Measuring Inflation Using Multiple Price Indexes

James P. Dow, Jr.
Department of Economics
University of California, Riverside
Riverside, CA 92521

June 1994

Abstract

Many price indexes are excessively sensitive to relative price changes of particular goods and so may not be reliable measures of the average inflation rate. This paper constructs alternate indexes of inflation treating the measurement of inflation as an optimal filtering problem, using partially disaggregated price indexes as separate observations of inflation. This procedure is shown to be easily implementable and produces measures that are less sensitive to relative price shocks than other price indexes. The effect of these measures on monetary policy and empirical relationships involving inflation is examined.

JEL # E31, E52

I. Measuring Inflation

Measures of inflation are used for two different purposes, calculating the cost-of-living, and as a guide to monetary policy. While the general interests of these two approaches are the same, they have different implications for month to month calculations of inflation. To determine the cost of living one only needs to determine the prices of goods individuals buy. There are issues of what goes into the bundles of goods and how to aggregate prices, but there is no question of what is being measured, inflation is *defined* as the rate of change of the aggregation of prices. Monetary policy, and monetary economics in general, takes a different approach. The average level of prices is a theoretical construct, that is related by theory to other variables such as money and output. For example, theories, such as the quantity theory of money, imply that the nominal price of each good is a function of the real price of the good, determined by the relative supply and demand for that good, adjusted for the average level of prices. This average price level is assumed independent of the factors that determine relative prices. Since the average price level is unobserved, it needs to be inferred from observations of individual prices. Common price indexes, such as the Consumer Price Index, may not be the best way to infer this. This paper constructs alternate price indexes which use the assumed economic structure to provide statistical estimates of the unobserved inflation rate.

The quantity theory of money implies that all transactions using money should be included in a price index, both final and intermediate goods, both consumer and producer goods. Since all indexes only observe a subset of goods we are in the position of determining the value of an unobserved variable from a sample of observations related to that variable. This is not so much a problem of measurement as it is a problem of inference. Indexes that weight the importance of a good by its quantity consumed, such as the CPI, are likely to be excessively sensitive to the specific relative price shocks of the goods that make up a large part of the index, and so will not provide an accurate measure of the underlying inflation rate.[1]

This problem has led to alternate indexes, such as the CPI less food or the CPI less food and energy, a response to beliefs that the CPI gives these goods excess weight and that they are particularly variable. However, these measures are clearly *ad hoc* and inconsistently applied. In addition, empirical studies of inflation have often felt compelled to smooth price index measures of inflation, in part, due to a belief that these indexes are excessively noisy. The most common method of smoothing has been a moving average filter (e.g. Lucas (1980)). This is likely to be a

[1]See Diewert (1990) for a discussion of the theory behind the construction of quantity weighted price indexes. Blinder (1980) provides a discussion of some of the problems of measures such as the CPI during the 1970's.

poor filter for a number of reasons. While the filter removes the noise by averaging a number of periods together, so that if the noise is independently distributed over time it will cancel out, the smoothed value is also an average of the underlying signal. The longer the averaging period, the better the filter is at removing the noise, but the worse the measure of the signal becomes. Since for many purposes we want the value of the signal at a specific point in time, what is needed is a filtering procedure that reduces noise without averaging over time.

Instead of weighting a good by its quantity in consumption, an inference approach suggests weighting a good by the information it provides about the underlying rate of inflation. It may be that food or energy are subject to large and frequent relative price changes so that their price change is a noisy signal of inflation. These variables should be given less weight, with more weight going to goods that provide signals of inflation with less noise. The exclusion of some goods from the CPI accomplishes this but at a cost of eliminating the information about inflation that is carried by the excluded goods. A better way is to allow the weights to be determined optimally according to the quality of each signal.

