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**ABSTRACT**

The debate over including asset prices in the construction of an inflation statistic has attracted renewed attention in recent years. Virtually all of this (and earlier) work on incorporating asset prices into an aggregate price statistic has been motivated by a presumed, but unidentified transmission mechanism through which asset prices are leading indicators of inflation at the retail level. In this paper, we take an alternative, longer-term perspective on the issue and argue that the exclusion of asset prices introduces an "excluded goods bias" in the computation of the inflation statistic that is of interest to the monetary authority.

We implement this idea using a relatively modern statistical technique, a dynamic factor index. This statistical algorithm allows us to see through the excessively "noisy" asset price data that have frustrated earlier researchers who have attempted to integrate these prices into an aggregate measure. We find that the failure to include asset prices in the aggregate price statistic has introduced a *downward* bias in the U.S. Consumer Price Index on the order of magnitude of roughly ¼ percentage point annually. Of the three broad assets categories considered here -- equities, bonds, and houses -- we find that the failure to include housing prices resulted in the largest potential measurement error. This conclusion is also supported by a cursory look at some cross-country evidence.

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## 1. INTRODUCTION

The debate on the appropriateness of considering asset price movements in the conduct of monetary policy has attracted much attention in recent years. Some have suggested that the failure of the Bank of Japan to consider the price behavior of their asset markets in the 1980s played a contributing role to the economic malaise suffered in that country during the past ten years.[1] More recently in the U.S., rapidly rising prices of equities and other assets in the late 1990s have heightened concern within the Federal Reserve System that, despite the relatively modest growth in conventional retail price measures, inflation prospects had intensified.

Much of the earlier work that has attempted to introduce asset prices into an aggregate price index has been motivated by a presumed but unspecified transmission mechanism through which asset prices are leading indicators of a future inflation at the retail level. However, we find the theoretical and empirical support for this approach lacking. In this paper, we consider an alternative, longer-term perspective on the inclusion of assets in an aggregate price statistic.

Our approach combines a relatively old theoretical concept with a modern statistical technique. We consider the case of asset prices, or more precisely the current nominal cost of a claim to a future unit of consumption, as a case of "excluded goods bias". Such biases are well known in the literature on price statistic construction and can arise whenever the price index fails to account for a systematic relative price change that is of relevance to the economic agent. In so doing, we redefine the object of the central

[1] For a thorough discussion, see Okina et. al. (2000).

bank from a current cost of living index, to a price index appropriate for the deflation of nominal permanent income.

We implement this insight with a weighting technique that identifies a common trend among varied component price data, a dynamic factor approach. This statistical algorithm allows us to see through the excessively "noisy" data that has frustrated earlier researchers who have attempted to introduce assets into a price aggregate, including those weighted solely on expenditure criteria.

The remainder of the paper is organized as follows. We begin in section two with a review of the most influential literature on the inclusion of asset prices in aggregate price measurement. In section three, we provide a simple model of excluded goods bias and show how the standard atemporal microeconomic derivation of a cost-of-living index can be extended to an intertemporal setting. Section four presents a series of alternative aggregation techniques for constructing inflation measures from a combination of prices of current consumption goods and the prices of assets, including housing, equities and bonds. We then proceed to a presentation of the dynamic factor approach that is the focal point of our empirical investigations. In section five, we apply this approach to US data, and then extend the analysis to a set of international data for eleven other countries. Section six concludes.

## II. ASSET PRICES AND INFLATION MEASUREMENT: A REVIEW

Early work on the inclusion of asset prices in measures of inflation can be traced to Irving Fisher (1911). Fisher's intent appears to have been a desire to find a broad transactions price metric to guide the monetary authority in establishing the price of gold. That is, he was considering an index number that best reflected the price level as implied by the equation of exchange. But Fisher was always very clear that different problems necessitated different indexes (broadly differentiated by the comparative places or comparative times under investigation.) The appropriateness of any index number can only be evaluated in the context to which it is to be applied.

The idea that asset prices should receive some consideration in the construction of aggregate price movements remained a largely dormant issue until Armen Alchian and Benjamin Klein, published their paper "On A Correct Measurement of Inflation" in 1973. In this work, Alchian and Klein argued that monetary policy should be concerned with broader measures of prices than those constructed from the income and product accounts deflators or standard expenditure-weighted indices.

What is the Alchian and Klein argument, and how should we approach the problem of asset prices and inflation? The following comparison provides an intuitive explanation of their view, as we interpret it. In the abstract theoretical economies of graduate microeconomics classes—the economy of Arrow and Debreu—we conceive of a world in which there is a full set of state-contingent claims -- that is, assets that represent commitments to deliver and purchase goods and services at all future dates under all possible circumstances. We can think of these claims as securities, and before anything starts in our hypothetical world, there is trading that determines all of their prices. Since all possible futures are considered, everything is settled once and for all in the initial period. Let us further propose that all transactions occur in money, and so there are nominal prices (it is a bit complicated to introduce money formally under these sorts of circumstances, but we will not dwell on what is basically a technical problem of economic theory.)[2]

Before time begins, we have trading that establishes the current money prices for the entire set of all possible goods and services to be delivered today and at all dates in the future. Without changing anything, imagine the same world, but with more money in it, and compare the two worlds. In the second world nominal prices will be higher, and so a given amount of money will purchase less of everything -- fewer claims to goods and services at all dates and in all states of the world. A comparison of prices in these two worlds would be a measure of the inflation implicit in increasing the quantity of money.

Bringing this all back to Alchian and Klein, they propose that we focus on measuring the purchasing power of money generally, rather than on prices of current consumption specifically. Instead of looking at the cost of a particular (carefully designed) basket of goods and services meant to measure current consumption, as is typically done by most consumer price indices, they suggest focusing on the current cost of expected life-time consumption.

There are various uses for such an index, like the deflation of nominal compensation, which presumably requires us to measure not only the price of current expenditures but also prices on current claims to expenditures in a future date (a utility-based saving concept). Further, as we will discuss in section four, the exclusion of prices for current claims on future expenditure may distort the interpretation of a current expenditure price index by a monetary authority that hopes to avoid imbalances between

[2] The simplest way to put in money is to assume that money is distributed by a government that then requires money payments on some future date. For example, there could be taxes that must be paid in government-supplied money.

the growth rate of the money stock and the trend growth in expected output—monetary inflation.

Over the past decade or so, the Alchian and Klein's argument has been critically examined by academic and central bank economists. A theoretical basis for the claim that asset prices can be used to help measure inflation has been provided by Robert Pollack (1989), while Shibuya (1992), Wynne (1994), Shiratsuka (1999), Flemming (1999) and Goodhart and Hofmann (2000) have done empirical work.

This work has been of two types. In the first, researchers have sought to operationalize Pollack's concept of an intertemporal cost-of-living index (ICOLI), and measure the changes in the cost of claims, at current prices, to a consumption basket that yields a fixed level of lifetime utility. The second strand of the literature examines whether the current price of assets can help predict future movements in the more conventional indices.

## III. A SIMPLE EXAMPLE OF EXCLUDED GOODS BIAS

For clarity in exposition, it is useful to begin with the following simple one-period static model with two goods. Assume that utility is Cobb-Douglas, and so

$$U = C_1^{\alpha} C_2^{(1-\alpha)}. \tag{1}$$

The budget constraint is

$$P_1 C_1 + P_2 C_2 = W. \tag{2}$$

Utility maximization implies that

$$\frac{P_1}{P_2} = \left(\frac{\alpha}{1-\alpha}\right)\frac{C_2}{C_1}. \tag{3}$$

We can show that the constant-utility price index is also Cobb-Douglas, and so

$$P = P_1^{\alpha} P_2^{(1-\alpha)} \tag{4}$$

These are equilibrium prices when $C_1$ and $C_2$ are equilibrium quantities.

Assume that $C_1$ and $C_2$ are produced from labor inputs, and that

$$\frac{C_2}{C_1} = \rho\,. \tag{5}$$

We are interested in studying the consequences of $\rho$ to $\rho'$. It is simple to show that following the change in $\rho$, the new prices are related to the old prices as

$$\left(\frac{P_1'}{P_1}\right) = \frac{\rho'}{\rho}\left(\frac{P_2'}{P_2}\right). \tag{6}$$

Now we wish to measure the change in the aggregate price index, which will be

$$\frac{P'}{P} = \frac{(P_1')^{\alpha}(P_2')^{(1-\alpha)}}{P_1^{\alpha} P_2^{(1-\alpha)}} = \left(\frac{P_1'}{P_1}\right)^{\alpha}\left(\frac{P_2'}{P_2}\right)^{(1-\alpha)} \tag{7}$$

Using (6) we obtain,

$$\frac{P'}{P} = \left(\frac{P_1'}{P_1}\right)\left(\frac{\rho}{\rho'}\right)^{(1-\alpha)}. \tag{8}$$

Looking at this equation we see that if we are trying to measure the change in the properly constructed constant-utility aggregate price index, and instead we measure only the change in $P_1$, then we will have a price index biased by a factor of $\left(\frac{\rho}{\rho'}\right)^{(1-\alpha)}$. This is the excluded goods bias.

We could include a change in nominal income, $W$ as well. This would be an increase to

$$W' = \gamma W\,. \tag{9}$$

Such a change is neutral, in the sense that both prices rise by a factor of $\gamma$.

To see how this works, we introduce this common price change into the problem. Assume that prices after the influx of money and the relative price change are

$$P_1^* = \gamma P_1' \tag{10}$$

$$P_2^* = \gamma P_2' \tag{11}$$

This formulation allows us to immediately disentangle the relative price change from the one that comes from the increase in nominal wages. It is important to keep in mind that the aggregate price index will not change by $\gamma$ as $\rho \neq \rho'$. But without a relative price change, then we expect to measure inflation as $\gamma$.

