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Price indices as a tool for measuring inflation and economic dynamics

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Abstract

This article provides a doctoral-level treatment of price indices as instruments for measuring inflation and tracing macroeconomic dynamics. It situates the principal index-number formulas- Laspeyres, Paasche, Fisher, Törnqvist, and Walsh- within the axiomatic and economic-theoretic approaches formalized by Fisher (1922), Eichhorn (1976), and Diewert (1976, 1998), and it examines how statistical agencies operationalize these formulas through the Consumer Price Index, the Producer Price Index, the GDP deflator, the Personal Consumption Expenditures deflator, and harmonized indices such as the HICP. Three figures are developed to render visible, respectively, the taxonomy of price indices by formula and domain, the substitution wedge between fixed-basket formulas and the true cost-of-living index, and the feedback system in which indices simultaneously measure inflation and enter the reaction functions that shape it.

Keywords: Price Indices; Inflation Measurement; Cost-Of-Living Index; Laspeyres; Paasche; Fisher; Superlative Indices; Monetary Policy.

1. Introduction

The measurement of the general price level occupies a foundational position in economics. Without a disciplined procedure for aggregating the heterogeneous price changes of millions of distinct goods and services into a single scalar indicator, the concepts that animate contemporary macroeconomic theory and policy-inflation, real output, real wages, real interest rates, purchasing-power parity, and economic welfare would remain analytically intractable. Price indices are the instruments that render these concepts operational, and the quality of economic analysis is accordingly bounded by the quality of the indices on which it rests.

The intellectual ambition of a price index is extraordinary. A single number is expected to represent the change, between two periods, in the cost of a representative consumption basket across an economy of many millions of transactions; to do so in a way that is invariant to arbitrary choices of units and base periods; to respect a set of logical consistency conditions; and, increasingly, to approximate the unobservable cost-of-living function of a representative household. That such an instrument can be constructed at all is a nontrivial achievement of statistical theory, with roots extending to the eighteenth-century work of Carli and Dutot and reaching systematic expression in Irving Fisher's (1922) axiomatic treatment.

2. Literature review

The axiomatic or test approach, pioneered by Fisher (1922) and formalized by Eichhorn (1976) and Balk (1995), defines a price index as a function that maps two price vectors and two quantity vectors to a positive real number, and evaluates

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candidate formulas by the logical tests they satisfy. Among the central tests are identity (if all prices are unchanged, the index equals unity), proportionality (if all prices change by the same factor, the index equals that factor), time reversal (the product of the index from t to s and from s to t equals unity), factor reversal (the product of the price index and the corresponding quantity index equals the expenditure ratio), and circularity (chaining through an intermediate period produces the same result as a direct comparison).

No single formula satisfies every desirable test simultaneously, a result related to the impossibility theorem of Eichhorn and Voeller (1976). The Fisher ideal index—the geometric mean of the Laspeyres and Paasche formulas—occupies a privileged place because it satisfies both the time-reversal and factor-reversal tests, which the component formulas individually violate. This axiomatic superiority is one of the principal reasons the Fisher formula is central to modern index practice.

The economic approach, developed by Konüs (1924) and extended by Diewert (1976), grounds the price index in consumer theory. The Konüs true cost-of-living index is defined as the ratio of the minimum expenditures required, at two different price vectors, to attain a fixed reference level of utility. This index is unobservable because preferences are not directly observed, but it is the construct that a price index ideally approximates for purposes of welfare analysis and real-income comparison.

Diewert (1976) established that under specific functional-form assumptions on the expenditure function, certain observable index formulas are exact—that is, equal to the true cost-of-living index for the corresponding preference structure. He further demonstrated that a class of indices—the superlative indices, including the Fisher, Törnqvist, and Walsh formulas—provide a second-order approximation to the true index for a flexible family of preferences. This result transformed index-number theory: it gave statistical agencies a theoretical justification for preferring specific formulas over others, independent of purely axiomatic considerations.

A third tradition treats observed price relatives as draws from a distribution whose location parameter represents the underlying rate of general inflation. The stochastic approach, revived by Clements and Izan (1987) and Selvanathan and Rao (1994), delivers estimators whose properties can be assessed by standard statistical criteria such as efficiency and unbiasedness. Its conceptual appeal is the explicit treatment of inflation as an economy-wide signal to be extracted from noisy individual price changes; its principal limitation is the imposition of restrictive assumptions about the distribution of price relatives, which are not always consistent with observed data. Contemporary work on trimmed-mean and median inflation measures (Bryan & Cecchetti, 1994) can be read as a pragmatic extension of the stochastic tradition.