The approach developed in this paper, and independently in Bryan and Ceccetti (1993), is to treat values of CPI and PPI sub-indexes as noisy observations of a common inflation rate and to use a Kalman filter to provide a measure of the underlying inflation rate. Bryan and Ceccetti show that the CPI is likely to be a biased measure of inflation due to the inappropriate weighting of the component price changes. They use the Kalman filter to calculate the average bias and find that there was a significant positive bias over the period 1967-1980, but very little bias for 1981-1990. Lichtenberg and Griliches (1989) also calculate a measure of unobserved changes in producer prices to determine bias by combining non-price information with the PPI.

The point of this paper is that, in addition to removing long run biases, the Kalman filter is effective in reducing short run noise. A key feature of the filtering approach is that it allows information from a variety of different price indexes to be easily combined. Since most theories of inflation imply that indexes should include the prices of all things being exchanged using money, the ability to use different sources of information is key. The measure constructed in this paper uses information from both the consumer and producer price indexes, and could potentially use information from other indexes as well. Because of errors in measurement it is likely that most current price indexes are too volatile, giving too much weight to relative price changes of the goods included in the measure. The filtered price indexes of this paper will be less volatile, while not requiring averaging across time, and so will produce a more accurate and reliable measure of short run movements of inflation.

In section II of this paper, a state space model is constructed with inflation as the unobserved state. A Kalman filter is estimated using maximum likelihood techniques, and then is applied to the data to recursively construct the inflation rate. Filtered series are compared with alternative price measures to determine if there are significant differences. It is found that the filtered rate of inflation preserves the long run behavior of inflation implied by the CPI, but is able to eliminate much of the temporary fluctuations that are due to relative price changes.

Estimating the Kalman filter is computationally intensive which may dissuade individuals from using this approach. Section III of the paper develops a simpler filter which is much easier to calculate and performs nearly as well as the Kalman filter.

Because these indexes respond less to high frequency noise they seem to be better measures of the behavior of inflation and so a clearer guide for macroeconomic policy. These measures may also be useful for empirical work since it is precisely with high frequency data that most theories of inflation break down. Section IV contains some concluding comments about the uses of this inflation measure including some simple empirical examples.

II. Common Factor Estimation

The common rate of price change in the economy (π_t) will be considered as the unobserved state of the economy. What are observed are actual prices changes of goods, or collections of goods, (π_{it}), which include both the common price change and the effect of relative price changes (u_{it}). The problem is to infer π_t from observations of π_{it}.

The price observations will be the primary sub-indexes of the CPI (urban) and the PPI (by stage of processing)[2]. This provides 13 series with monthly data starting from 1967. In principle, the procedure can use any number or variety of price series. The value of adding an extra variable to the price index will depend, in part, on having independent real price shocks so that common price movements can be separated from real shocks. The principal components of the CPI were chosen since they are of roughly similar size and have distinct types of goods, which implies some degree of independence in the individual price shocks. A potential source of bias in the CPI is that it does not include all goods or transactions. Two kinds of series (CPI and PPI) are combined since they are likely to have separate information about prices (although the goods included in the PPI are inputs into goods in the CPI and so the price shocks will be related), and the transactions version of the quantity theory also implies that all transactions involving money should be included in measures of inflation, and the PPI provides information from a different level of transacting.

The system of one state equation and 13 observation equations and is given by

---

[2]Bryan and Ceccetti use consumer price indexes at an even lower level of aggregation (36 indexes) but do not use any indexes from the PPI.

$$\pi_t = \phi_1 \pi_{t-1} + \varepsilon_t \qquad \varepsilon \sim (0, \sigma_\varepsilon^2),$$
$$\pi_{it} = \pi_t + u_{it} \qquad u_i \sim (0, \sigma_i^2) \qquad (i = 1,13)$$

To make the unconditional means of the price changes equal to zero, the mean of inflation (π) is removed, so that the price change variables stand for their deviation from a constant.[3]