We now wish to examine the price index

$$\frac{P^*}{P} = \left(\frac{P_1^*}{P_1}\right)^{\alpha}\left(\frac{P_2^*}{P_2}\right)^{(1-\alpha)} = \left(\frac{\gamma P_1'}{P_1}\right)^{\alpha}\left(\frac{\gamma P_2'}{P_2}\right)^{(1-\alpha)} \tag{12}$$

Which gives us

$$\frac{P^*}{P} = \gamma\left(\frac{P_1'}{P_1}\right)\left(\frac{\rho}{\rho'}\right)^{(1-\alpha)}. \tag{13}$$

Now, normalizing $\frac{P_1'}{P_1} = 1$ (which means picking good one as the numeraire) we see that correctly measured inflation is

$$\frac{P^*}{P} = \gamma\left(\frac{\rho}{\rho'}\right)^{(1-\alpha)} \tag{14}$$

but ignoring the second good gives us $\gamma$.

Our conclusion is that the difficulty arises from a change in $\frac{C_2}{C_1}$, which creates a relative price change and a substitution effect. This will be more important both the larger the change measured by $\left(\frac{\rho}{\rho'}\right)$ , and the larger the elasticity of substitution between the two goods, $\alpha$ .

Of course, the intertemporal problem is exactly the same. To formulate it, we would simply assume that people live two periods, working and consuming when young and only consuming when old. The young work and are paid a nominal wage, $W$ for their one unit of inelastically supplied labor. They take their money and purchase both goods for current consumption and claims on goods for future consumption. That is, they expend all of their monetary income when they are young. [3]

A change in the price of future consumption relative ($P_2$) to the price of current consumption ($P_1$) is caused by a change in output in one period relative to that in the other. This is $\rho$, the ratio of $C_2$ to $C_1$. We note that in the context of this very simple intertermporal model, this price ratio $P_2/P_1$ is the real interest rate, and that changes in the real interest rate come from technological changes that change the growth rate of output $\rho$.

In addition to changes in relative prices, we can also introduce a form of "pure" inflation that arises from increasing the monetary wage W that is paid to workers when they are young. In this very simple formulation, we can think of increases in nominal wages as analogous to increases in the money stock. Aggregate inflation enters through the parameter $\gamma$.

Looking back at equation (13) we can see the proper change in the (utility-based) price index depends on several things. First, there is the change the current price of

[3] The Cobb-Douglas utility function is analogous to a log-linear utility function with a discount factor equal to $(1-\alpha)/\alpha$. It is easier algebraically to retain the Cobb-Douglas form, and so we continue with it.

current consumption. But the index also depends on the change in the current price of next period's consumption. In this simple formulation, the dependence on the prices of claims to future goods and services shows up as a change in the growth rate of consumption. Ignoring the second term, the ratio of ρ to ρ' creates a bias in the measure of inflation.

How big a problem do we face if we ignore current claims on future consumption? First, notice that there is a bias only when the growth rate of consumption changes. This is what creates the relative price movement that precipitates the excluded goods bias. But even so, the problem could conceivably be large. If we think of this two-period model as covering a lifetime, then the time periods must be rather long. For this example, we take a period to be 35 years. If consumption grows at 2% per year, approximately the growth rate of per capital U.S. GDP, then $\rho$ is a number like $\rho = 1.02^{35} = 2$. Consider a case in which this rises by one-half on one percentage point to $\rho' = 1.025^{35} = 2.37$.

Next, we need an estimate of $\alpha$, the importance of the first period consumption in utility. Assuming an annual discount factor of 0.98 and two 35-year periods, the approximate weight on consumption in the first 35-year period is approximately one-third. This means that our measure of inflation, at the time of the permanent change in economic growth, is off by a factor of 0.893, and so inflation is overestimated by 10.7%. Granted that this is for a 35 year period, but the potential error seems very large.

## IV-1. INTEGRATING ASSET PRICES INTO A PRICE INDEX: EXPENDITURE WEIGHT APPROACHES

The identification of a potentially large excluded goods bias in a price index suggests an obvious solution—include the omitted prices in the aggregate price calculation. Unfortunately, data on the price of contingent claims to future consumption do not usually exist. This has prevented the exact implementation of the original Alchian and Klein proposal. In more recent work, both Pollack and Shibuya demonstrate how, under straightforward circumstances, an intertemporal cost of living index (ICOLI) can be constructed by using the current prices of existing assets (which are claims on future consumption) in place of the theoretically appropriate Arrow-Debreu contingent claims prices that are not extant in the real world.

As Shibuya notes, the construction of an ICOLI will necessarily put the bulk of the weight in the price index on future consumption, and thus on asset prices. The reason for this is very straightforward. The intertemporal index is constructed from the present value of the sum of future consumption. Ignoring changes in consumption over time, and assuming that the rate of time discount is about 3%, current consumption is only one part in about 33, and so the weight on asset prices (claims to future consumption) will be 97%, while that on current consumption prices will be 3%.[4]

In Shiratsuka's application to the case of Japan, the weight of 97% on asset prices implies that there was both much higher inflation in Japan in the 1980s, and much worse deflation in the 1990s, than shown in the standard measures of consumer prices—implicitly suggesting that monetary policy was initially too expansionary, and later

[4] The rule-of-thumb for such a calculation is that the weight on the index of current consumption prices will be approximately equal to the rate of time discount.

too contractionary. But the high weight accorded asset prices, and the implicit policy prescription, results in the recommendation that policymakers target asset prices.

But there are shortcomings to this interpretation of Alchian and Klein. Bond markets facilitate the transformation of current money into future money, and so if monetary policy stabilizes the price of current consumption over time, it makes intertemporal exchange of goods predictable as well. A policy that controls the time path of the terms of trade between current money and current consumption, together with nominal bonds that allow the transformation of current into future money, stabilizes the price of lifetime consumption, and so no further information is needed.

Indeed, there is a fundamental confusion that pervades much of the discussion of the inclusion asset prices in measures of inflation that concerns that idea that asset price movements somehow give information about future inflation. The claim is that an asset price will increase in anticipation of future goods price increases. If this occurs while current goods prices are stable, then a central bank that only targets current consumption flow prices will fail to respond adequately to stabilize future goods prices.

This is the argument that has led both Shiratsuka and Goodhart and Hofmann focus attention on the ability of current prices of assets, including residential property and share prices, to forecast movements in conventionally measured consumer price inflation several years ahead.

While there is empirical evidence to suggest that increases in asset prices may help foretell a future inflation at the retail level (albeit marginally), the theoretical mechanism for such a finding must be an indirect one whereby increases in aggregate demand outstrip those of aggregate supply. It is not the case that increases in equity prices themselves are a sign that market participants have increased their forecast of future consumer price inflation.

To see why this is so, carefully consider the determinants of asset prices. In the absence of bubbles, the price of assets is the present discounted value of the stream of goods or services that come from owning it—the dividend or earnings flow. If we measure the future value of the dividend in current dollars, then we would discount the stream using the real rate of interest. If prices were measured in future dollars, then we would need to use the nominal rate of interest. But in either case, changes in the path of future inflation leave the level of the asset price unaffected, and so fluctuations in asset prices must come from other sources. Surely, increases in the current price of an asset can affect inflation through the wealth effect on consumption, but this macroeconomic mechanism has nothing to do with asset prices being signals of future inflation.[5]

Alternatively, our interpretation of Alchian and Klein is based on a related article by Tullock (1979) who describes the case of an excluded goods bias in the event of a hypothetical "diamond rush" where the cost of living appears to be exceptionally high when judged by the rapid rise in the price of current consumables. And in fact, if we are considering the question, "what are the costs associated with current consumption compared to the pre-rush era?," then this narrowly defined market basket of price ratios may be the appropriate statistic.

However, if we are concerned with the question, "What is the real wage of diamond-mine laborers?," this market basket may be especially misleading. Indeed, judged only by the current cost of living, the real wage of labor may easily appear to be

[5] Flemming's (1999) suggestion that the central bank's inflation target be based, in part, on the fluctuation in the nominal price of an index bond follows directly from such reasoning.

falling dramatically as the demand for current consumables surges due to their higher demand. The missing price, in this example, is the exceptionally low priced un-mined diamond assets which, once included in the appropriately constructed price index, reveal the rapidly rising real wage of labor that gave rise to the diamond rush to begin with.

## IV-2. INTEGRATING ASSET PRICES INTO A PRICE INDEX: A SIGNAL-EXTRACTION APPROACH

Returning to the issue of how we might employ asset prices in the measurement of current inflation and the purchasing power of money, consider the simplest possible case of what we will call pure inflation. Pure inflation is the case in which there are no relative price changes -- it is as if we were to wake up one morning and suddenly all nominal quantities have been multiplied by some factor. If all prices change proportionally, then measurement of inflation is trivial, as we can look at any individual price and it is a perfect indicator of what happened to all prices. That is to say, we could compute the amount of inflation by looking at the price of houses, equities, restaurant meals, or chewing gum. It simply would not matter.[6]

In fact, measuring the change in the purchasing power of money would simply require that we measure the change in a single price. Unfortunately, real life is not quite so simple, and inflation tends to come with relative price changes as well. These changes in the nominal price of one product relative to another are caused either by changes in technology or in tastes, and they are entirely real. In measuring inflation, the goal is to get rid of these by finding a set of prices in which they cancel out.

[6] The possible existence of nominal bonds complicates this example somewhat, and so we will ignore them for the time being.

