conclude that the customs aggregate contains more than one elementary aggregate.

Quantity proportionality test

We note for completeness that if the quantities transacted of products within an elementary aggregate are highly correlated from period to period—that is, product quantities remain in roughly fixed proportions—then unit values across products can be used to track price change in the elementary aggregate *even if it fails the price dispersion test.* Fixed quantity proportions over time at high levels of product detail is, however, an untenable assumption for most price indices, and this is certainly true of export and import price indices. The challenge to constructing a test of proportional quantities within a customs product-destination/source cell is that it often is not possible to obtain repeated observations of the value and quantity shipped by a given shipper of a given specific product, as this would require a laborious process of going through customs documents from month to month looking for possibilities of matches. Nevertheless, an approach to testing for proportional shipping quantities would be to examine the average shipping quantity across quantiles (say, quintiles or deciles) of the values of shipments and compare relatives of the average quantity shipped between months for each quantile. If the quantity relatives are all the same or tightly clustered, some support would be lent to the proposition that relative quantities have not changed.

Goods and services: surveying international transactors to identify products

When a customs elementary aggregate is deemed to contain multiple products, or in order to survey goods and services transactions beyond the scope of customs sources, it is necessary to design surveys of international transactors to obtain product prices. In part because statistical surveys can be designed for export and import price indices whereas customs administrative files are designed principally for tax collection, surveys can capture information on the characteristics of goods and services and the level of specificity needed to identify products. The kinds of characteristics of products and transactions on which survey information is to be recorded for each product type generally are determined as a result of review of trade association literature, comment fields on customs forms, various press sources, and previous survey experience with the elementary aggregate, if available.

The first survey task is to assemble a comprehensive list or frame of resident international transactors in the various goods and services to be surveyed. For goods, transactor sample frames normally are set up using the customs source, as the names of the seller and buyer should be on each customs form. The seller's name would be captured from export declarations to form an establishment sample frame for exports, and the buyer's name would be captured from tariff filings to form the frame for imports. For international trade in services, lists of establishments also may be set up from administrative sources. Exporters of services might be assembled from individual and business income tax filings reporting a foreign source of, respectively, earned income and sales. However, for transportation and transportation insurance activities related to imports, if the transactor information is recorded on properly completed customs documents, then customs sources can be used to assemble the survey frame of establishments.

Other factors to consider in sourcing data for trade price indices from direct price surveys are the following:

- The products should be periodically reselected within the elementary aggregates, at least every five years, to keep the sample representative of current trade flows.
- For customs elementary aggregates containing multiple products, the coverage of commodities and transactors from samples may be volatile from month to month or quarter to quarter if infrequent (or casual) transactors account for an important share of exports or imports; sample allocations in volatile product strata therefore should be larger, other things being equal.
- Questionnaires for price collection need to include for goods the fob value and date of the export declaration and for services the date of delivery, to comply with the change of ownership accrual principle required by the *BPM5* and *1993 SNA*.

V. Compilation Issues

Beyond the comprehensiveness and coverage of the source data, the quality of trade indices depends on how well certain issues are addressed in the compilation process. These include product quality change, infrequent trade, and the seasonal patterns exhibited by some commodities, as well as issues specific to unit values or true price indices used to estimate price indices for the elementary aggregates.

Quality Change

Significant changes in the characteristics of the commodities selected for constructing measures of price change can be a major source of error if not handled properly. To ensure that compilers do not make a direct comparison between the prices of different commodities, each commodity must be described by a full enumeration of its price-determining characteristics, particularly in the case of manufactured commodities and services. In this way, another price may be declared comparable to an existing one if its accompanying list of characteristics matches the first. Otherwise, adjustment for quality differences between the two prices should be made. In most statistical agencies, quality changes are made using direct and estimation techniques. Direct adjustment involves assigning a monetary value to the quality difference and then adjusting the price for this difference. The standard estimation techniques are the overlap pricing technique (situations where old and new products coexist in the market for at least one period), the link technique (situations when neither overlapping prices nor a direct estimation of the cost of quality difference between the old product and its substitute exist), or the hedonic technique.[27]

Unique and Infrequently Traded Goods and Services

Unique goods and services have characteristics that are unlikely to be repeated in future trade transactions at the (usually monthly) frequency of the index. These tend to be capital goods such as ships, aircraft, and other equipment made to order, and customized services, such as consultancies. This is not so much a problem of knowing the proper price-determining characteristics, but rather that the configurations of known characteristics constantly change and are nonrecurring. Dealing with this by estimating a value for the observed changes in configuration often is subjective. Further, potential sources of quality information on exports of unique goods and services usually are better than on imports. While an individual exporter usually provides guidance on the characteristics and pricing of his unique product,