The model will be rewritten in state space form

$$x_t = Ax_{t-1} + \varepsilon_t \qquad A = \phi_1 \qquad Q = \sigma_\varepsilon^2$$
$$Z_t = Hx_t + u_t$$

$$H = \begin{matrix} 1 \\ 1 \\ . \\ . \\ 1 \end{matrix} \qquad R = \begin{matrix} \sigma_1^2 & 0 & . & . & 0 \\ 0 & \sigma_2^2 & & & . \\ . & & . & & . \\ . & & & . & 0 \\ 0 & . & . & 0 & \sigma_{13}^2 \end{matrix}$$

where x_t is the unobserved state vector and Z_t is the vector of observations. The parameters are kept to a tractable number by using the assumed theory to determine the H matrix and by letting the relative price shocks be i.i.d. With this, there are 15 parameters left to estimate (ϕ_1, σ_ε^2, σ_1^2 ..σ_{13}^2). If the parameters of the model were known, the best estimate of the state could be determined from the direct application of a Kalman filter. Since they are not known, this will be a joint estimation and filtering problem, using a Kalman filter to estimate the unobserved state for a given parameter set, and using a maximum likelihood procedure to estimate the parameters.

The estimation follows the procedure outlined by Clark (1987) and Engle and Watson (1981). The optimal filtering formula is given by the Kalman Filter. The prediction equations are

$$x_{t|t-1} = Ax_{t-1}$$
$$P_{t|t-1} = AP_{t-1}A' + Q$$

The estimate of the state vector (x_t) is updated by comparing the forecasts ($Hx_{t|t-1}$) with the observed values (Z_t). The information in the errors is weighted by the filter gain,

$$K_t = P_{t|t-1}H'(HP_{t|t-1}H' + R)^{-1}$$

---

[3]The mean value that was subtracted was the average of the VWPI given in section III.

so that the new estimates are given by the updating equations,

$$P_t = (I-K_tH)P_{t|t-1}$$
$$x_t = x_{t|t-1} + K_t(Z_t - Hx_{t|t-1})$$

The logic of the Kalman filter is relatively straightforward. The forecasting equation is used to determine estimates of the observed variables (the change in the sub-indexes) given the estimate of the inflation rate. The errors in the forecasts may be attributed to either a change in the relative prices or to a change in the underlying inflation rate. The Kalman filter gain (K) assigns the error according the variabilities of the individual shocks, relative to the variability of inflation. From the forecast errors, the behavior of inflation is inferred and a new estimate of inflation is created.

The likelihood of the estimation by the Kalman filter is given by Schweppe (1965).

$$L = -.5\left[\sum \log(|s_t|) + \sum e_t' s_t^{-1} e_t\right]$$
$$e_t = Z_t - Hx_{t|t-1}$$
$$s_t = HP_{t|t-1}H' + R$$

Estimating the model is then a matter of choosing the parameter vector (ϕ_1, σ_ε^2, σ_i^2) to maximize the likelihood function[4].

The estimated parameter values are given in table 1. Inflation is estimated to be highly autocorrelated, which agrees with previous evidence suggesting that changes in inflation are highly persistent. This will result in a Kalman filtered series that is very smooth. After the parameters are chosen the estimates of inflation conditional on past information are constructed by applying the Kalman filter. To determine the estimates of inflation conditional on all information, the data are then passed "backwards" through the filter. Finally, the value of π is added back in. This measure is the final index, which will be called the "Kalman filter index" or "KFI".

To evaluate how the filter is determining the common factor the correlations of the residuals are presented in table 3. The highest correlations seem to be associated with goods that have common inputs, such as Transportation and Fuel and Utilities, and those goods associated with the PPI sub-indexes (10-13). These residuals are strongly correlated among themselves

---

[4]The optimization was programmed in GAUSS, using the Optmum package (Newton's method).

suggesting comovement that is not being picked up by the common "inflation rate", implying that there may be separate CPI and PPI shocks with the CPI shock dominating in this measure. PPI goods are also correlated with Food, since crude material prices are related to food prices. We would expect there to be a number of additional common factors in relative price shocks since the categories of the CPI are not completely unrelated. There is also noticeable autocorrelation in several of the series. An AR(2) process for inflation was tried but it was found that this did not appreciable change the filtered inflation series, suggesting that the autocorrelation is due to relative price shocks. Allowing cross correlations of relative price shocks might improve the fit of the model but would require a dramatic increase in the number of parameters to estimate and so a corresponding increase in estimation difficulty.