We can appeal to earlier work of Bryan and Cecchetti (1993) for a simple framework to understand the problem. Using their simple intuition, we can think of the inflation in the price of all goods, services and assets today as having a common and idiosyncratic component. In symbols:

$$\pi_{it} = \pi_t + x_{it} \tag{15}$$

where i indexes the set of goods, services or assets, and t is time. We can think of an inflation index as a weighting together of these individual inflation measures. If we have a set of weights, this would be:

$$\dot{P}_t = \sum_i w_{it} \pi_{it} \tag{16}$$

where the weights are the $w_{it}$ and can change over time, but have the property that at any given time they sum to one. That is

$$\sum_i w_{it} = 1 \forall t \tag{17}$$

Using this fact, we can now rewrite the price index

$$\dot{P}_t = \pi_t + \sum_i w_{it} x_{it} \tag{18}$$

Since our goal is the measurement of the common trend in all prices, we are trying to find a set of goods, services and assets where the (weighted) relative changes cancel out. These relative changes will cancel out, however, only in the case where there exists a complete set of prices. In the case of the excluded goods bias discussed earlier, such that relative price adjustments produce a non-zero sum, this measurement error will be imbedded in the common inflation signal ($\pi_t$) in equation (18). For the purposes of this investigation, this relative price change is created by the intertemporal substitution between current and future consumption induced by a change in the real interest rate.

During periods when the real interest rate has declined, real current prices of current consumption fall relative to real current claims on future consumption, causing any aggregate price measure (regardless of weighting technology) based only on current consumption prices to be too high.

Bryan and Cecchetti (1993) refer to the index $\pi_t$ as a dynamic factor index (DFI). It is derived from the joint statistical properties of a price series, rather than from consumer theory. As such, it is a very different implementation of the intertemporal cost-of-living index discussed by Alchain and Klein, and formalized Pollack and implemented by Shibuya. Instead, it is a direct measure of the purchasing power of money based on the intuition provided by Goodhart (1999).

But once we formulate the problem in this way, we can see that the issue of weighting any given nominal price is an empirical one, having to do with their informativeness about the common trend. If, for example, we knew that the price of a particular variety of shoes never experienced any relative price changes, then we could save government statistical agencies quite a bit of money.

Alternatively, if there were only two goods in the economy, and they experienced substantial relative price shocks, and then focusing attention on one price alone, rather than a properly constructed average, could be misleading. Starting with a set of prices that includes asset prices, we can ask whether their inclusion adds any information to our estimate of the common trend?

### IV-3. INTERGRATING ASSET PRICES INTO A PRICE INDEX: A DYNAMIC FACTOR INDEX APPROACH

The decision as to whether asset prices should be included when measuring inflation depends, therefore, on how informative they are about measuring the common price growth trend. From the simple framework outlined in the previous section, we can see that this is reflected in the weight given to various asset prices in the construction of the common index. Building upon this framework, we write the model as

$$\dot{p}_{it} = \dot{\pi}_t + \dot{x}_{it} \tag{19}$$

$$\psi(L)\dot{\pi}_t = \delta + \xi_t \tag{20}$$

$$\theta_i(L)\dot{x}_{it} = \eta_{it} \tag{21}$$

where $\dot{p}_{it}$, $\dot{\pi}_t$, and $\dot{x}_{it}$ are the first differences of the logs of the observed variables, the common unobserved component representing inflation and the idiosyncratic relative price movement in the $i^{th}$ series, respectively. $\psi(L)$ and $\theta_i(L)$ are vectors of lag polynomials and $\xi_t$ and $\eta_t$ are i.i.d. random variables. Throughout, it is assumed that both the common element, $\dot{\pi}_t$, and the idiosyncratic components, $x_{it}$ can be modeled as AR(2) processes.

The main identifying assumption of the model is that the common component and the idiosyncratic components are mutually uncorrelated at all leads and lags. This is achieved by assuming that $\theta(L)$ is diagonal and that all the error terms in the model are mutually uncorrelated. This is consistent with the notion that the common component captures all the comovement in the observed series, leaving $x_{it}$ to reflect only idiosyncratic movements. To set the scale of $\dot{\pi}_t$, the variance of $\xi_t$ is normalized to one.

The parameters of the model are then estimated via maximum likelihood using the Kalman filter. As a by-product, the Kalman filter recursively constructs MMSE estimates of the unobserved components $\dot{\pi}_t$ and $x_{it}$ given observations of $p_{it}$. The common index can be written as a linear component of current and past values of the observed series

$$\hat{\pi}_t = \sum_i \hat{w}_i(L)\, \dot{p}_{it} \qquad (22)$$

It is these weights that are implicitly used to construct the common component that are of primary interest in this context, as it is on the basis of these weights the question of whether asset prices should be included when measuring inflation can be assessed. In a perfect world, this model should yield the weights as described in equation 7 of the theoretical model, $\alpha$ and $1-\alpha$.

In an alternative approach to this "signal-extraction" problem, Wynne (2000) describes the implementation of a simple variance-weighted price index where

$$w_i = \frac{\frac{1}{\sigma_i^2}}{\sum_{i=1}^{N} \frac{1}{\sigma_i^2}} \qquad (23)$$

for all of the series in the data where $\sigma_i^2$ is the variance of the rate of change in the price of good i.

A simple variance-weighting scheme of this type is a good indicator of the likely importance of a particular series in the construction of more complex (and difficult to compute) dynamic factor indices. To see why, note that the variance of the "common" element in any scheme, similar to that describe in equation (23) above, will have the property that the estimated inflation index will have variance equal to or less than the variance of the least volatile component used. As a result, the variance-weights derived from (23) will give an indication of the likely importance of each series in constructing measures of inflation.

## V.1 RESULTS: THE CASE OF THE UNITED STATES

To evaluate the importance of asset prices in the construction of a DFI measure of inflation for the US, monthly data on house, stock and bond prices were examined in conjunction with CPI component series at varying levels of aggregation. The first approach looked at the traditional measure of "core" inflation – CPI excluding food and energy. Individual series for food and energy were also included along with the three asset price series. The implicit weights for the constituent series were extracted by computing the response of the common component to unit impulses in each of the series. Weights were also calculated based on the variances of the observed series for comparative purposes (as described by equation 23.) This static version of the model attributes a weight to a series based solely on the inverse of its variance, ignoring the time series properties of the data.

The weights that resulted from these experiments are reported in table 1. First, we note the relative weights assigned to the three CPI components as derived by the DFI model without asset prices (column 2) relative to the expenditure weights given these components in the actual CPI (column 1.) Energy prices were assigned a disproportionately small weight (4.4%) compared to its expenditure weight (7%). This seems to support the common finding that energy prices are excluded from most commonly accepted measures of "core" retail price inflation. On the other hand, food prices appear to have a reasonably strong common inflation signal, suggesting that their exclusion from a price index may not be entirely justified.

Turning to the influence of asset prices, we computed the common DFI index first with all three asset-price series included, then we proceeded to drop alternative series in order to gauge the impact on the weights attributed to the remaining series. Focusing first on column 3 where all three asset-price series are included, it is evident that housing is the asset price series that conveys the most information about the common trend in prices. Indeed, at this level of aggregation, the housing price index would appear to have a disproportionately large weight attached to it (20.5%), according to the statistical model we apply.

When evaluating the weights, remember that the strength of the common price signal in any particular component should be judged against the case where its signal-to-noise quality is identical to the average price component, 1/n, where n is the number of component prices included in the statistic's calculation. In the case of table 1, column 1, this is approximately 17%. The signal to noise ratio for equities and bonds was considerably less than this benchmark, with DFI weights of 4.5% and 2.4%, respectively. As a general observation then, these asset price components (like energy prices) are exceptionally "noisy" in the sense that their idiosyncratic behavior reduces their usefulness in the estimation of a common inflation trend.

Indeed, the highly variable nature of certain asset prices has generally undone any practical implementation of a broader price index that includes asset prices. This quality in the data is suggested by the very small weights attached to equity and bond prices resulting from the variance weighting approach (0.3% and 0.1%, respectively.) But despite the relatively high variance of the housing price series (resulting in a variance weight of only 0.3%), the common inflation signal contained in this asset appears to be exceptionally strong.

In our approach, this finding is not particularly surprising. Every asset is composed of a large number of particular characteristics. Equity prices, for example, represents claims to an increasing quantity of future consumption, tantamount to a substantial quality bias in the price measure. Although a similar complaint can be made for the housing data (which do not hold constant the characteristics or amenities of the housing stock, or make adjustments for changes in tax treatment), housing is more analogous to a real consol, the appropriate asset price in our theoretical treatment.

We disaggregated further the CPI on the basis of its nine major component groupings, recomputed the DFI's for every possible combination of assets and examined the resulting component weights (table 2).[7] At this level of disaggregation, the weight attached to housing prices falls sharply (to 3%), although taken together with the housing services index in the CPI, the total housing component of the index commands a weight of about 14 percent. These weights stay roughly the same when the other asset price series are omitted. In contrast, zero-coupon bond prices are relatively uninformative, attracting small weights in all three cases. The weights attributed to stock prices are consistently higher than those for bonds but are nonetheless somewhat small in all cases.

Nevertheless, each of these assets is assigned a substantially larger weight in our statistical model than suggested by the variance weights. Cumulatively, the variance

[7] The CPI data used are based, where possible, on the methodologically consistent research series (CPI-U-RS) published by the BLS and are seasonally adjusted where appropriate. The inclusion of nine components at the group level breakdown reflects the need to accommodate changes to the group structure by the BLS in 1997. The data series range from December 1977 to December 1999. Two of the relative price series at the 9-series level of disaggregation have roots close to 1, indicating that the standard errors around the DFI may be very large.

weights suggest giving this combination of assets less than ¼ percentage point weight in the price index, compared with about a 4½ percent weight in the DFI. Again, this highlights the importance of considering the time-series properties of the data in allocating weights.[8]

Finally, the DFI weights attributed to the components of the CPI and the expenditure-based weights actually used in the construction of the CPI stand in sharp contrast. Price series with disproportionately large service (or wage) components, such as medical care, recreation, and education, receive much higher weight in the DFI than in the CPI, highlighting the difference between the traditional cost-of-living approach to inflation measurement and this more statistically-based measure. (Experiments using a more finely disaggregated CPI are reported in Appendix table 4, although these experiments do not materially alter our interpretation of the results.)

How much do the inflation measures using asset prices differ from conventional headline and “core” CPI indices of inflation? We answer this question by examining the time-series themselves. In table 3, we report the annualized growth trends in the various inflation estimates (using the nine-component CPI data) over periods of varying length, full sample (January 1978 to December 1999), the most recent ten years, and the most recent five years.