A further design choice concerns the frequency of weight updating. Fixed-base indices compare every period to a single base, which over long horizons allows the weight structure to become increasingly unrepresentative of contemporary consumption. Chain indices update weights at short intervals—typically annually—and link the resulting year-on-year indices to form a longer series. Chain-linking attenuates substitution bias but introduces chain drift when relative prices oscillate, and it complicates the additive decomposition of aggregate growth into contributions from components. Modern practice, codified in Eurostat (2018) and in the System of National Accounts (United Nations et al., 2009), generally favors annually chained Fisher or Törnqvist indices for national accounts deflators while retaining a modified Laspeyres structure for consumer price indices.

3. Analysis and Results

Figure 1 organizes the foregoing formulas and their institutional manifestations. At the top level, price indices divide into fixed-basket, superlative, and unit-value or hedonic formulations. Each of these feeds into domain-specific measures: the Consumer Price Index (typically a modified Laspeyres structure), the Producer Price Index, and the GDP deflator (a current-weight, Paasche-type construct that emerges endogenously from the separate deflation of national-accounts aggregates). Specialized indices—core and trimmed-mean measures, the chained PCE and chained CPI, and asset- or housing-price indices—address specific analytical or policy needs. The figure's lower panel summarizes the uses to which these instruments are put: inflation measurement, deflation of nominal variables, indexation, monetary-policy calibration, international comparison, and welfare analysis.

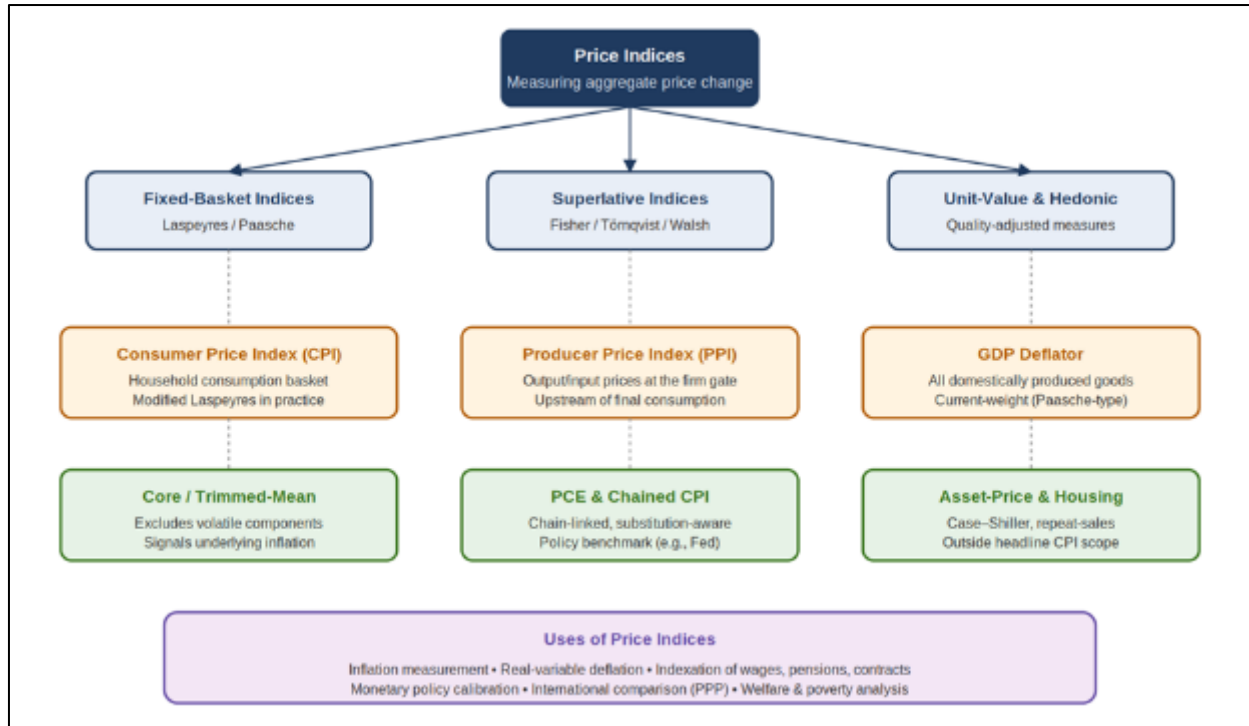


Figure 1 A taxonomy of price indices by formula, domain, and purpose

The central quantitative relationship among the formulas is depicted in Figure 2. Over any horizon during which relative prices change and consumers substitute, the Laspeyres index measures an inflation rate above the true cost-of-living index, the Paasche index measures a rate below it, and the true rate lies between the two. The Fisher ideal index, as the geometric mean of the two, tracks the true index to a close approximation. The wedge between Laspeyres and Paasche widens with the magnitude of relative-price movements and with the elasticity of substitution in household consumption.

