The Consumer Price Index as a Measure of Inflation

by Michael F. Bryan and Stephen G. Cecchetti

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Introduction

As the economy approaches the Federal Reserve's stated objective of price stability, it has become necessary to examine carefully the price indices on which policy is based. The most popularly used aggregate price statistic in the United States is the Consumer Price Index (CPI). This fact alone probably accounts for the prominence it has achieved as a measure of inflation and as a focal point in the Federal Reserve's inflation fight. As an expenditure-weighted index of cost-of-living changes, though, the CPI was never intended to be used as an indicator of *inflation*.

Broadly speaking, there are two problems associated with using the CPI to measure inflation. The first concerns the transitory noise created by nonmonetary events, such as sector-specific shocks and sampling errors. The second involves a potential bias in the index that results both from the expenditure-based weighting scheme the CPI employs (weighting bias) and from persistent errors in measuring certain prices (measurement bias). In an earlier paper, Bryan and Cecchetti (1993), we study the first of these issues.[1] Here, we examine the second.

The existence of bias, or deviations between the trend in the price indices and inflation, implies that *any* fixed-weight price index will be an imperfect long-run target for a policy aimed at aggregate price stability. The magnitude of the bias in the CPI is an empirical matter. Previous researchers have addressed the issue of bias in price statistics by performing calculations based on highly disaggregated information.[2] This approach provides at best only a broad approximation. Moreover, the bias in price statistics depends on the severity and origin of supply shocks, on changes in technology and tastes, and on other time-varying phenomena, so the time-invariant estimates derived from these studies are of only limited value to policymakers.

Our strategy is different. Using a simple statistical framework, we compute a price index that is immune to the weighting bias inherent

■ 1 That paper shows how the use of limited-influence estimators, such as the median of the cross-sectional distribution of individual consumer goods prices, removes transitory elements that create difficulties with interpreting month-to-month movements in the aggregate CPI. We find that the median CPI performs well as a high-frequency measure of the persistent component of inflation.

■ 2 See Wynne and Sigalla (1993) for a thorough review of the literature.

in the CPI as a measure of inflation. The recent work of Stock and Watson (1991) provides a method for combining information in many time series to generate an index of coincident economic conditions. This paper attempts to do for prices what Stock and Watson have done for output. We use a dynamic factor model analogous to theirs to compute the common inflation element in a broad cross-section of consumer price changes.

Unlike expenditure or output-weighted price indices, the dynamic factor index is an unbiased estimate of the component common to each of the individual price changes in the cross-section of data we examine. By comparing the trend in the dynamic factor index with the trend in the CPI, we are able to gauge the extent of the weighting bias in the CPI as a measure of inflation. Our results suggest that over the 25-year period from 1967 to 1992, the weighting bias in the CPI averaged roughly 0.6 percentage point per year. But, since we can construct a time series for the dynamic factor index, we are able to estimate the bias over two economically distinct periods. We find that there was a large positive weighting bias during the 15 years beginning in 1967, but that the weighting bias has been insignificant since 1981.

The following section discusses the sources of bias in fixed-weight price indices. We continue with a brief description of the dynamic factor model employed to construct an unbiased measure of consumer price inflation together with its standard error, and then present a summary of our results.

I. Bias and Expenditure-Weighted Price Indices

In order to understand the bias in fixed-weight price indices as measures of inflation, we begin by defining measured inflation, π_t, as a constant expenditure-weighted index of price changes from period t–1 to t; or

$$(1) \quad \pi_t = \sum_j w_{jo}\, \dot{p}_{jt},$$

where w_{jo} is a set of base-period expenditure weights and $\dot{p}_{jt}$ is the percentage change in the price of good j from period t–1 to t.[3] The expenditure weights are defined to sum to one.

The next step is to note that changes in the individual goods prices, the $\dot{p}_{jt}$'s, share a common inflation component and an idiosyncratic relative price movement, represented as

$$(2) \quad \dot{p}_{jt} = \dot{m}_t + \dot{x}_{jt},$$

where $\dot{m}_t$ is inflation and $\dot{x}_{jt}$ is a relative, or real, price disturbance.