[27]In the overlap method, compilers estimate the relative value of the quality difference between two items available at the same time as the ratio of their prices at that time. In the link method, the short-term relative price change of a new variety is brought into, or "linked into," the index when two successive prices are available on the new variety, whether or not overlap prices are available with existing varieties. To value the change in characteristics between old and new products whether they are available at the same time or not, the hedonic technique uses the coefficients of a statistical regression ("hedonic") model relating price to characteristics.

an importer may not be able to do so because he generally must depend on often incomplete information from the foreign supplier.

One approach to price indices for these products is for the compiling agency to reach an agreement with the respondent establishing a *model pricing* arrangement. The compiler and respondent agree on a typical model of the unique or custom product and the respondent reports, in each period, what the price of that model would be from period to period. Some of the components of a product may not have an explicit market price, in which case proxies often are used. A proxy for the price of a component can be estimated as a combination of indices of employee compensation in the manufacture of the component in question and the prices of the materials used. For a model to be representative, its definition should be precise and include transaction characteristics. In an import price index for telecommunications equipment, for example, one should consider such elements as the package, country of origin, whether the parties to the transaction are part of the same organization or otherwise related, and method of payment.

Seasonality and Discontinuities

Some commodities move in and out of trade for intervals of time. The result in both cases is periodic unavailability of price data on these commodities. Compilers handle this by imputing missing data using information on price change available for other products at the same HS level. Imputing missing prices for each product ensures that the long-term price relative will be "self-correcting" when the relative is calculated as a chain of short-term relatives and the compiler expects to observe a price again in the future. Compilers typically base imputations on the short-term change in the price index for the next-higher level aggregate when all the products in an elementary aggregate become seasonally unavailable. Other approaches may be used depending on the way seasonal products are handled.[28]

When enough items remain available to compute elementary aggregate indices throughout the year, there still may be seasonal price fluctuations. In these cases it may be useful to produce seasonally adjusted unit-value or price indices for analytical purposes. Time-series fluctuations can be smoothed using methods such as X-12 ARIMA from the U.S. Bureau of the Census, a 12-month moving average, and comparison of the current month with the corresponding month in the previous year.[29]

[28]Alterman, Diewert, and Feenstra (1999) recommend year-on-year monthly indices for elementary aggregates. In this context, imputations might be made using year-on-year product price relatives within an elementary aggregate. For elementary aggregates entirely missing when out of season, however, short-term relative imputation still may be used, since year-on-year methods might not be used for nonseasonal elementary aggregates. Many statistical offices impute by repeating the last observed price. This can cause marked jumps in the index when the price is observed again, however, and should be used only if compilers are reasonably certain the price has in fact not changed over the imputation period.

[29]The X-12 ARIMA seasonal adjustment method requires a minimum of five years of monthly data. As already noted in the imputation context, Alterman, Diewert, and Feenstra (1999) recommend "year-over-year" monthly indices for seasonal commodities rather than filtering techniques such as X-12.

Instability in the Trader Population

Some elementary aggregates are composed mostly of establishments that frequently enter and exit the market, say, within a year. To the extent that product entry and exit are staggered, the imputation methods used for seasonal items and new goods can handle this.

Shipment Not Made in the Current Period

Some products included in the index list may not be shipped in certain periods. To compile the index for the elementary aggregate to which they belong, the common practice is to impute the price changes for these products with the index for the elementary aggregate (e.g., based on the price information from the other products in the elementary aggregate). There may be a case in some customs product aggregates for imputing the previous period price multiplied by the exchange rate index for the partner country. An example where this might be defensible would be an elementary aggregate dominated by long-term, nonescalated contracts denominated in a foreign currency.