The values produced by the Kalman filter are plotted on figure 1(a-c), along with the CPI[5]. The estimate of high autocorrelation for inflation prevents the measure from responding to temporary price shocks which filters out the high frequency noise. Given the assumptions of the model and the estimated persistence of inflation we would expect the CPI to be excessively volatile. And that is exactly what we see. The KFI is much smoother, while still capturing the longer run changes in inflation.

To get a feel for what the filter is doing it is helpful to examine the points of particular difference between the measures[6]. In August 1973 there were exceptional jumps in the price of Food along with changes in the price of Fuel and Shelter. These are filtered out by the KFI since little weight is given to Food, Fuel and Shelter, so that the increase in the CPI is over twice that of the KFI. There were also large increases in Fuel and Shelter in 1979 and through 1980 (a period which also had significant fluctuations in the prices associated with Food, Transport, Medical Care, and Entertainment) so that for most of this period the change in the CPI is greater than the change in the KFI. A dramatic example of the difference between the indexes is the sharp fall in the price of Shelter at July 1980 which produces a large negative spike in the CPI, but leaves the KFI almost unaffected. In 1982 the CPI showed exceptional variability (due to volatile Food, Fuel and Shelter) which also affected the KFI although its fluctuations were much smaller. There was also a negative spike in early 1986 (a drop in the price of Fuel and Transport) which affected both measures, but with the fall in the CPI being twice as large. The evidence from this period suggests that a number of different goods are subject to sudden, but temporary, fluctuations in the rate of change of their prices, so that there will be a significant gain to filtering prices in the manner offered by this paper. Most of the large differences were

---

[5]The Kalman filter series is available from the author upon request.

[6] Blinder (1982) provides a more detailed description of individual events behind the change in the CPI over part of this period.

during the mid and late 70's and early 80's, which is consistent with the Bryan and Ceccetti finding that the weighting bias of the CPI is unimportant after 1980.

The benefits are best seen in the period 73-83 where there are dramatic, but temporary, fluctuations in the CPI. During this time the CPI would prove to be a poor guide for monetary policy since concerns over inflation one month would likely be reversed the next. The filtered index is able to eliminate the temporary fluctuations while preserving the fundamental trend movements in inflation, and so is the more reliable guide to the longer run behavior of prices.

Since the coefficients are determined from the historical behavior of the price series, the measure will be sensitive to changes in the stochastic processes of the price indexes. The usefulness of the filter depends, in part, on the stability of the variances of the relative price shocks. If the filter was estimated with data from before 1974 it would incorrectly weight the energy shocks which drove much of the variability of the CPI during the 70's and 80's. For historical use this is not a problem since we know the character of the series over the period of interest. For forecasting or real-time interpretation of data this is a more serious problem since the index will overreact if the variance of a series suddenly increases. This is also a problem with measures such as the CPI, and the same solution exists, that is, recalculating the coefficients at intervals.

Combining monthly inflation numbers into quarterly values can also act as a filter, reducing the importance of temporary monthly relative price shocks. Quarterly changes of the CPI and the KFI were calculated from the monthly values and plotted on figure 2. At this frequency it is actually easier to see how the procedure filters the data. The trend behavior in inflation implied by the CPI is completely captured by the KFI, but it has greatly reduced quarter to quarter changes that are not persistent, particularly the fluctuations in the downward movement of inflation in the early 1980's.

The notion of a "core" rate of inflation is similar in spirit to the measures of this paper and is often offered as an alternative to the CPI that better captures the underlying rate of inflation. The CPI with food and energy prices removed is sometimes used as a measure of the "core" rate of inflation since it eliminates two major sources of relative price shocks. This measure is plotted against the Kalman filter on figure 3. Behavior during the mid-1970's is similar since food and energy were the primary relative price shocks during this period. However, in the 1980's, removing food and energy does not seem to eliminate much of the temporary fluctuations. Here, much of the fluctuation was due to changes in the price of shelter and other goods, and changes in food and energy often canceled out opposing shocks. This illustrates the dangers of eliminating certain components of the CPI in an *ad hoc* manner. Variability comes from so many series that one would need to eliminate half of the series to avoid any major shocks. By giving less weight to highly variable series, rather than eliminating them, the filtered measures will react less to a wider variety of real price shocks.