Substituting equation (2) into (1), and noting that $\sum w_{jo} = 1$, we can write measured inflation as

$$(3) \quad \pi_t = \dot{m}_t + \sum_j w_{jo}\dot{x}_{jt},$$

which states that the growth rate of a standard fixed-weight price statistic sums inflation and a weighted average of relative price disturbances. For purposes of policy formulation, we need to obtain a measure of the common element $\dot{m}_t$ or, alternatively, a measure of π_t constructed so that the expectation of the sum on the right side of equation (3) is zero.[4]

Unfortunately, the expectation of π_t does not equal $\dot{m}_t$: $E(\sum w_{jo}\,\dot{x}_{jt}) \neq 0$. There are two reasons for this "bias." First, the individual prices may, on average, be measured incorrectly. We broadly refer to this as a "measurement bias." In addition, actual expenditure shares, w_{jt}, and $\dot{x}_{jt}$ are correlated, producing a "weighting bias." In either case, the expectation of the observed $\dot{x}_{jt}$'s will be nonzero. Our approach is designed to minimize errors caused by weighting bias. And although the dynamic factor approach we have chosen will have little directly to say about measurement biases—inasmuch as they are unrelated to the choice of weighting schemes employed—we can make inferences about certain types of these biases by examining subsets of the data.

■ 3 Strictly speaking, the weights used by the Bureau of Labor Statistics (BLS) in the construction of the CPI vary slightly with relative price changes from year to year. This is necessary in order to hold constant the implicit real quantity of any item used in the calculation of the index. This fixed-weight price index also differs slightly from the CPI because we are summing the weighted logs of the individual prices rather than the weighted levels.

■ 4 If the $\dot{x}_{jt}$'s are mean zero and the weights are constant, then $E(\pi_t) = \dot{m}_t$. However, realizations of π_t are unlikely to equal $\dot{m}_t$, and we can also think of π_t as a *noisy* measure of inflation. There are several reasons why realizations of $\sum w_{jo}\dot{x}_{jt}$ will not equal zero period by period. First, there is simple sampling error in the individual price data. But in its absence, $\sum w_{jo}\dot{x}_{jt}$ may not equal zero period by period because of the way the economy adjusts to real shocks. In our earlier paper, we use a simple model derived from Ball and Mankiw (1992) to describe how supply shocks may cause price indices such as π_t in equation (1) to contain transitory movements away from $\dot{m}_t$.

It should be clear at this point that the bias in a price statistic as a measure of inflation, which is a statistical concept, is distinct from the bias as a measure of the cost of living, although the two may share similar origins, as we explain shortly. In a strict sense, the choice of the term "bias" may be somewhat unfortunate here, as it does not reflect an error in the calculation of the CPI per se, but rather an error caused by applying the CPI to a problem it was never intended to address. Bias in the CPI as a measure of *inflation* is simply the deviation in the trend of π_t from $\dot{m}_t$, whereas bias in the CPI as a measure of *the cost of living* is defined as the deviation in the CPI trend from a constant utility price index.

Consider the case of substitution bias, in which the price of a single good rises. Label this as good k, so that $\dot{x}_{kt} > 0$. In the absence of monetary accommodation, the household budget constraint requires the sum of the relative price disturbances weighted by actual expenditure shares to be zero, or

$$(4) \quad \sum_j w_{jt}\dot{x}_{jt} = 0.$$

For each relative price increase $\dot{x}_{kt}$, the relative price of the remaining goods must fall proportionately such that $w_{kt}\dot{x}_{kt} + \sum_{j \neq k} w_{jt}\dot{x}_{jt} = 0$. Yet, consumer theory implies that expenditure shares will change depending on the price elasticity of demand for the product: Goods having an elasticity greater than one will experience declines in their relative expenditure, and vice versa. The implication here is that if an actual expenditure weight tends to fall for a product whose relative price rises, it reduces the *exactly* offsetting relative price influence of the remaining set of commodities when applied to their original expenditure weights and creates a positive bias in the inflation statistic: $w_{k0}\dot{x}_{kt} + \sum_{j \neq k} w_{j0}\dot{x}_{jt} > 0$.