This asymmetry is of more than theoretical interest. The Boskin Commission (1996) estimated that the U.S. CPI overstated true inflation by approximately 1.1 percentage points per year, of which roughly 0.4 percentage points were attributable to substitution bias arising from the Laspeyres structure. Over extended periods, even modest annual biases compound into substantial errors: a 1-point annual bias generates a cumulative overstatement approaching 35 percent over three decades, with direct consequences for the measured growth of real wages, real GDP, and poverty thresholds. The adoption of chained CPI measures and of the chain-type PCE deflator by the U.S. Federal Reserve as its primary inflation benchmark constitutes a direct institutional response to these findings.

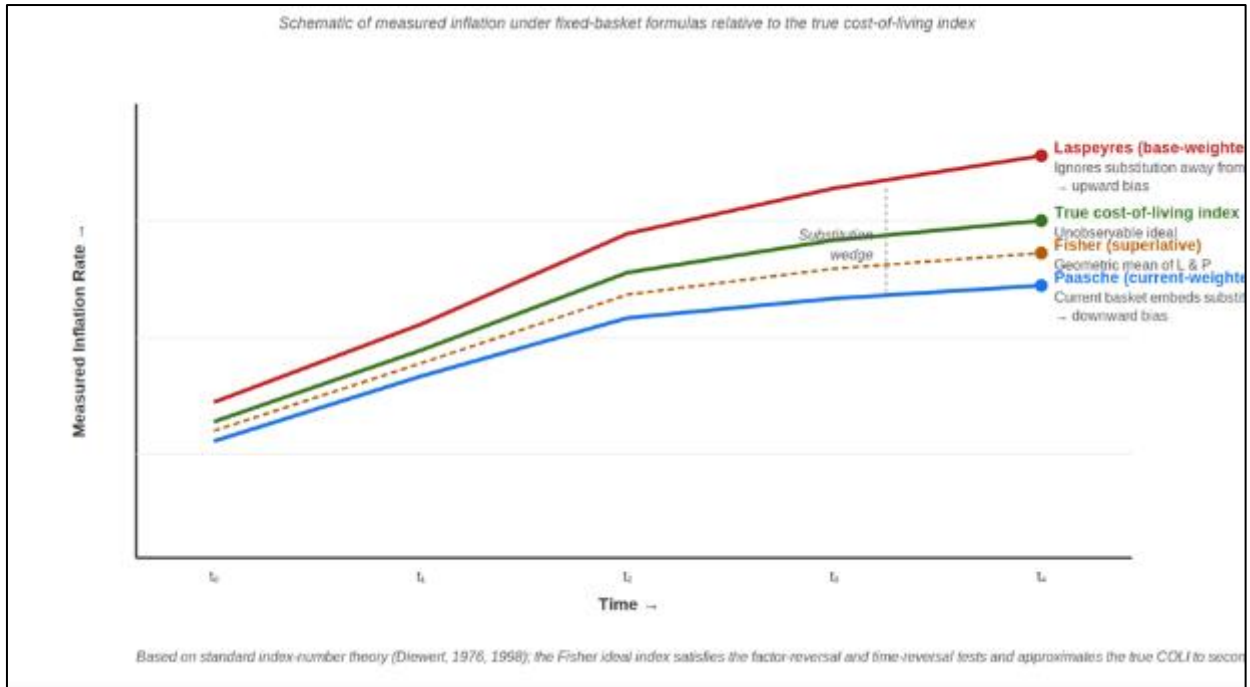


Figure 2 Laspeyres vs. Paasche: the substitution wedge and the superlative middle ground

A persistent challenge in index construction is the separation of price change from quality change. When the specification of a surveyed good improves—a more powerful processor in a laptop, a safer automobile, a more effective pharmaceutical—the observed transaction price conflates a pure price movement with a payment for additional quality. Failure to adjust for quality improvement produces upward bias in the measured price index. The principal methods of adjustment are direct matched-model replacement, option-cost methods, and hedonic regression, in which the price is modeled as a function of measured product characteristics and the residual price change is interpreted as pure inflation (Triplet, 2006). Hedonic methods are now standard for rapidly evolving product categories such as consumer electronics, but their extension to services and to the quality dimensions of digital goods remains methodologically contested.