The other major source of information about price changes, in addition to the CPI and the PPI, are the various national income deflators. These are not available at the monthly level, and so are not direct substitutes for the CPI, however, the measures can be compared at quarterly frequencies (figure 4). The KFI is somewhat smoother than the GDP price deflator, although the difference is less than with the CPI. The similarities between the two series implies that the KFI would be a better substitute for the price deflator than the CPI, if data at a monthly frequency are desired. It is interesting to note that the Kalman filter and GDP price deflator often seem to react to different shocks, suggesting that there may be some benefit in combining the information in the two indexes.

III. A Simple Variance Weighted Price Index

Because of the high cost of estimating Kalman filters, it may be of interest to determine if there are other, simpler, filters that can do much the same thing. This section calculates a weighted average of price changes and shows that, while not identical to the Kalman filter, it produces results that are quite similar. The desired form of the filter is a simple weighted average of actual price changes,

$$\hat{\pi} = \sum_{i=1}^{n} a_i \pi_i \qquad (3.1)$$

where the price weights, a_i, take the value,

$$a_i = \frac{1/\sigma_i^2}{\sum_j 1/\sigma_j^2} \qquad (3.2)$$

and σ_i^2 are the variances of the price changes.[7] The only values to be estimated are then the variances, which will simply be set equal to the observed variances of the price changes.

---

7 The coefficients are motivated by a simple signal extraction problem where only current price changes are used to estimate current inflation. Allowing the "expected" value of the price change to be determined from a similarly weighted average of observed price changes will produce (3.2). This can be thought of as an *ad hoc*, although plausible, specification.

The index of inflation calculated using formula (3.1) which will be called the Variance Weighted Price Index (VWPI). The calculated weights (the a_i's), along with the weights assigned to each category in the CPI, are reported in table 3. The weights assigned to the various categories of goods by the VWPI are significantly different from those in the CPI. Goods such as Entertainment, Medical Care, and Other Goods and Services are given the most weight since they have low volatility and so carry more information about inflation. Shelter, Transportation, and Food and Beverages, on the other hand, are given little weight in spite of the fact that they account for much of consumer expenditure. One advantage of this procedure (and of the Kalman filter) is that one does not have to make *ad hoc* adjustments for goods that are particularly prone to large relative price changes. Crude Materials are highly volatile which suggests that they should be removed from a price index, however, the procedure effectively does that on its own by assigning it a very small weight. A weakness of this particular implementation of this procedure is the assumption that there are no trends in real shocks. In this example, Medical Care gets a large weight since it is a small variance series; however, the cost of medical care has been increasing faster than the price of other goods, which could lead the index to overestimate inflation, although in this case the increase in the cost of medical care is balanced by the slow price growth of other goods.

In figure 5 quarterly values of the CPI,VWPI and Kalman filter are plotted for the years 1967-1992[8]. The primary difference between the KFI and the VWPI is that the KFI takes into account correlation in inflation across time. Since the Kalman filter estimates inflation to be highly persistent, it will tend to produce a smoother series as is seen on figure 5. Even so, the VWPI does a pretty good job of reproducing the KFI and avoiding the excess variability of the CPI, particularly in the early 1980's. Compared with the CPI, the VWPI has nearly the same mean price change over the calculated period (.00470 for the VWPI to .00472 for the CPI) and a significantly smaller variance (0.47×10^{-5} to 1.02×10^{-5}).