Substitution bias is simply a specific form of a general weighting bias. To see this more clearly, consider a simple two-period example. We can represent actual expenditure weights in period 1 as a function of the base period weight and the relative price disturbance in period 1,

$$(5) \quad w_{j1} = w_{j0} + \beta_j \dot{x}_{j1},$$

where β_j measures the covariation of actual expenditure weights and relative price disturbances. Substituting equation (5) into (4) yields

$$(6) \quad \sum_j w_{j0}\,\dot{x}_{j1} + \sum_j \beta_j \dot{x}_{j1}^2 = 0$$

or

$$(6') \quad \sum_j w_{j0}\,\dot{x}_{j1} = -\sum_j \beta_j \dot{x}_{j1}^2.$$

This is the weighting bias — only if $\beta_j = 0$ will the sum of the base-period weights and the relative price disturbances be zero. Otherwise, a weighting bias will arise that has the opposite sign of the covariation of the expenditure weights and the relative price disturbance. Nevertheless, there exists a set of weights, w_{jt}, such that

$$(7) \quad E(\sum_j w_{jt}\,\dot{x}_{jt}) = 0.$$

The w_{jt}'s can be thought of as the inflation weights — those that yield a price index without a weighting bias.

II. Origins of Bias in the CPI

In general, we think of all of the biases in the CPI as a measure of inflation as arising from some combination of weighting and measurement bias. As we have already described, weighting bias is the consequence of covariation between relative price changes and a set of properly constructed weights. The classic example of such a weighting bias is substitution bias, where the β_j's are negative and the weighting bias is positive.

Studies of the size of the commodity substitution bias conducted in recent years have concluded that the amount of substitution bias in the CPI is relatively small. For example, Manser and McDonald (1988) estimate that the commodity substitution bias averaged between 0.14 and 0.22 percentage point per year over the period 1959 to 1985. This is largely a confirmation of Braithwait's (1980) earlier estimate of 0.1 percentage point per year over the 1958 to 1973 period. Moreover, Manser and McDonald find the level of the bias to be one-third greater for the high-inflation period (1972 to 1985) than for the more moderate inflation period of 1959 to 1972.

It is entirely conceivable that there are cases in which the correlation between expenditure weights and measured relative price changes is positive, imparting a downward weighting bias in fixed-weight inflation measures. One such case would be a demand-induced relative price increase resulting from a change in tastes, where the relative price of a commodity rises *because* the relative expenditure on it has risen.

Consider also the case in which new goods are introduced. The market basket purchased by households will expand to include items not given any weight in the current index or, alternatively, actual expenditure weights on the included goods will fall. As a consequence, price changes for the goods included in the price index are given too much weight relative to a correctly measured price index. If the relative price change for the new good is negative, the new good produces a positive bias in the price index that is analogous to substitution bias. But it is possible to imagine a case in which the relative price change of the new good is positive, resulting in a negative bias in the price statistic. This would hold true if new goods cause a substitution away from, as well as a decrease in the relative price of, the goods included in the index.

Similarly, changes in *relative* product quality produce a weighting bias by introducing a correlation between actual expenditure weights and relative prices. Quality changes imply that the same effective quantity is available for a generally lower price and, depending on the elasticity of demand for the product, the share of expenditure on such a good could either rise or fall as its effective price drops.[5]

In many instances, weighting bias is not the sole source of the error from using the CPI as a measure of inflation. A number of potential biases arise when the prices of individual commodities are mismeasured. To see how this affects the indices we are studying, consider the case in which measured price changes have three components: the common element, $\dot{m}_t$, the correctly measured relative price change, $\dot{x}_{jt}$, and a common, nonzero measurement error, $\dot{e}_t$. We can write this as

$$(8) \quad \dot{p}_{jt} = \dot{m}_t + \dot{x}_{jt} + \dot{e}_t .$$

It is readily apparent that the measured price index will be

$$(9) \quad \pi_t = \dot{m}_t + \dot{e}_t + \sum_j w_{j0}\dot{x}_{jt} .$$

That is, measurement error will be embedded in the inflation statistic independent of the weighting scheme. New goods (and other excluded goods more generally) introduce the potential for measurement bias to the extent that the set of prices is no longer complete. Moreover, insofar as *average* quality changes are reflected in the price data, they also create a measurement bias by producing a common trend in the price data that is unrelated to inflation.[6]

So-called "outlet substitution bias," arising from the tendency of consumers to escape some part of price increases by shifting purchases toward lower-priced (discount) stores, is another recently identified source of measurement bias. We can think of this bias as some combination of new-goods bias and quality bias, as the goods sold by the discount retailers might be considered separate commodities from those sold by full-service, higher-priced stores.[7]