The long-term growth differential between the inflation measures is somewhat small. When all three assets are included in the DFI, the annualized 22-year growth trend is 4.6 percent—0.4 percentage points above the CPI, and 0.2 percentage points above the

[8] We note the fact that the variance weight on house prices increases when longer horizons than one-month differences are looked at, and may reflect some of the same influences. The larger weight attributed in house prices in Cecchetti et al (2000) at least partly reflects the use in that paper of quarterly data.

CPI excluding food and energy and the median CPI. These suggest that a bias does indeed exist from failing to include asset prices in the price data, although the order of magnitude is about ¼ percentage point annually.

Over shorter horizons, such as ten-year and five-year periods, the differences were a bit higher. Between 1989 and 1999, we find that the exclusion of asset prices reduced the measurement of inflation by about 0.3 to 0.4 percent annually (3.32 percent for the DFI including all three asset categories, vs. 2.89 percent for the DFI without assets, and 2.82 for the CPI excluding food and energy.) For the most recent five-year period, the inflation differentials were slightly higher still, although only in the instances where equity prices were included in the index.

That these measures of inflation can yield different inflation trends can be seen in the year-to-year growth trends reproduced in figures 1-4. The most striking difference is seen in figure 1, between the commonly reported CPI (research series, CPI-rs) and the other indexes, such as the CPI excluding food and energy (CPIXFE), the median CPI, and the DFI without assets (DFI-none).[9] Note that the CPI rose substantially above the other inflation indexes during the late 1970s, but was well below the other measured inflation trends during the 1980s. This is due to the singular impact on the inflation estimate coming from energy prices. In all three of the alternative inflation measures, the statistic is designed to limit the influence of such idiosyncratic occurrences.[10]

In figure 2, we show the inflation patterns of the benchmark CPIXFE and the DFI computed using all three asset categories (DFI-hsb). In the early 1980s, the "core" retail

[9] In all of the figures shown and described in this section were calculated using the 9-component CPI level of disaggregation.
[10] Correlations between the various inflation measures are reported in appendix table 5.

inflation statistic reveals substantially greater inflation than the asset-based DFI. Since 1987, however, the DFI with assets has tended to run somewhat higher than the CPI excluding food and energy. This impression changes only marginally when different asset combinations are used in the construction of the DFI (figures 3 and 4.)

Finally, consider the impression one gets of the growth in real nominal compensation in the U.S. by deflating nominal compensation with each of these price statistics (8-quarter growth trend shown.) In the base case (shown in figure 5), the real compensation per hour series computed by deflating with the CPI shows much less real growth as a consequence of higher energy prices. Including asset prices (figure 6) yields the result that real compensation growth in the U.S. since 1985 has been somewhat less than that reported using the more conventional retail price data. Again, these patterns are only marginally influenced by varying the combinations of asset prices included in the computation of the DFI (figures 7 and 8.)

## V.2: THE RESULTS: A CROSS-COUNTRY COMPARISON

To further assess the role of asset prices in measuring inflation, both DFI and variance-based weights were calculated using a data set for twelve countries complied by Goodhart and Hofmann (2000). Quarterly data beginning in December 1977 on aggregate CPI, house prices and stock prices for each country were examined[11]. The DFI weights are illustrated in figure 9 while figure 10 shows the weights calculated using the static variance-based approach.

[11] The data series for most countries were quarterly observations from December 1977 to December 1997. Data for Canada and Finland start in March 1980 and that for France starts in June 1980. Japanese data are semi-annual and span June 1957 to December 1997.

Several things are worth noting from these charts. First, the DFI approach attributed significant weights to house prices in every country and, with one exception, the weight on house prices exceeded that on stock prices. In fact, in several cases, the weight attributed to house prices is larger that that attributed to the CPI. This may indicate a need to disaggregate the CPI series to capture more of the statistical properties of the constituent series. As in the US case, the weights for asset prices using the DFI method were much higher than those based on the variance approach. As mentioned above, the variance weights on asset prices for the US are higher here with the quarterly data than they were when monthly data were used.

Observations by nation also reveal some interesting patterns. In Japan, both house and equity prices received nearly identical shares—the informational content in assets is about the same as the current consumption price index. The inflation "signal" in these markets is roughly comparable. In Canada, Ireland, and the Netherlands, housing prices provide a dominant share of the common factor weight—an exceptionally strong signal—while in France, the U.K., and most Scandinavian countries, the inflation signal coming from asset prices, including housing, is somewhat small.

Further, the trend growth differentials of the dynamic factor index and the CPI also suggest rather large differences by nation. The largest inflation trend differential (1980-1997) was found for the U.K. (5.2% CPI versus 8.4% for the DFI.) The smallest differential is in the Netherlands (0.4% annually.) However, in general, the international data appears to support the findings of the US analysis that there may be a potentially large role for house prices in the inflation measures of interest to the central bank. Every one of the DFI indexes showed a higher trend inflation than the more narrowly defined retail CPIs.

## VI. CONCLUSION

We have presented an integrated framework for including asset prices in constructing current inflation and our results suggest that asset prices can affect the measurement of aggregate price movements. This is particularly true of housing prices, which appear to play a significant role in the measurement of the inflation trend both in the U.S. and abroad. As a consequence, the Dynamic Factor Index measures that include asset prices indicate that inflation has been somewhat higher than other measures would suggest in recent times.

A key question, then, is to ask how policy would have been different had it been based on these measures. Any attempt to estimate this would need to take account of the fact that history changes each time new data are added to this model and so only real-time information should be used. Overall, however, other simpler measures of “core” inflation such as the ex-food and energy approach seem to mirror the movements in the DFI somewhat closely and as such, the inclusion of assets may not have produced dramatically different real-time policy responses. Indeed, much of the focus on asset prices appears to be on the unusual and somewhat dramatic run-up in certain asset prices in recent years. In our approach, which minimizes any idiosyncratic movement in component price data, we are led to the conclusion that such asset price movements contained relatively little information of a common inflation that is useful for month-to-month, or perhaps even year-to-year monetary policy choices.

Nevertheless, failure to include asset prices appears to induce a bias in the estimate of the inflation trend that may have an impact on our understanding of the broader movements in real economic variables, such as labor compensation. Such information is very likely to be important in a world where the monetary authority hopes to eliminate the movements in the aggregate price level that may enter into the decisionmaking of households.

As a final caveat, we also note that the results reported in this work indicate that the weights attributed to the various component series seem to be somewhat sensitive to the level of disaggregation. On the premise that the greater the level of diaggregation, the more information we get, a further breakdown of some key groups such as housing may be helpful. In light of this, it may be useful to decompose the international CPI series where possible to see the magnitude of this aggregation effect.

## Table 1: 3 CPI Series Level of Disaggregation

| | | DFI Weights | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **CPI Weights** | No asset prices | House, stock and bond prices | House and bond prices | House and stock prices | Bond prices only | House prices only | **Variance Weights** |
| CPI ex food & energy | 77.73 | 37.32 | 35.66 | 37.22 | 36.45 | 40.36 | 38.17 | 75.15 |
| Food | 15.32 | 58.25 | 30.24 | 31.61 | 32.45 | 53.54 | 34.62 | 22.95 |
| Energy | 6.95 | 4.43 | 6.84 | 7.43 | 7.16 | 5.36 | 7.92 | 1.24 |
| House Prices | - | - | 20.46 | 21.41 | 19.53 | - | 19.29 | 0.30 |
| Stock Prices | - | - | 4.45 | - | 4.41 | - | - | 0.27 |
| Bond Prices | - | - | 2.35 | 2.33 | - | 0.74 | - | 0.08 |
| Sum of Weights | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

## Table 2: 9 CPI Series Level of Disaggregation

| | | | DFI Weights | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **CPI Weights*** | **CPI XFE Weights*** | No asset prices | House, stock and bond prices | House and bond prices | House and stock prices | Stock and bond prices | Stock prices only | Bond prices only | House prices only | **Variance Weights** |
| Food & Beverages | 16.74 | 1.32 | 7.66 | 9.16 | 8.81 | 8.93 | 8.01 | 7.90 | 7.75 | 8.60 | 10.65 |
| Housing | 40.70 | 47.88 | 15.43 | 10.48 | 11.38 | 11.36 | 13.31 | 14.29 | 14.43 | 12.46 | 20.69 |
| Apparel | 4.80 | 6.26 | 8.49 | 12.75 | 12.18 | 12.22 | 9.96 | 9.25 | 9.08 | 11.21 | 5.35 |
| Transportation | 18.05 | 19.09 | 3.85 | 4.73 | 4.61 | 4.64 | 4.07 | 3.98 | 3.93 | 4.48 | 1.90 |
| Medical Care | 5.92 | 7.71 | 10.96 | 9.36 | 9.75 | 9.64 | 10.48 | 10.66 | 10.79 | 10.06 | 21.82 |
| Entertainment/ Recreation | 6.31 | 8.03 | 21.50 | 15.55 | 17.12 | 17.02 | 19.89 | 20.63 | 20.97 | 18.54 | 19.46 |
| Tuition, School Fees & Child Care | 2.61 | 3.40 | 9.24 | 14.82 | 13.85 | 13.54 | 11.43 | 10.22 | 10.19 | 12.15 | 6.28 |
| Tobacco & Other Smoking Products | 1.29 | 1.68 | 1.13 | 2.48 | 1.96 | 1.96 | 1.43 | 1.27 | 1.24 | 1.60 | 0.47 |
| Personal Care | 3.57 | 4.64 | 21.73 | 16.29 | 17.95 | 18.00 | 20.61 | 21.31 | 21.37 | 19.47 | 13.13 |
| House Prices | | | - | 2.96 | 2.01 | 1.98 | - | | - | 1.44 | 0.11 |
| Stock Prices | | | - | 0.92 | - | 0.72 | 0.54 | 0.48 | - | - | 0.10 |
| Bond Prices | | | - | 0.49 | 0.38 | - | 0.28 | | 0.24 | - | 0.03 |
| Sum of Weights | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

* Note: Some minor components have been omitted to allow for easier comparisons. Component weights have been rescaled accordingly so that totals sum to 100.