The fact that the KFI and the VWPI are smoother than the CPI is, in part, a result of the assumed independence of the shocks. Other assumptions would produce different results. If the real price shocks were negatively correlated with the inflation shock, then we would expect measures such as the CPI to be too smooth, and a better filter would increase the volatility of the series. One could also produce even smoother series, say, by averaging the CPI across time, but this would be excessively smooth and give a poor measure of inflation at any point in time. Each month's value would not be the best estimate of the value at the month, given the behavior in other months, but the average value of several months. Given the assumptions about inflation,

---

[8]Because the CPI values were reported at one decimal place the values during the 1960's are subject to significant rounding error.

the filters of this paper are designed to do the correct amount of smoothing while providing a measure of the inflation shock for each month.

IV. Applications of Measures of Inflation

The indexes of this paper treat price sub-indexes as separate observations of inflation and then apply filters to determine the underlying rate of inflation. While these measures would not be appropriate as measures of the "cost of living", they may be preferable as measures of the "average" rate of price change for empirical studies involving inflation, and as a guide for monetary policy. While it is beyond the scope of this paper to provide a theory of inflation, it is possible to determine if filtering has any effect on simple empirical relationships. The two basic relationships involving price changes are the quantity theory of money and the Fisher equation relating interest rates to inflation.

The velocity of money, as it is commonly calculated, is effectively a residual; that is, it is the change in the price level that cannot be attributed to changes in money or output. The usefulness of monetary theories of inflation depends on the stability, or at least, predictability, of velocity. The income velocity of several monetary measures (M1, M2 and the St. Louis adjusted monetary base) were calculated using the quarterly CPI and Kalman filter indexes (and using real GDP as an output measure). For all three measures of money the coefficient of variation of velocity was smaller using the Kalman filter measure. The velocity of the monetary base and M1 show a significant break in trend which makes calculations of variability unreliable. But for M2, which has exhibited stationary velocity, the results are the most dramatic, with the coefficient of variation associated with the Kalman filter being 1/3 less than the CPI measure. Since velocity, as calculated here, is an unexplained residual, reducing the variance in velocity should increase the ability of other factors to explain inflation.

If velocity is stable, "excess" money growth (money growth less the growth of real output) should be matched with price growth. To test this, the following equation was estimated,

$$\Delta p_t = \alpha + \sum_{i=0}^{4} \beta_i \Delta x_{t-i} + u_t$$

Where Δp and Δx are the differences of log prices and log excess money, respectively. All three money measures and both price measures were tried. Previous work (e.g. Hallman, Porter and Small (1991)) suggests that the relationship should work best for M2 since this is the only measure of money with trendless velocity. The estimations find support for this. When M1 was used as the measure of money there was no significant relationship for either price index. However, there was a distinct pattern with M2 and the adjusted base. The results are given on table 4. In both cases we cannot reject that the beta coefficients are equal to zero when the CPI is used, but can confidently reject that they are zero when the Kalman filter is used. It is clear that the noise that is being eliminated by the Kalman filter is unrelated to the level of nominal demand. It is a bit surprising that the contemporaneous change in excess money is the most significant term. This may reflect, in part, short run movements in credit in response to changes in money demand. But, regardless of the reason for the connection of money and prices, the relationship seems much closer when the Kalman filtered index is used. Other simple tests of the closeness of money and output were run, using different lags and different variables (e.g. industrial production for output) and the results were the same. If there was a relationship, the relationship was stronger or more significant for the Kalman filtered index than for the CPI. While looking at these kinds of correlations is no substitute for a serious empirical treatment of inflation it does suggest that the way inflation is measured may effect how well tests of theories of inflation perform. This should be particularly true when using high frequency data, an area where the theories have tended to perform poorly.