Barter, Transfer Prices, and Misreported Values

In some instances, reported prices may suggest barter arrangements, transfer pricing (between related enterprises), or simply misreporting. Barter and transfer prices often coincide with so-called “non-arm’s-length” transactions between a pair of related enterprises, one of which is resident and the other nonresident. Indicators of “non-arm’s-length” transactions are transaction characteristics that should be part of the product specification. For a given item, it is not legitimate, or is at least risky, to compare a transfer price directly with a market price determined in an “arm’s-length” transaction. Transfer prices may deviate significantly from market prices. Multinational entities may have an incentive to set transfer prices to minimize aggregate tax liability by understating profits in high-tax countries and overstating them in low-tax countries. Undervaluation of transactions also may well occur when households import personal property after changing domiciles from one country to another. In most instances, this type of misreporting again is motivated by a desire to avoid taxes. The problem thus is related directly to the level of tariffs, and the cost in time and effort to comply with trade laws relative to the expected penalty for noncompliance. The problem may be acute not only for customs source data, but also for survey sources. Customs officials or economic statisticians should correct for barter and transfer prices and errors from customs value misreporting by imputing the market price of a similar item, wherever possible. If misreporting is extensive, it can have significant negative effects on the quality of prices computed as customs unit values at the transaction level.

VI. Data Dissemination and Revisions

The data disseminated usually include tables of the indices compiled, notes explaining movements in these series, and a technical description of compilation procedures. It is common practice to publish a summary table that includes indices for all items and major product aggregates of exports and imports. It is also helpful to publish various aggregate groupings that interest policymakers, such as manufactured and nonmanufactured goods, petroleum and nonpetroleum imports, and agricultural and nonagricultural exports. While providing tables listing import and export merchandise goods indices at a more detailed level of the HS or the Standard International Trade Classification (e.g., the two-digit level of aggregation) could be beneficial to users, it is advisable to confine published data to indices whose reliability and accuracy meet minimum standards in terms of either their statistical variances or the size of the supporting samples of prices. A user survey might shed light on which index aggregates would be most useful to users. It is good practice to disseminate the weights of component indices as well as detailed product categories. By publishing these weights, users of the data will be able to compute their own index groupings for analysis from the detailed data. In addition, a short, user-friendly summary could be reproduced for each release that briefly describes the methodology and classifications employed.

The existence of a well-established and transparent revision policy to foreign trade indices is an effective tool for reducing the tension between timeliness of data and ensuring the good quality of these data. Changes in the economy often entail large variations in the prices/unit values of exported/imported commodities as a result of changes in quality, sporadic trading in some commodities, and a change in the composition of trade regarding products within elementary aggregates and elementary aggregates within the higher-level aggregates. This is particularly true of electronic goods, machinery, and vehicles. The reliability of export and import price indices can be maintained by revising the list of commodities and weights on a frequent basis, ideally every year. In addition to updates of weights and the list of products covered, trade indices may be revised to reflect new information about historical periods. As needed and with adequate advance notice to users, revisions may be made to indices for the past two to three years in order to correct for trade documents processed after the index processing cutoff date or for misclassification of trade documents by month or product class. To alleviate potential problems raised by revisions to past data, the reasons for the revisions, the way they were conducted, their outcome, and explanations of major differences from previous estimates should be clearly presented to users.

VII. Concluding Remarks

For open economies export and import price indices are critical elements of the system of economic statistics. Much of our treatment of this subject has focused on how we should interpret export and import price indices. We prefer the *nonresident* conceptual orientation because it most directly applies to the national accounts presentation of export expenditure and import supply aggregates. We have shown that resident and nonresident orientations have opposite implications for the direction of the substitution bias of the most commonly used index formulas: the Laspeyres and Paasche. We have argued that timeliness of weighting information for merchandise trade makes it possible to compile timely superlative indices whose substitution bias is much smaller than the Laspeyres and Paasche. We also have argued for chaining export and import price indices to accommodate the expected shifts in the underlying export and import aggregator functions.

At the current state of the art, the main issues in compiling export and import price indices are

- Implementing the correct accrual principle for goods imports in customs source data;
- Identifying goods products and tracking their prices at a sufficient level of detail in customs source data;
- Dealing with very high turnover in the population of products and establishments;
- Coping with errors in customs source data for goods arising from misreporting (usually underreporting) the value of imported products that can have an acute negative impact on the accuracy of prices computed as unit values; and
- Coping with errors in survey source data for goods and services arising from misreporting the values of non-arm's-length transactions.

Other problems in export and import price indices are common to all price indices and include

- Inadequate coverage of service products;
- Identifying service products and tracking their prices at a sufficient level of detail;
- Rapid quality (characteristics) change in both goods and services products (related to the high turnover in product types specific to trade price indices);
- Price imputation methodology when products are missing;
- Choosing a formula for elementary and upper aggregates; and
- Determining the frequency with which new weighting information should be linked into the index.

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