## TABLE 3: GROWTH TRENDS FOR ALTERNATIVE PRICE INDEXES

| **Inflation Measure (annualized growth rate)** | **Jan. 1978 to Dec. 1999** | **Jan. 1989 to Dec. 1999** | **Dec. 1994 to Dec. 1999** |
|---|---|---|---|
| CPI | 4.18 | 2.65 | 2.21 |
| CPI excluding food/energy | 4.37 | 2.82 | 2.28 |
| Median CPI | 4.40 | 2.95 | 2.88 |
| **Dynamic Factor Measures, Nine CPI Components Plus…** | | | |
| No assets | 4.35 | 2.89 | 2.34 |
| Equities, housing, bonds | 4.58 | 3.32 | 2.95 |
| Housing and equities | 4.51 | 3.17 | 2.71 |
| Housing and bonds | 4.45 | 3.12 | 2.61 |
| Bonds and equities | 4.43 | 3.00 | 2.45 |
| Housing only | 4.41 | 3.02 | 2.49 |
| Equities only | 4.41 | 2.96 | 2.42 |
| Bonds only | 4.36 | 2.91 | 2.35 |
| | | | |
| **Variance Weighted (all assets)** | 4.5 | 3.0 | 2.4 |

**FIGURE 1: Retail Price Trends (four-quarter growth trends.)**

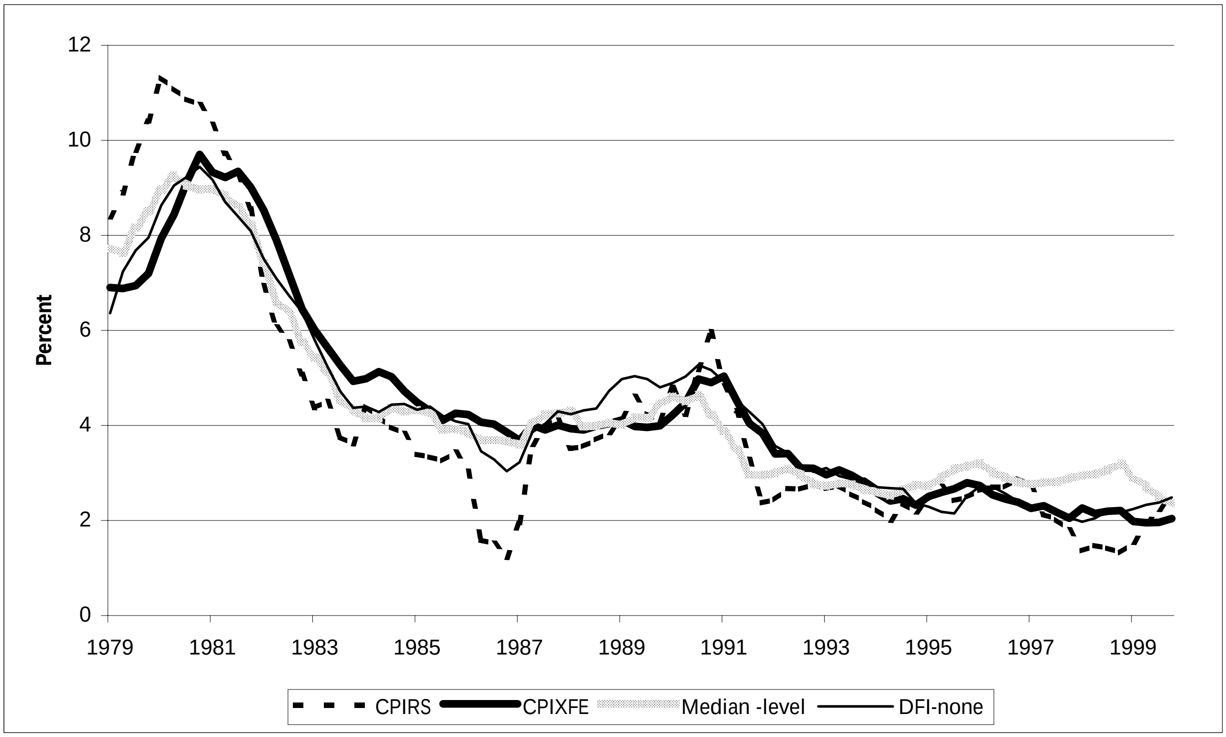



**FIGURE 2: "Core" CPI and the 3-Asset DFI (four-quarter growth trends.)**

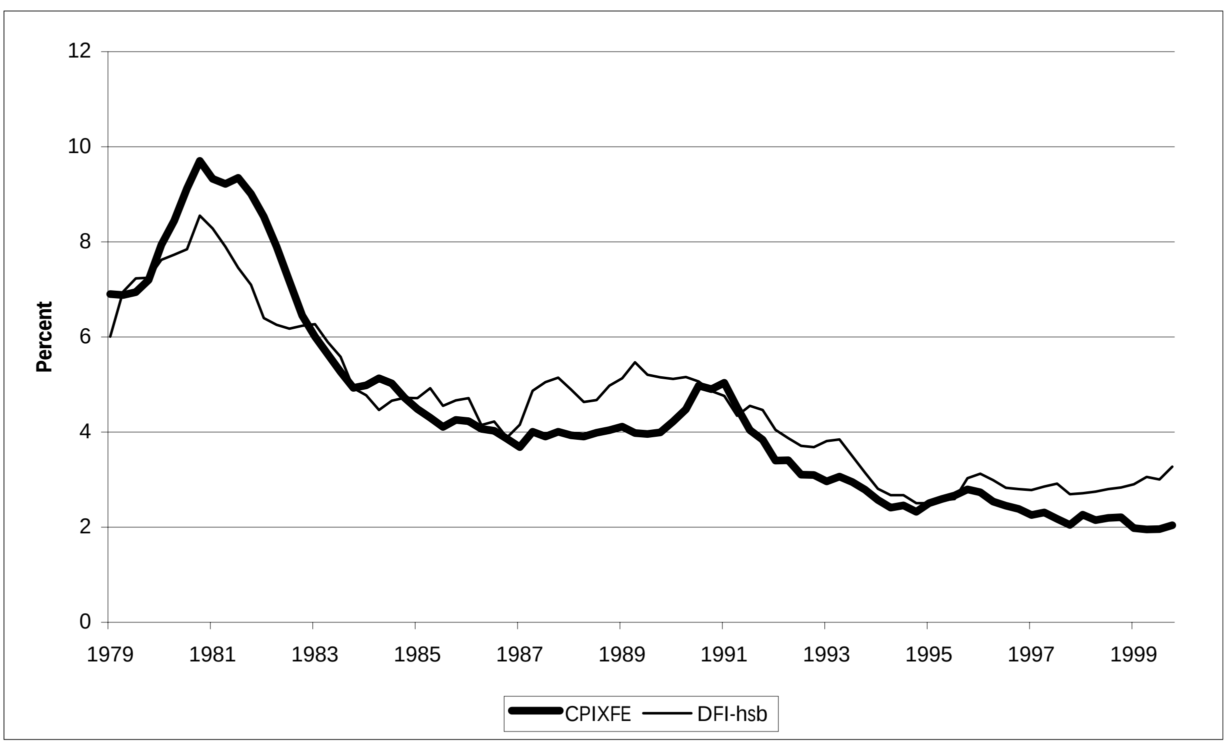


**FIGURE 3: "Core" Inflation and Two-Asset DFI's**

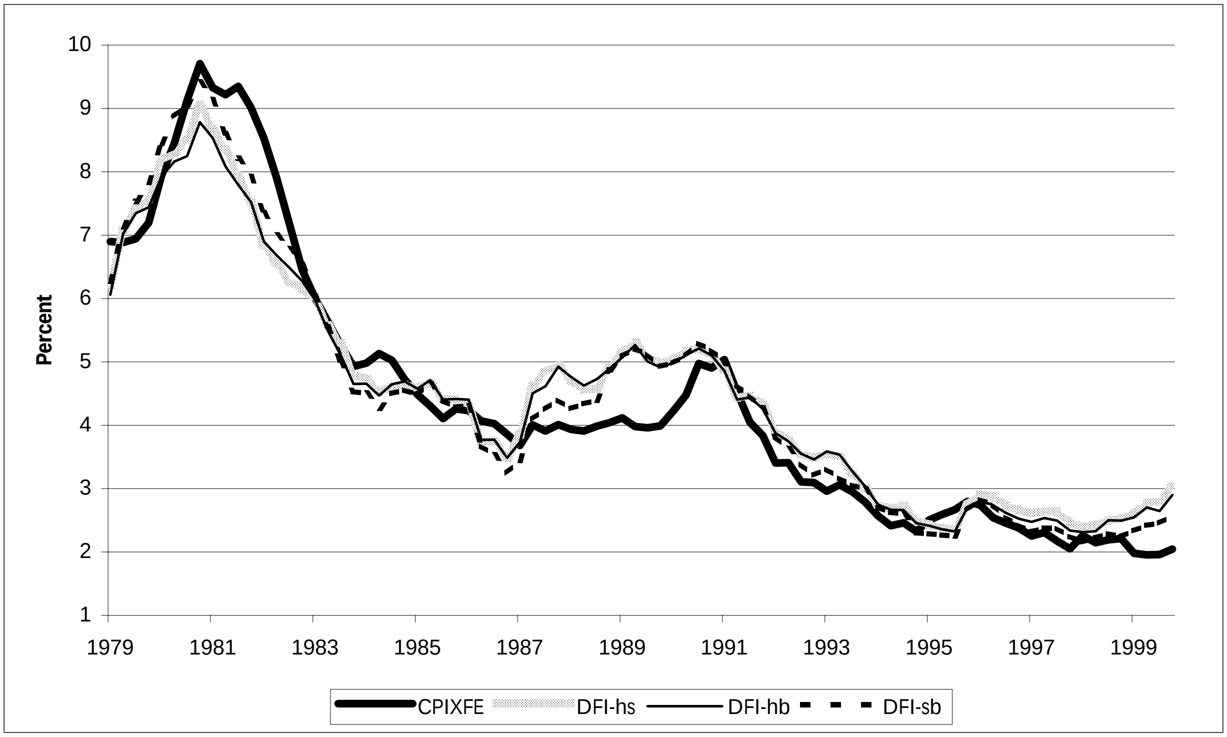



**FIGURE 4: "Core" Inflation and One-Asset DFI's**

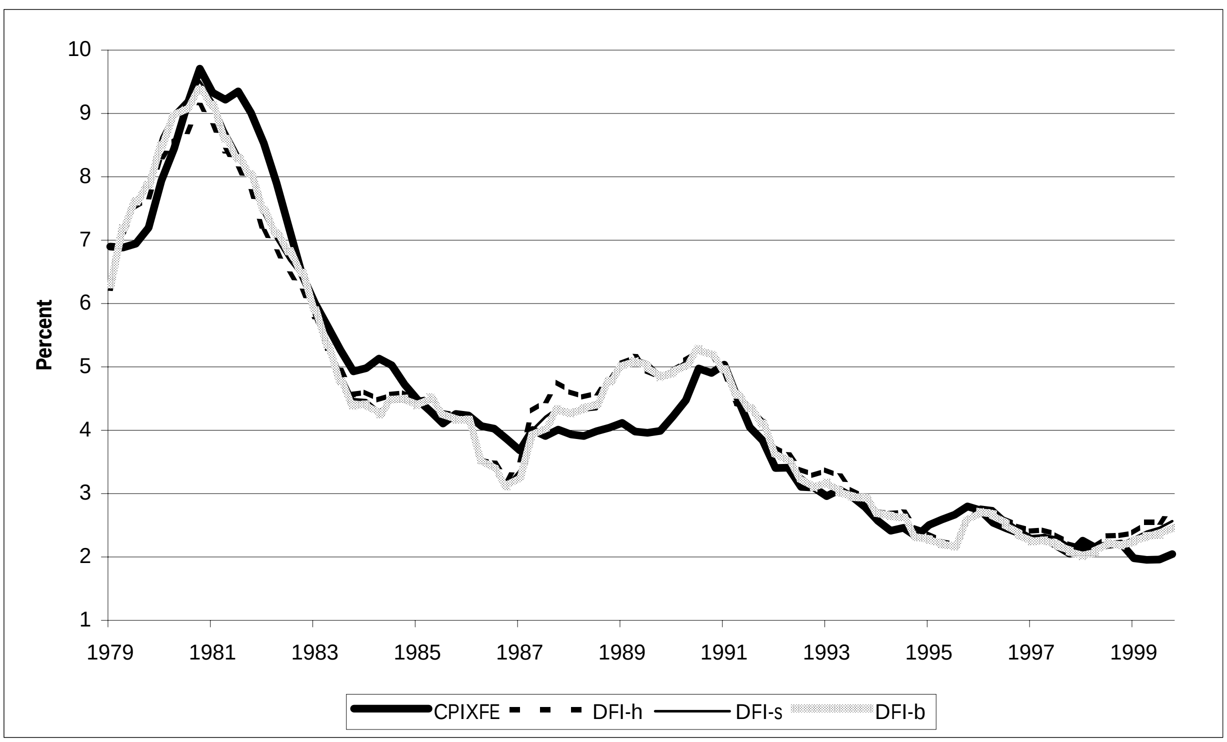


**FIGURE 5: Real Compensation Per Hour From Alternative Retail Price Measures (8-Quarter Growth Trend, a.r.)**

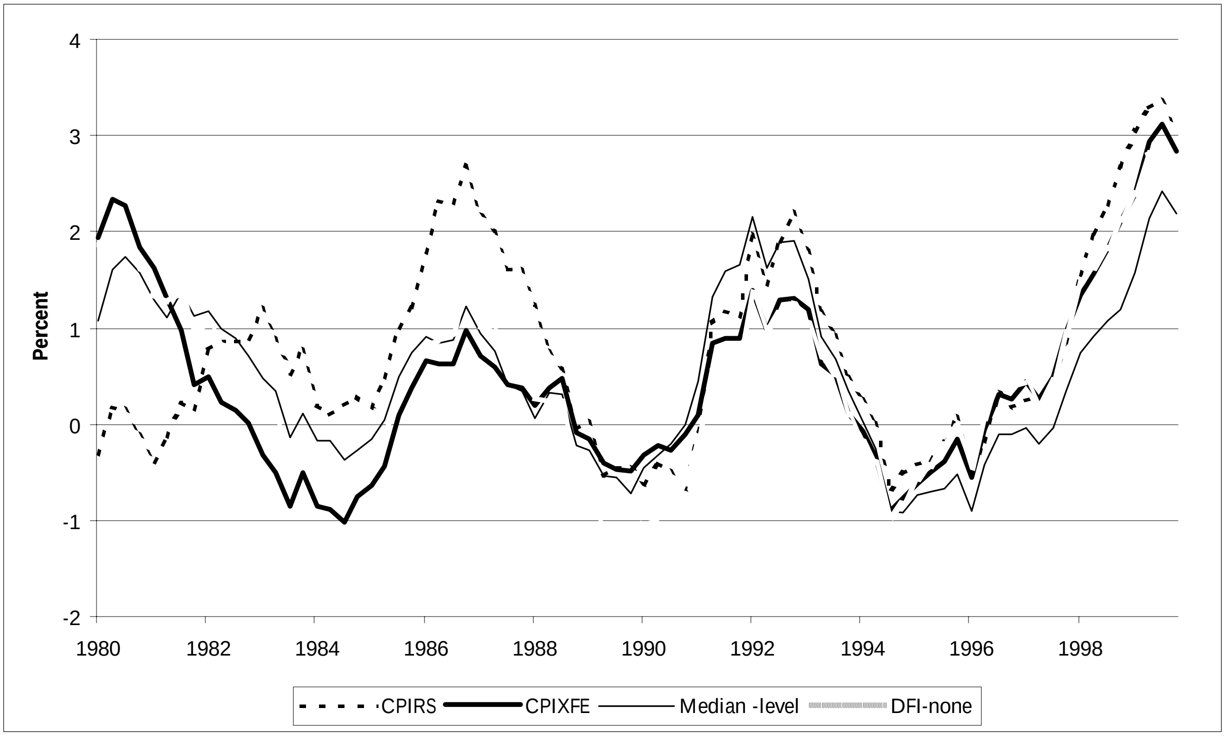



**FIGURE 6: Real Compensation Per Hour Using "Core" Inflation and 3-Asset DFI**

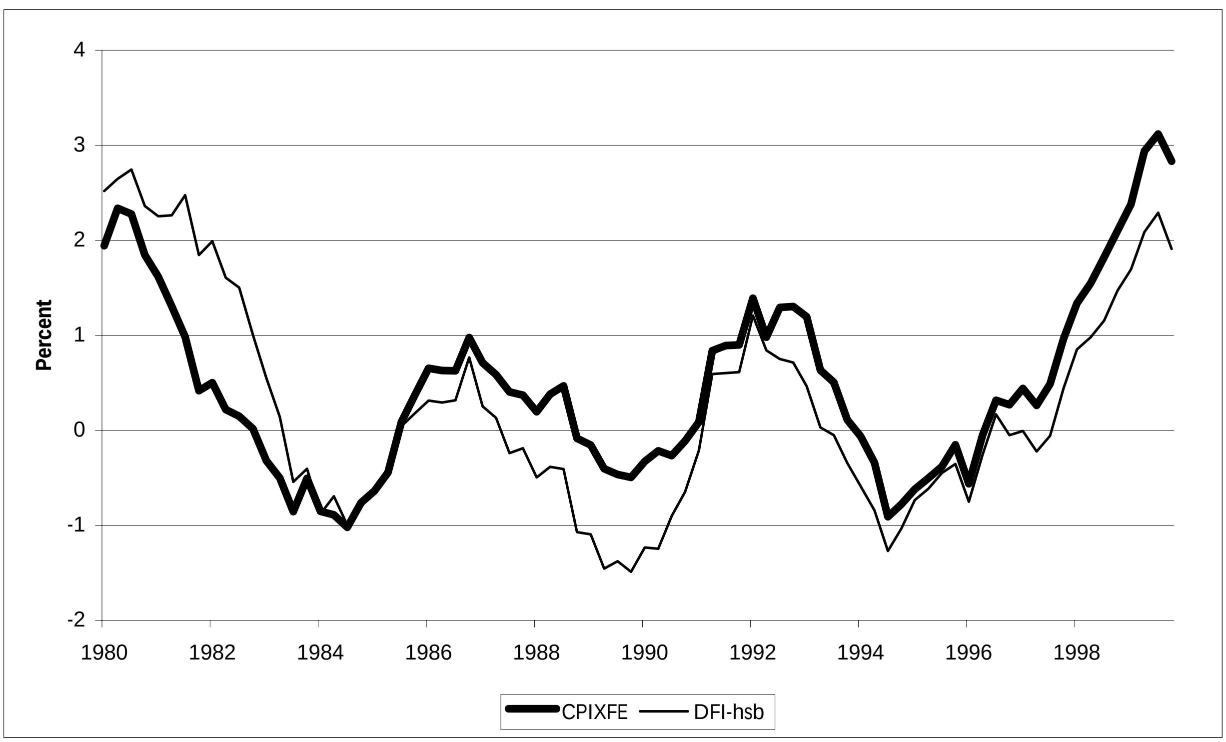