Another use for measures of inflation is in calculating real interest rates from nominal interest rates. One concern, in particular, has been the stationarity of interest rates. To test for this, augmented Dickey-Fuller tests were applied to monthly values of inflation rates calculated from the CPI and the Kalman filter and to the return to the three month Treasury bill (note that we know the true answer for the Kalman filtered series). Results are reported on table 5. Optimal lag length was determined by sequentially testing for the exclusion of lagged regressors (see Hamilton, 1994, for a description of this procedure). Optimal lag length varied dramatically: 1 lag for the Kalman filter, 16 for the nominal interest rate and 17 for the CPI. Statistics were reported for 0, 1, 12 and 17 lags for each series to facilitate comparison between the series and to show how results change with lags. Since the Kalman filtered series is highly autocorrelated it requires the inclusion of lagged terms to reject the unit root. The high frequency, transient, volatility in the CPI results in a dramatic rejection of the unit root if no lags are included. Adding lags results in a rejection at the level of the Kalman filtered series. The results for the nominal interest rate is mixed, depending on the number of lags.

Overall, this evidence suggests a rejection of the null hypothesis of a unit root for the inflation measures and a possible rejection for the nominal rate. This rejection differs from previous work because of the exclusion of the period before 1967, which was characterized by smaller and more persistent changes in inflation and interest rates.

A measure of the ex-post real interest rate was calculated by subtracting the actual inflation rate from the nominal interest rate. Since the interest rate was for a three month security, the inflation rate for three months, starting at the time of the interest rate (and converted to an annual rate), was used. This dramatically reduces the volatility of the CPI by averaging out short term noise. Two real interest rate series were calculated, one using the CPI as the measure of inflation, the other using the Kalman filter index. The two series were tested for unit roots and the results reported on table 5. At the longer lag lengths (suggested by F-tests) the null hypothesis could not be rejected. Notice that if real interest rates have a unit root then nominal rates must also have one, although the test may be less decisive due to the added factor of stationary inflation.

Both measures of the real interest rate are plotted on figure 6. They clearly show the same behavior, although, as would be expected, the real return using the CPI is much more volatile. To formalize this, means and variances for the series were calculated and reported on table 6. Both the values for levels and differences are reported, as the appropriate statistic will depend on the conclusion made about stationarity. While the means are similar, again it is clear that the series using the Kalman filter is much less volatile. This suggests that much of the calculated variability in real interest rates may be due to errors in measuring inflation. Because interest data is available on a monthly frequency it is important to have an inflation series that is reliable at a monthly frequency. The use of the Kalman filter provides such a series.

The Kalman filter can also be used for forecasting inflation; however, it is important to realize that this is not a test of the measure. The CPI is likely to be a better forecaster of future values of the CPI while the Kalman filter is likely to be a better forecaster of future values of the Kalman filter. Using the accuracy of a variable in forecasting a *measure* of inflation as an indication of the accuracy in forecasting *inflation* presupposes that the measure is correct. If we are willing to commit to a particular measure then we can evaluate alternative variables by their ability to forecast, but clearly this cannot be used to determine which is the correct measure.

In conclusion, given its large responses to relative price shocks, the monthly CPI is not the most reliable measure of what is commonly meant by "the rate of inflation", and so it is important to provide an alternate measure. Since how inflation is measured is not likely to be independent of why inflation is being measured, the alternate measure should be based on the theory that requires its measurement. The two filters presented in this paper are based on a simple theory which emphasizes the distinctions between common and relative price changes. The paper has shown that these kinds of filters can produce data available on a monthly frequency, and that some forms of the filter are quite easy to calculate. The filtered inflation rates are found to produce results different from other measures of inflation, particularly for short run fluctuations, and so may provide a more reliable guide for monetary policy and empirical studies

The paper has not given an explanation of how government policy and private actions will result in changes in inflation in the future. Instead, it argues for conservatism in interpreting price statistics. Filtered price indexes, such as the ones calculated in the paper, formalize the notion that the information carried by the CPI each month has a large noise component and so sudden, dramatic changes should not imply equally dramatic responses in policy. Filtered indexes provide one way of reducing that noise in a consistent and quantitative manner.

References

Blinder, A., (1980) The Consumer Price Index and the Measurement of Recent Inflation, *Brooking Papers on Economic Activity*, 539-571.

Blinder, A., (1982) The Anatomy of Double-Digit Inflation in the 1970's, in *Inflation: Causes and Effects*, R. Hall ed. Univ. of Chicago Press, Chicago.