■ **5** As an empirical matter, measuring new goods bias is much more difficult than measuring commodity substitution bias, since new goods prices are unobservable prior to their introduction. As noted in Diewert (1987), Hicks (1940) suggests that the price of the new good prior to its introduction should be the shadow price at which demand is equal to zero. While this is an excellent theoretical criterion, implementation is simply not possible. As a result, little work has been done on estimating the importance of new goods bias. There are, however, several rough estimates of the size of this problem. Diewert (1987) suggests that the bias caused by new goods could be as high as 0.5 to 1.0 percentage point annually, while Lebow, Roberts, and Stockton (1992) gauge the amount as *no more than* 0.5 percentage point per year.

■ **6** The quality adjustment problem has been the subject of the bulk of academic work on price measurement bias. Beginning with Griliches' (1961) study of automobile prices, this literature has concentrated on estimating the quality bias in the prices of specific durable goods, presumably because the quality of durable goods is more easily quantifiable and data are usually readily available. Estimates of quality bias in the aggregate price index are then extrapolated from the measurements derived for specific commodity groups. For example, Gordon (1992) estimates that quality changes account for slightly more than 1.5 percentage points of the average rise in the prices of consumer durable goods over the 1947 to 1983 period. By applying this estimate to goods that they presuppose to be subject to quality improvements, Lebow, Roberts, and Stockton (1992) estimate aggregate quality bias in the CPI to be 0.3 percentage point annually.

■ **7** The recent growth in the discount retail business has led economists to increase their concern over outlet substitution bias. When consumers substitute between retail outlets on the basis of price, and this shift in the buying pattern is not captured in the point-of-purchase survey conducted by the BLS, the CPI overstates inflation. While the Labor Department adjusts its sample over time, no more than 20 percent of the change in outlet patterns is incorporated into a particular year's survey. Consequently, this measurement problem can affect the aggregate price statistic for a period of several years. A recent study by Reinsdorf (1993) examines the effect of outlet substitution during the 1980s on food and fuel commodities. Assuming that none of the price differences among outlets reflect quality differentials, he concludes that outlet bias accounts for between 0.25 and 2.0 percentage points annually for food, and between 0.25 and 1.0 percentage point annually for energy.

III. A Dynamic Factor Index Approach

Our objective is to compute a reduced-bias estimate of inflation from consumer price data. Recall from equation (3) that we can write a fixed expenditure-weight price index as the sum of common inflation, $\dot{m}_t$, and a term representing the weighted sum of relative price changes, $\sum w_{j0}\dot{x}_{jt}$. This makes clear that the measurement of inflation requires a set of weights that allow us to construct an estimate of the common element in all price changes. Price indices such as the CPI, the Producer Price Index (PPI), or the implicit price deflator for personal consumption expenditures (PCE) share a common core, but as a result of their weighting methodologies, each has a unique weighting bias as a measure of inflation.

As an alternative to the expenditure weighting schemes generally used, we propose weighting commodity prices based on the strength of the inflation signal, $\dot{m}_t$, relative to the noise, $\dot{x}_{jt}$, in each time series. To do this, we assume that the log of each individual product price is the sum of two components: a nonstationary, common core, and a nonstationary, idiosyncratic component measuring movements in relative prices. Taking first differences, the model can be written as

$$(10) \quad \dot{p}_t = \dot{m}_t + \dot{x}_t ,$$

$$(11) \quad \psi(L)\, \dot{m}_t = \delta + \xi_t ,$$

$$(12) \quad \theta(L)\dot{x}_t = \beta + \eta_t ,$$

where $\dot{p}_t$ and $\dot{x}_t$ are vectors; Ψ and θ are, respectively, a vector and matrix of lag polynomials with stationary roots; ξ and η are i.i.d. random variables; and β and δ are vector and scalar constants.[8] We identify $\dot{m}_t$ by assuming that relative price disturbances are uncorrelated with common inflation at all leads and lags. This is what is meant by a common component. If $\dot{m}_t$ were correlated with any of the $\dot{x}_t$'s, then they would contain a part of the common core. In addition, it is necessary to restrict the β's to sum to zero. For computational convenience, we further assume that $\theta(L)$ is a diagonal matrix of lag polynomials, that η_t is serially uncorrelated, and that the covariance matrix of η_t is diagonal.[9]