**FIGURE 7: Real Compensation Per Hour Using "Core" Inflation and 2-Asset DFI's (8-Quarter Growth Trends, a.r.)**

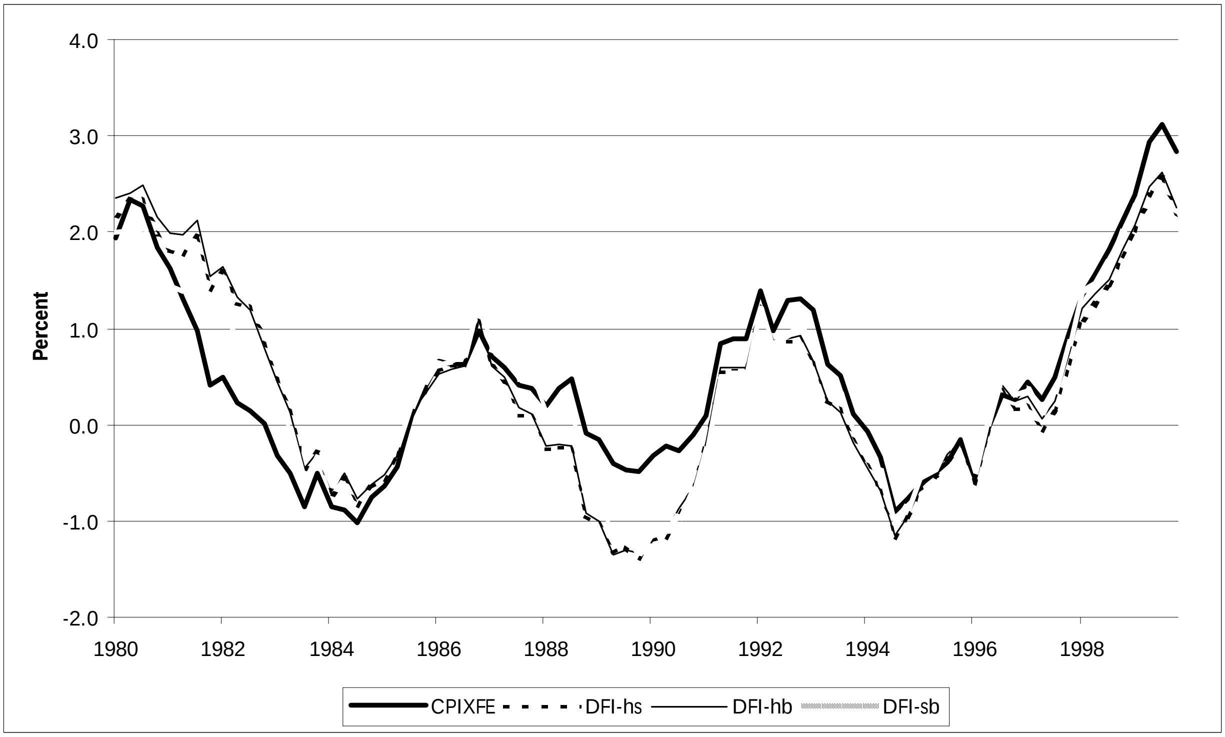
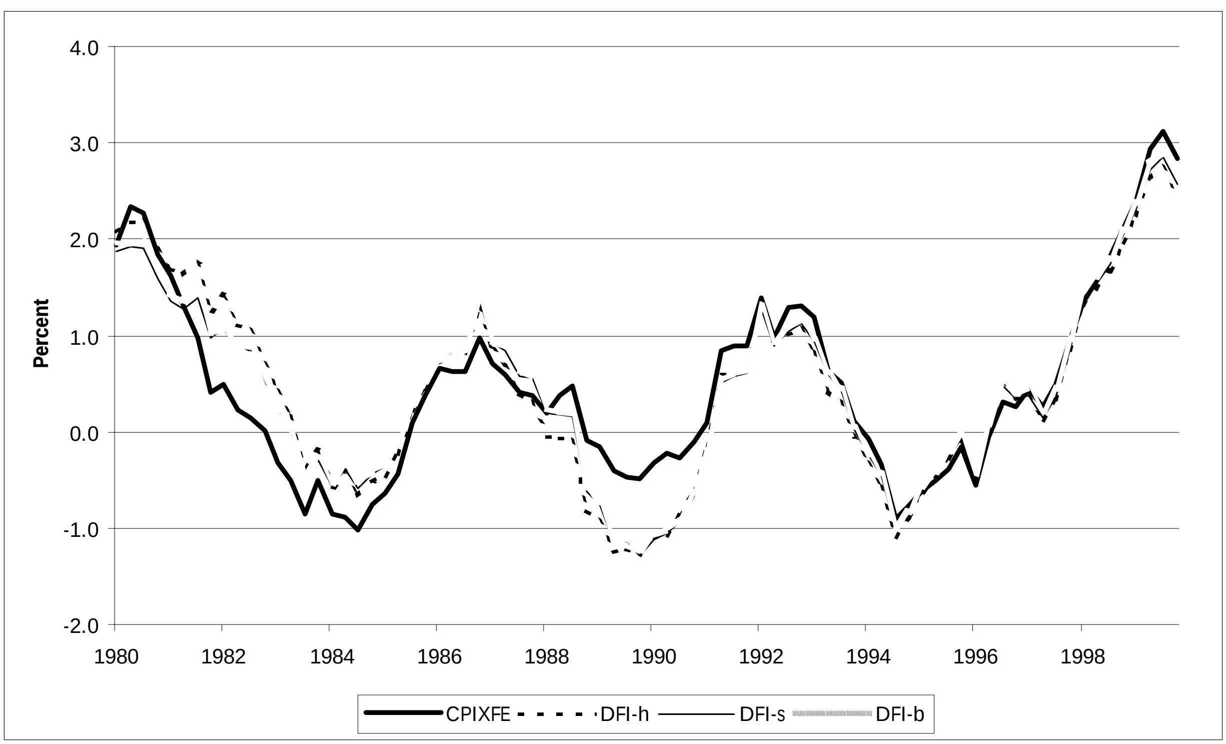
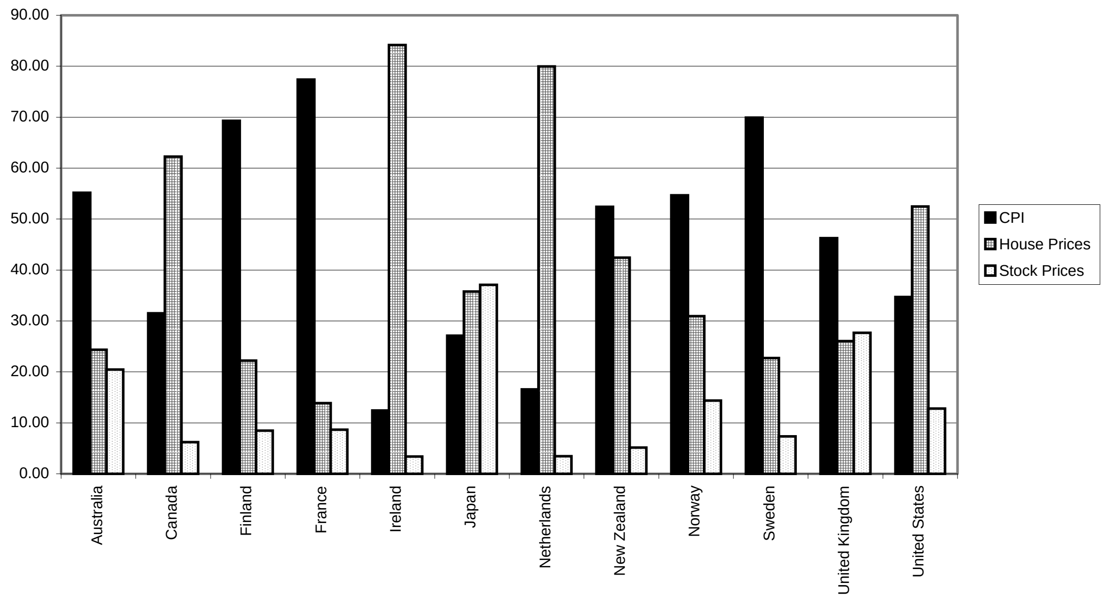



**FIGURE 8: Real Compensation Per Hour Using "Core" Inflation and 1-Asset DFI's (8-Quarter Growth Trends, a.r.)**



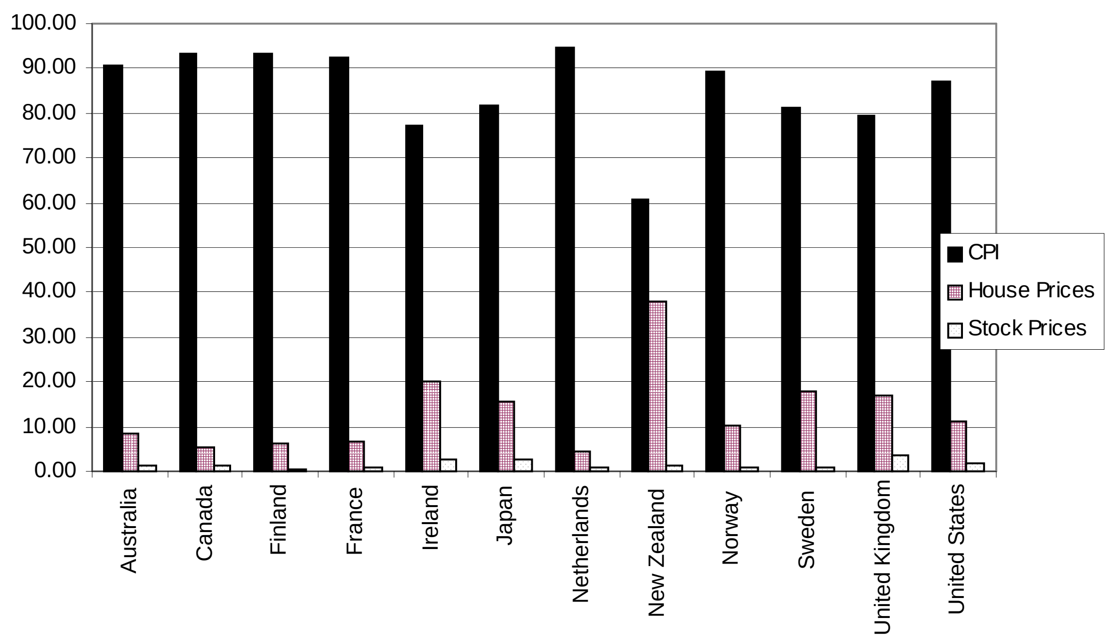
## FIGURE 9

**Chart 9: DFI Weights by Country**




## FIGURE 10

**Chart 10: Variance Weights by Country**



## References


Alchian, A. A. and B. Klein (1973), *"On a Correct Measure of Inflation,"* Journal of Money, Credit, and Banking 5 (1), February, Part 1, pp. 173-191.