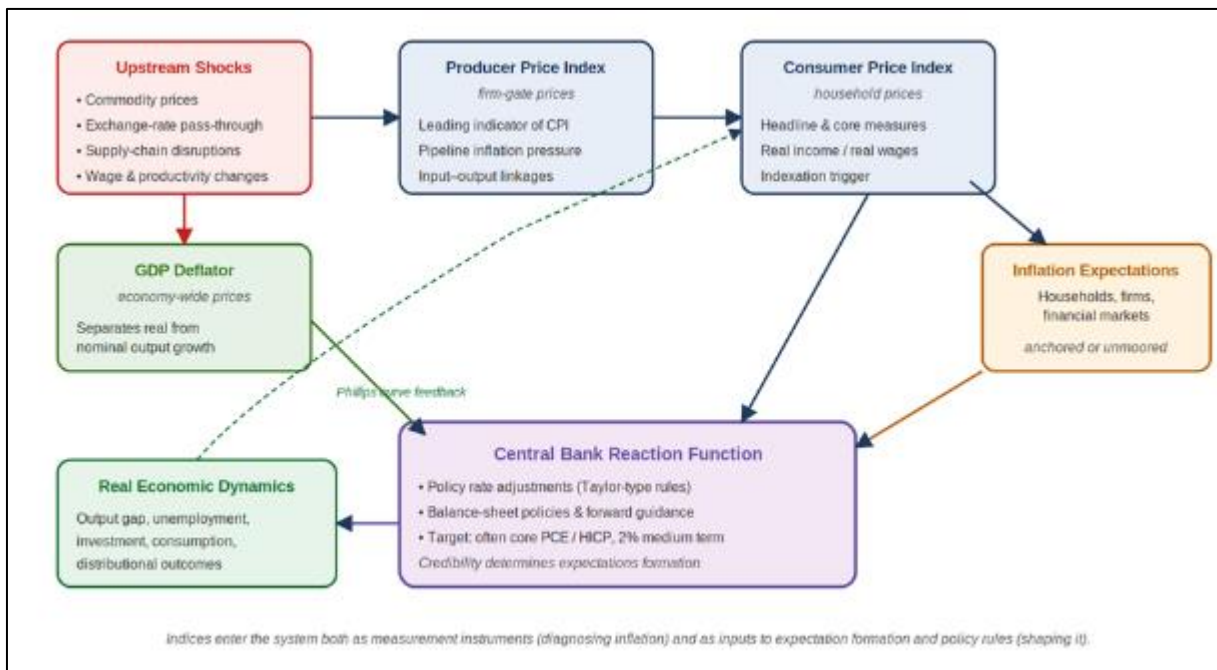


Figure 3 Price indices in the macroeconomic transmission and policy feedback system

Because indices are contractually embedded in the economy-uprating social security benefits, adjusting wage schedules, escalating rental payments, setting the coupon on inflation-linked securities-any bias in measurement translates directly into changes in real resource flows. A CPI that overstates inflation by one percentage point transfers real purchasing power to indexed claimants at the expense of payers; a CPI that understates it does the reverse. The fiscal consequences of the U.S. shift from the conventional CPI to the chained CPI for the uprating of income-tax brackets, analyzed by the Congressional Budget Office (2019), illustrate the quantitative scale of these effects over multi-decade horizons.

Headline inflation contains both a persistent component-reflecting underlying monetary conditions, expectations, and slack-and a transitory component driven by energy, food, and other volatile prices. For monetary-policy calibration, the persistent component is of greater interest, and the development of core inflation measures represents a sustained attempt to extract it. The exclusion-based approach (for example, CPI ex-food-and-energy) is administratively simple but discards potentially informative components; trimmed-mean and median measures (Bryan & Cecchetti, 1994) use cross-sectional information to identify and exclude outlying price changes period by period, with evidence of improved forecasting performance. The appropriate core measure depends on the structure of shocks hitting the economy, and no single measure dominates across all environments.