Maximum likelihood estimation of $\dot{m}_t$ is accomplished by applying a Kalman filter to a set of either aggregate or individual price data. The result is an estimate of both the parameter vector, $\hat{\alpha} = \{\hat{\Psi}, \hat{\theta}, \hat{\Gamma}\}$, where Γ is the diagonal covariance matrix of η and the common factor, $\hat{\dot{m}}_t$. We can write $\hat{\dot{m}}_t$ as a weighted sum of current and past individual $\dot{p}_{jt}$'s. Expressly,

$$(13) \quad \hat{\dot{m}}_t = \sum_j \hat{w}_j(L)\, \dot{p}_{jt} ,$$

which is an unbiased estimate of $\hat{\dot{m}}_t$. Put slightly differently, the dynamic factor index is an estimate of the common trend in the individual inflation series such that $E\left(\sum_j \hat{w}_j(L)\, \dot{x}_{jt}\right) = 0.$

Our main interest is in measuring the average weighting bias in the CPI over various sample periods. This is the difference between the average inflation in the CPI and the average $\hat{\dot{m}}_t$, which we label $\bar{m}_t$. We would also like to construct an estimate of the standard error of this bias.

Rewriting (13) in matrix form, we have

$$(14) \quad \hat{\dot{m}}_t = \hat{W}(L)\, \dot{p}_t .$$

It follows that

$$(15) \quad \bar{m} = \hat{W}(1)\, \hat{\mu}_p ,$$

where $\hat{\mu}_p$ is the vector of estimated means of inflation in the individual component price series and $\hat{W}(1)$ is a function of the elements of $\hat{\alpha}$.[10]

It is useful to rewrite the CPI in a way analogous to (15). From equation (1), we have

$$(16) \quad \bar{\pi} = W_o\, \hat{\mu}_p ,$$

which is the estimate of average inflation in the CPI constructed as a constant weighted log-linear index. An estimate of the bias follows as

$$(17) \quad \widehat{Bias} = \bar{\pi} - \bar{m} = W_o \hat{\mu}_p - \hat{W}(1)\, \hat{\mu}_p$$
$$= [\, W_o - \hat{W}(1)\,]\, \hat{\mu}_p .$$

The construction of standard error estimates is slightly more complicated, but still straightforward. To do this, we require an estimate of all

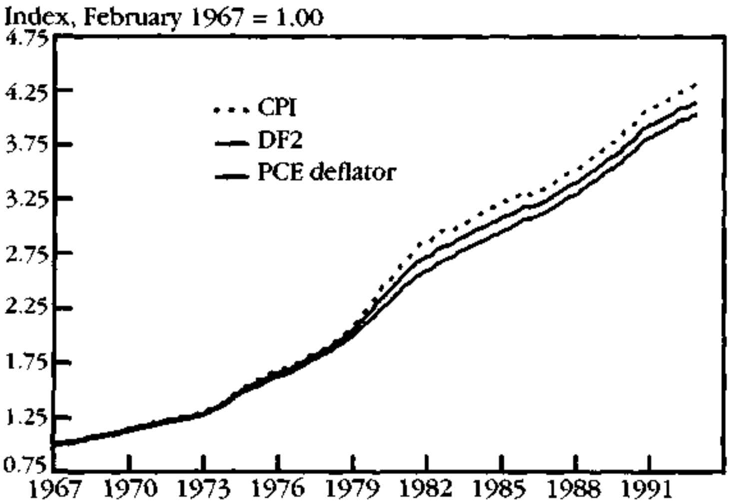
8 See Stock and Watson (1991) for details.

9 Throughout, we assume that both $\dot{m}_t$ and the $\dot{x}_{jt}$'s can be modeled as AR(2)'s.

10 The notation $W(1)$ represents the evaluation of the lag polynomials at $L = 1$, and so is the sum of the polynomial coefficients.

FIGURE 1

Comparison of the CPI, PCE Deflator, and DF2



SOURCES: U.S. Department of Labor, Bureau of Labor Statistics; U.S. Department of Commerce, Bureau of Economic Analysis; and authors' calculations.