Bureau of Labor Statistics (1997), *"Handbook of Methods"*, Chapter 17.

Bureau of Labor Statistics, "*Detailed Report*", Various Issues.

Bryan, M. and S. Cecchetti (1993), *"The Consumer Price Index as a Measure of Inflation"*, Economic Review of the Federal Reserve Bank of Cleveland, 29, Quarter 4, pp. 15-24.

Cecchetti, S. (1996), *"Measuring short-run Inflation for Central Bankers"*, NBER working paper no. 5786.

Cecchetti, S., Genberg, G., Lipsky, J. and S. Wadhwani (2000), "*Asset Prices and Central Bank Policy*", The Geneva Reports on the World Economy No. 2 ICMB.

Fisher, Irving (1911). The Purchasing Power of Money, The MacMillan Company.

Goodhart, C. (1999), "*Time, Inflation and Asset Prices*", Paper presented at conference on "The Measurement of Inflation" organized by the Office of National Statistics and Eurostat at the University of Wales, Cardiff, August 30.

Goodhart, C. and B. Hoffman (2000), *"Do Asset Prices help to Predict Consumer Price Inflation"*, Unpublished manuscript.

Hamilton, J.D. (1994), *"Time Series Analysis"* Chapter 13. Princeton University Press.

Harvey, A. C. (1981) *"Time Series Models"*, Chapter 4. Oxford: Phillip Allan.

Harvey, A. C. (1989) "*Forecasting, Structural Time Series Models and the Kalman Filter"*, Chapters 3 and 4. Cambridge: Cambridge University Press.

Okina, Kunio, Masaaki Shirakawa, and Shigenori Shiratsuka (2000), "The Asset Price Bubble and Monetary Policy; Japan's Experience in the Late 1980s and the Lessons," Discussion Papers 2000-E12, Institute for Monetary and Economic Studies, Bank of Japan (May 2000).

Pollack, Robert A (1975). "The Intertemporal Cost-of-Living Index," Annals of Economic and Social Measurement 4(1), Winter, 179-195. (Reprinted in Robert A. Pollack (1989), The Theory of the Cost-of-Living Index, New York: Oxford University Press.)

Reed, S. and K. Stewart (1999), *"Consumer Price Index Research Series using current methods, 1978-98"*, Monthly Labor Review, June.

Shibuya, Hiroshi (1992), "Dynamic Equilibrium Price Index: Asset Price and Inflation," Bank of Japan Monetary and Economic Studies, Bank of Japan, vol. 10 (1), pp. 95-109.

Shiratsuka, Shigenori (1999), "Asset Price Fluctuations and Price Indices," Institute for Monetary and Economic Studies, Bank of Japan, Discussion Paper No. 99-E-21.

Stock, J. and M. Watson (1991), *"A Probability Model of the Coincident Economic Indicators",* in K. Lahiri and G.H. Moore, ed., "Leading Economic Indicators, New Approaches and Forecasting Records, pp 63-89. Cambridge: Cambridge University Press.

Tullock, Gordon (1979), "When is Inflation Not Inflation?: A Note," Journal of Money, Credit, and Banking, vol. 11 (2), pp. 219-221.

Wynne, Mark A, "Monetary Policy and Asset Prices," Bank of England Quarterly Bulletin, vol. 39 (4), November (1999), pp. 428-435.

Wynne, M. (2000), *"Core Inflation: A Review of Some Conceptual Issues"*, Unpublished manuscript.

**Table 4 APPENDIX: 16 CPI Series Level of Disaggregation**

| | DFI Weights | | | | Variance Weights | CPI Weights |
|---|---|---|---|---|---|---|
| | House, stock and bond prices | House and stock prices | House prices only | No asset prices | | |
| Food at home | **5.06** | 5.05 | 5.01 | 4.66 | 3.61 | 9.60 |
| Food away from home | **7.34** | 7.51 | 7.65 | 8.05 | 13.07 | 5.71 |
| Alcohol | **6.16** | 6.10 | 6.03 | 5.86 | 5.13 | 0.99 |
| Housing | **6.83** | 7.00 | 7.23 | 8.06 | 14.90 | 39.64 |
| Men & Boys Apparel | **10.12** | 10.01 | 9.81 | 9.02 | 3.93 | 1.34 |
| Women & Girls Apparel | **4.42** | 4.27 | 4.16 | 3.51 | 1.15 | 1.88 |
| Infant and Toddler Apparel | **4.79** | 4.66 | 4.49 | 3.88 | 0.73 | 0.27 |
| Footwear | **2.80** | 2.72 | 2.67 | 2.34 | 0.52 | 0.83 |
| Public Transportation | **3.12** | 3.15 | 3.17 | 3.05 | 1.30 | 1.40 |
| Private Transportation | **2.73** | 2.74 | 2.73 | 2.69 | 0.63 | 16.05 |
| Medical Care Commodities | **6.90** | 7.03 | 7.21 | 7.73 | 12.44 | 1.27 |
| Medical Care Services | **5.65** | 5.71 | 5.85 | 6.29 | 13.85 | 4.50 |
| Entertainment/Recreation | **9.85** | 10.12 | 10.45 | 11.79 | 14.02 | 6.01 |
| Tuition, School fees &Child Care | **9.35** | 9.29 | 9.31 | 9.15 | 4.74 | 2.40 |
| Tobacco & Other Smoking Products | **1.60** | 1.53 | 1.46 | 1.24 | 0.34 | 0.89 |
| Personal Care | **10.36** | 10.71 | 11.09 | 12.67 | 9.46 | 3.43 |
| House Prices | **2.00** | 1.82 | 1.67 | - | 0.08 | - |
| Stock Prices | **0.63** | 0.59 | - | - | 0.07 | - |
| Bond Prices | **0.32** | - | - | - | 0.02 | - |
| Sum of Weights | **100** | 100 | 100 | 100 | 100 | 96.20 |

## Table 5 APPENDIX

Correlation between Various Inflation Measures:  Table 1 Approach

| | *Headline CPI* | *DFI-(housing)* | *DFI-(all)* | *CPI Median* | *CPI ex F&E* |
|---|---|---|---|---|---|
| Headline CPI | 1.0000 | | | | |
| DFI-(housing) | 0.5638 | 1.0000 | | | |
| DFI-(all) | 0.2753 | 0.8896 | 1.0000 | | |
| CPI Median | 0.9582 | 0.5767 | 0.3396 | 1.0000 | |
| CPI ex F&E | 0.9108 | 0.4524 | 0.2258 | 0.9569 | 1.0000 |

Correlation between Various Inflation Measures:  Table 2 Approach

| | *Headline CPI* | *DFI (Housing)* | *DFI (all)* | *CPI Median* | *CPI ex F&E* |
|---|---|---|---|---|---|
| Headline CPI | 1.0000 | | | | |
| DFI (Housing) | 0.9441 | 1.0000 | | | |
| DFI (all) | 0.9072 | 0.9881 | 1.0000 | | |
| CPI Median | 0.9582 | 0.9560 | 0.9344 | 1.0000 | |
| CPI ex F&E | 0.9108 | 0.9708 | 0.9522 | 0.9569 | 1.0000 |

Correlation between Various Inflation Measures:  Table 3 Approach

| | *Headline CPI* | *DFI (Housing)* | *DFI (all)* | *CPI Median* | *CPI ex F&E* |
|---|---|---|---|---|---|
| Headline CPI | 1.0000 | | | | |
| DFI (Housing) | 0.9228 | 1.0000 | | | |
| DFI (all) | 0.9079 | 0.9972 | 1.0000 | | |
| CPI Median | 0.9582 | 0.9290 | 0.9204 | 1.0000 | |
| CPI ex F&E | 0.9108 | 0.9543 | 0.9453 | 0.9569 | 1.0000 |

Correlation between Various Inflation Measures:  Table 2 Approach 1990-1999

| | *Headline CPI* | *DFI (Housing)* | *DFI (all)* | *CPI Median* | *CPI ex F&E* |
|---|---|---|---|---|---|
| Headline CPI | 1.0000 | | | | |
| DFI (Housing) | 0.8669 | 1.0000 | | | |
| DFI (all) | 0.7927 | 0.9751 | 1.0000 | | |
| CPI Median | 0.7781 | 0.7737 | 0.7463 | 1.0000 | |
| CPI ex F&E | 0.8797 | 0.9575 | 0.9141 | 0.7888 | 1.0000 |

Correlation between Various Inflation Measures:  Table 3 Approach 1990-1999

| | *Headline CPI* | *DFI (Housing)* | *DFI (all)* | *CPI Median* | *CPI ex F&E* |
|---|---|---|---|---|---|
| Headline CPI | 1.0000 | | | | |
| DFI (Housing) | 0.8390 | 1.0000 | | | |
| DFI (all) | 0.8064 | 0.9953 | 1.0000 | | |
| CPI Median | 0.7781 | 0.7638 | 0.7566 | 1.0000 | |
| CPI ex F&E | 0.8797 | 0.9472 | 0.9320 | 0.7888 | 1.0000 |