The 2021–2024 global inflation episode, in which CPI inflation in the United States, the euro area, and the United Kingdom reached multi-decade highs before receding, re-centered price indices in public and academic attention. The episode made salient several features that modern macroeconomic theory had in some respects taken for granted: the sensitivity of expected inflation to successive upside surprises in published indices; the importance of forward guidance about the index measures that policy targets; and the susceptibility of core measures, constructed under pre-episode assumptions about the distribution of shocks, to misrepresent the persistent component when that distribution changes. The experience has stimulated renewed research into high-frequency measurement, nowcasting from scanner and online data, and the integration of disaggregated price distributions into policy analysis.

The data environment for index construction has been transformed by the availability of transaction-level scanner data from retailers and by large-scale web scraping of online prices. The Billion Prices Project, launched by Cavallo and Rigobon (2016), demonstrated the feasibility of constructing daily price indices for many countries using automated collection, and documented close alignment with official statistics in most contexts alongside meaningful divergences in others-most notably in economies with active price controls or limited official independence. Statistical agencies have moved to integrate scanner and scraped data into their production systems, improving sample coverage, frequency, and the capture of short-lived products while raising new methodological questions about sample selection, index aggregation at fine scales, and the treatment of dynamic assortments.

A substantial and growing share of consumer welfare is delivered through goods that are nominally free at the point of consumption-search, social media, messaging, navigation, entertainment. Conventional price indices, which aggregate transaction prices, are silent on the welfare contribution of such goods and on its evolution. Brynjolfsson et al. (2020) proposed willingness-to-accept elicitation as a method for valuing these goods, with resulting adjustments that, if incorporated into official indices, would lower measured inflation and raise measured real-income growth. Whether and how to integrate such adjustments into headline statistics is an open question with significant implications for the measurement of economic dynamics in knowledge- and platform-intensive economies.

Headline indices represent a weighted average of the price changes faced by a representative household. Because consumption baskets vary systematically with income, age, and location, the inflation rate experienced by any given household may differ substantially from the published aggregate. Jaravel (2019) documented persistent differences in measured inflation across the income distribution in the United States, with higher-income households facing lower inflation rates than lower-income households, partly because innovation and competition have been concentrated in categories these households consume more intensively. The construction of distributional price indices-household-group-specific, regional, and by demographic cut-represents a frontier of inflation measurement with direct implications for inequality analysis and for the design of targeted indexation.

Several methodological tensions structure the current research frontier. The first concerns the reconciliation of axiomatic, economic, and stochastic approaches, which have developed in partial isolation and which yield different answers to basic questions about the appropriate formula. The second concerns the measurement of services, which now constitute the majority of consumption in advanced economies and whose price change is more difficult to separate from quality change than is true for goods-owner-occupied housing, financial services, healthcare, and education being particularly difficult categories. The third concerns the treatment of shrinkflation and hidden quality deterioration, where observed transaction prices are stable but the quantity or quality delivered per transaction declines. The fourth

concerns the construction of globally comparable indices across countries whose statistical capacities, basket compositions, and institutional practices differ substantially, a challenge relevant to purchasing-power-parity comparisons and to the empirical study of cross-country inflation dynamics.

4. Conclusion

Price indices are simultaneously among the most technically demanding and the most institutionally consequential constructions in economic measurement. Their formulas are built on a sophisticated apparatus of axiomatic, economic, and stochastic theory, and their operationalization requires statistical agencies to navigate a dense thicket of sampling, quality-adjustment, and aggregation decisions. Their influence extends well beyond the statistical tables in which they are reported: they set the benchmark for monetary policy, anchor inflation expectations, index wages and pensions, and define the real terms in which virtually all macroeconomic analysis is conducted.

The three figures developed in this article render this dual role visible. Figure 1 locates specific formulas within a broader taxonomy tied to domains and purposes. Figure 2 isolates the substitution wedge that has motivated a generation of methodological reform. Figure 3 positions indices within the feedback system that links measurement to expectations, policy, and the dynamics of the real economy. A coherent research agenda for the coming decade will integrate the traditional concerns of index-number theory with the measurement opportunities of transaction-level and online data, with the distributional analysis of consumer inflation, and with the renewed policy salience of inflation measurement that the events of 2021–2024 have firmly re-established. The instruments that economies use to measure inflation are not neutral recording devices; they are part of the economy they measure, and their further refinement is a matter of both technical and substantive consequence.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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