TABLE 1

Comparisons of the CPI and the CPI/PCE Dynamic Factor Index (annualized percent changes)

	Feb. 1967–Dec. 1981	Jan. 1982–Dec. 1992	Full Sample
CPI all items	7.05	3.75	5.65
	(0.94)	(0.33)	(0.71)
PCE deflator	6.36	4.05	5.38
	(0.71)	(0.26)	(0.53)
DF2	6.65	3.75	5.48
	(0.81)	(0.33)	(0.59)
Weighting bias	0.39	0.00	0.17
	(0.23)	(0.00)	(0.15)

NOTE: Numbers in parentheses are standard errors. The covariance matrix of the means of the two components was computed using a Newey and West (1987) robust covariance estimator with 24 lags. Subperiod calculations were made independently from the full sample. All values are the average annual difference in the natural log of the index.
SOURCE: Authors.

of the parameters used to calculate $\overline{m}$ and $\overline{\pi}$. This includes the estimated covariance matrix of $\hat{\alpha}$ as well as an estimate of the covariance matrix of the vector of estimated means $\hat{\mu}_p$. The first of these is a by-product of the maximum likelihood estimation of $\hat{\alpha}$, while the second can be constructed from the raw inflation data.

Calculation of the covariance matrix of $\hat{\mu}_p$ is complicated by the fact that the $\dot{p}_{jt}$'s have substantial serial correlation. In fact, the model (10)-(12) implies that when $\Psi(L)$ and the $\theta(L)$'s are all second-order polynomials, the individual inflation series will follow an ARMA(4,2).[11] This leads us to use the Newey and West (1987) heteroskedasticity and autocorrelation consistent covariance estimator, with 24 lags.

We can now construct an estimate of the covariance matrix of the entire parameter vector $\hat{\gamma} = \{\hat{\alpha}, \hat{\mu}_p\}$, called $\hat{\Sigma}$. Assuming that $\hat{\alpha}$ and $\hat{\mu}_p$ are independent, then $\hat{\Sigma}$ is block diagonal. Because $\overline{m}$ and $\overline{\pi}$ are both functions of $\hat{\gamma}$, we can construct standard errors by computing the vector of first partial derivatives of each with respect to $\hat{\gamma}$. The variance estimates follow by pre- and post-multiplying $\hat{\Sigma}$ by this vector of derivatives.

It is worth noting that the uncertainty in $\widehat{Bias}$ comes from variation in $\hat{W}(1)$, which is a function of $\hat{\alpha}$, and variation in $\hat{\mu}_p$. But the uncertainty in the mean vector creates variation in the estimation of mean CPI inflation as well, and so the variance in the estimated bias is likely to be lower than the variance in either $\overline{m}$ or $\overline{\pi}$.[12]

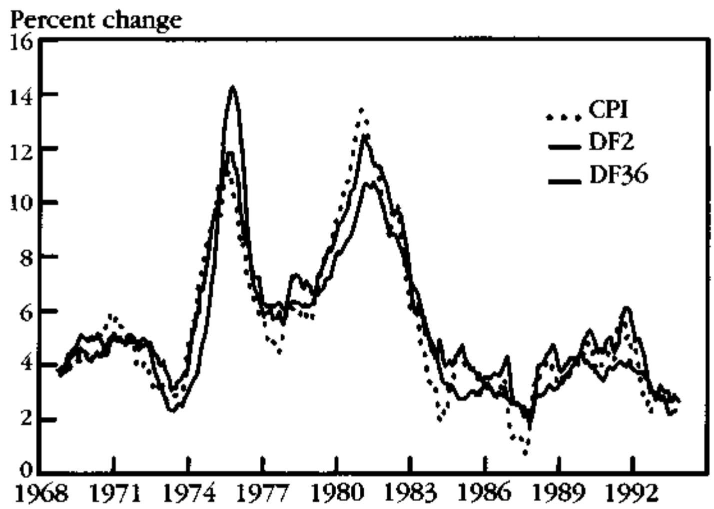
IV. The Results

We constructed two alternative dynamic factor indices of inflation based on consumer price data from 1967 to 1992. The first, labeled DF2, is the common element derived from the CPI and the PCE deflator, two aggregate consumer

11 It is simple to show that the model implies that, ignoring constants, each individual inflation series can be written as $\theta_j(L)\Psi(L)\dot{p}_{jt} = \theta_j(L)\xi_t + \Psi(L)\eta_{jt}$, which is a restricted ARMA (4,2).

12 As implied by the discussion at the end of the previous section, the block diagonality of the covariance matrix allows us to measure the relative contribution of variation in the model parameters, the elements of $\hat{\alpha}$, and the mean vector, $\hat{\mu}_p$, to the estimated variance of the bias. In virtually all of the cases we examine, the uncertainty from estimation of the means accounts for more than 95 percent of the uncertainty in $\widehat{Bias}$.

FIGURE 2



SOURCES: U.S. Department of Labor, Bureau of Labor Statistics; U.S. Department of Commerce, Bureau of Economic Analysis; and authors' calculations.

TABLE 2

	Feb. 1967–Dec. 1981	Jan. 1982–Dec. 1992	Full Sample
CPI[a]	6.93	4.04	5.71
	(0.85)	(0.26)	(0.63)
DF36	6.05	4.11	5.11
	(0.68)	(0.25)	(0.52)
Weighting bias	0.88	−0.07	0.60
	(0.26)	(0.13)	(0.17)

a. The CPI used here was constructed as the weighted sum of the difference of the natural logs of the individual components (1985 weights).

NOTE: Numbers in parentheses are standard errors. The covariance matrix of the means of the 36 components was computed using a Newey and West (1987) robust covariance estimator with 24 lags. Subperiod calculations were made independently from the full sample. All values are the average annual difference in the natural log of the index.

SOURCE: Authors.

price statistics that are constructed from essentially the same price data, but that employ different weighting schemes (figure 1). Over the full sample, this dynamic factor index averaged 5.48 percent per year with a standard error of 0.59 percentage point. This yields a weighting bias over the period of 0.17 percentage point with a standard error of 0.15 percentage point (table 1). Subperiod estimates, which are computed separately using data for only the subsamples, reveal more bias in the 1967 to 1981 interval, about 0.4 percentage point annually. Over the latter period, there appears to have been no bias in the CPI.

The aggregate CPI and the PCE deflator may not provide a rich enough set of price data to measure the common element accurately. As an alternative, we calculated the dynamic factor index from disaggregated price data for 36 components of the CPI (DF36), spanning the complete set of the consumer market basket over the same January 1967 to December 1992 period.[13] The 12-month growth rates of the CPI, DF2, and DF36 are reproduced in figure 2.

The average rate of increase of this more comprehensive dynamic factor index over the sample period is 5.11 percent, compared with 5.71 percent for the CPI, implying an average annual bias in the CPI of 0.60 percentage point over the 1967 to 1992 period with a standard error of 0.17 percentage point (table 2). Using 36 rather than two indices increases the estimated weighting bias with virtually no change in precision. But again, we find substantial differences in the magnitude of the CPI weighting bias between the two subperiods. Between 1967 and 1981, we estimate the weighting bias at 0.88 percentage point annually (with a standard error of 0.26). But since 1981, we fix the bias in the CPI to be nearly zero (−0.07 percentage point with a standard error of 0.13 percentage point).

The dynamic factor indices have limitations, of course. First, the degree of disaggregation and the extent of the sample covered by the price data used are incomplete. More generally, our calculations do not account for the potentially important measurement biases that arise when goods are systematically excluded or when there is a common measurement error, such as unmeasured aggregate quality changes. While we cannot address such measurement biases directly, we can gauge their severity by

13 A catalog of the 36 components can be found in Bryan and Cecchetti (1993).

TABLE 3

[illegible]

	Feb. 1967– Dec. 1981	Jan. 1982– Dec. 1992	Full Sample
CPI[a]	6.93	4.04	5.71
	(0.85)	(0.26)	(0.63)
DF36	6.05	4.11	5.11
	(0.68)	(0.25)	(0.52)
DFGOODS	5.43	3.55	4.47
	(0.69)	(0.30)	(0.54)
DFSERVICES	7.06	4.90	6.02
	(0.70)	(0.27)	(0.53)
Estimated Bias			
CPI–DF36	0.88	−0.07	0.60
	(0.26)	(0.13)	(0.17)
CPI–DFGOODS	1.50	0.49	1.23
	(0.30)	(0.15)	(0.20)

a. The CPI used here was constructed as the weighted sum of the difference of the natural logs of the individual components (1985 weights).
NOTE: Numbers in parentheses are standard errors. The covariance matrix of the means of the 36 components was computed using a Newey and West (1987) robust covariance estimator with 24 lags. Subperiod calculations were made independently from the full sample. All values are the average annual difference in the natural log of the index.
SOURCE: Authors.

comparing dynamic factor indices computed from commodity subsets of the data.[14]

In our statistical model, equations (10) to (12), relative price changes are taken to be stationary. With the additional assumption that relative price changes are zero on average (that is, that the β's in equation [12] are all zero), we can estimate the common factor from any subset of the data. Some economists have suggested that the most serious problem may be in measuring service output. This means that services prices are unreliable, and we use that insight to examine the size of this potential measurement bias.[15]

To test the hypothesis that there is a systematic bias in the measurement of services prices, and to evaluate the recommendation that these prices be excluded from the calculation of inflation, we have split the CPI into goods and services components and have computed a dynamic factor index for each. The results are reported in table 3.

Assuming that the difference between inflation in goods prices and inflation in services prices is entirely a result of measurement bias in the latter category, we can gauge the weighting bias in the CPI from the difference between the dynamic factor index estimated using goods only (DFGOODS) and the aggregate CPI. Again, while we note rather substantial differences between the two prior to 1982, for the recent period, we estimate the weighting bias in the CPI at less than 0.5 percentage point per year.

These results also allow us to estimate the size of the measurement bias in services prices directly by comparing the dynamic factor indices for goods only (DFGOODS) and services only (DFSERVICES). Curiously, the deviation between the dynamic factor indices calculated from the component data, while relatively large for the 1967 to 1981 period (1.63 percentage points annually), is slightly smaller in the post-1981 period (1.35 percentage points annually). While there appears to have been a systematic bias in services prices before 1982, which may be attributable to their mismeasurement, that difference was reduced after 1981.[16]

V. Conclusion

Gauging the accuracy of price indices, which has a long tradition in economics, has taken on new enthusiasm in the recent era of relatively moderate inflation. At issue is whether a goal of zero inflation literally means zero or whether, because of various biases in the calculation of inflation, some low but nonzero rate of measured inflation is sufficient.

We have computed dynamic factor indices of consumer prices, which are constructed by essentially weighting commodities on the strength

■ 14 Measurement bias might manifest itself as low-frequency components in the $\dot{x}_{jt}$'s of certain series. The implication is that the single-factor model we employ may not be sufficiently general to capture the time-series behavior of some prices. If this were a serious problem, then we should find that some of the roots of the estimated AR(2) coefficients in $\hat{\theta}(L)$ imply nearly nonstationary behavior. Our estimates suggest that this may be a problem for medical commodities, motor fuel, and transportation services, but is unlikely to affect the commodities generally thought to suffer from significant measurement difficulties.

■ 15 A recent example is in Poole (1992).

■ 16 In the early 1980s, the methodology used to construct the shelter component of the CPI, which accounts for roughly half of all services in the index, was changed from a relatively volatile purchase-price basis to a rental equivalence basis. To account for this change, we reconstructed the shelter component to conform to a rental equivalence basis for the entire sample. This change, not surprisingly, had little impact on the dynamic factor index calculations. Nevertheless, the results reported here are on the adjusted basis.

of a common inflation signal, in an attempt to assess a potentially important source of bias in the CPI as a measure of inflation—weighting bias. Our estimate of weighting bias in the CPI is roughly 0.6 percent annually in the 1967 to 1992 period, but the size of that bias varies substantially within subperiods. In fact, on the basis of the estimates provided here, we conclude that since 1981, weighting bias in the CPI as a measure of inflation has been negligible.

If there is measurement bias common to the consumer prices in our data set, such as may occur from the systematic mismeasurement of quality changes, it would still be embedded in the estimates presented here. We found significant differences between the dynamic factor estimates derived from all items and the dynamic factor indices derived from goods prices only.

In this paper, we have considered only the case of consumer prices, given their importance in the monetary policy setting and also allowing for comparisons with other studies of bias. Conceivably, a measurement bias common to all consumer prices caused by, say, a reallocation of the economy's resources between investment and consumption goods may be embedded in the dynamic factor indices presented here.[17] This could presumably be corrected by allowing the dynamic factor index to include a broader range of prices, particularly asset prices. An area of future research, then, would involve the integration of investment goods into these dynamic factor calculations.

■ **17** The potential for a systematic measurement bias, caused by the exclusion of investment goods in the CPI, has been suggested by Alchian and Klein (1973).

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