Bryan, M. and S. Ceccetti, (1993) The Consumer Price Index as a Measure of Inflation, *Economic Review*, Federal Reserve Bank of Cleveland, forthcoming.

Clark, P., (1987) The Cyclical Component of U.S. Economic Activity, *Quarterly Journal of Economics* 797-814.

Diewert, W., (1990) *Price Level Measurement*, editor, North-Holland, Amsterdam.

Engle, R. and M. Watson, (1981) A One-factor Multivariate Time Series Model of Metropolitan Wage Rates, *Journal of the American Statistical Association* 76, 774-781.

Hallman, J., R. Porter and D. Small, (1991) Is the Price Level Tied to the M2 Monetary Aggregate in the Long Run, *American Economic Review* 81, 841-858.

Hamilton, J., (1994) *Time Series Analysis,* Princeton University Press.

Lichtenberg, F and Z. Griliches, (1989) Errors of Measurement in Output Deflators, *Journal of Business and Economic Statistics* 7, 1-9.

Lucas, R., (1980) Two Illustrations of the Quantity Theory of Money, *American Economic Review 70.*

Schweppe, R (1965), Evaluation of Likelihood Functions for Gaussian Signals, *IEEE Transactions on Information Theory* 11, 61-70.

Table 1

Estimates of parameter values[a]

Estimated value of ϕ_1	0.959
Estimated value of σ_π^2	3.6
Sub-Index (Estimated value of σ_i^2)	
Food and Beverages	5.1
Apparel and Upkeep	4.3
Transportation	7.8
Medical Care	1.9
Entertainment	1.0
Shelter	3.2
Fuel and Utilities	5.6
Household Expenditure	1.3
Other	2.0
Crude Materials	112.6
Intermediate Goods	7.1
Finished Capital Equipment	2.1
Finished Consumer Goods	6.7

[a]Variances are multiplied by 1000.

Table 2

Correlations of residuals

index	1	2	3	4	5	6	7	8	9	10	11	12	13	r[a]
1. Food	1.00	0.15	-0.01	-0.15	-0.05	0.14	0.08	0.04	-0.04	0.51	0.30	0.03	0.52	0.24
2. Apparel		1.00	0.01	0.05	0.14	0.05	-0.02	0.27	-0.03	0.08	0.10	-0.01	0.06	0.15
3. Transportation			1.00	-0.08	0.05	0.08	0.39	0.01	-0.14	0.18	0.40	0.11	0.35	0.47
4. Medical Care				1.00	0.15	0.06	-0.05	-0.04	0.30	-0.15	-0.12	-0.05	-0.22	0.11
5. Entertainment					1.00	-.01	-0.05	0.19	0.19	-0.09	-0.04	-0.03	-0.05	-0.03
6. Shelter						1.00	0.04	0.04	-0.05	-0.00	0.06	-0.02	0.01	0.36
7. Fuel							1.00	0.06	-0.10	0.21	0.37	0.20	0.35	0.47
8. Household								1.00	-0.15	0.01	0.24	0.33	0.08	0.14
9. Other									1.00	-0.09	-0.18	-0.16	-0.17	0.28
10. Crude Mat.										1.00	0.52	0.10	0.71	0.04
11. Int. Goods											1.00	0.36	0.65	0.36
12. Finished Capital												1.00	0.25	0.12
13. Finished Consumer Goods													1.00	0.18

[a]Autocorrelation of residuals.

Table 3.

Weights given to the sub-categories of goods

Sub-Index	Variance of rate of change x10^5	Weight in CPI	Weight in VWPI
Food and Beverages	2.84	.196	.047
Apparel and Upkeep	2.01	.050	.066
Transportation	4.87	.214	.027
Medical Care	0.78	.065	.169
Entertainment	0.68	.042	.194
Shelter[a]	2.09	.223	.063
Fuel and Utilities	3.93	.081	.034
Household Expenditure	1.14	.076	.116
Other	0.83	.054	.159
Crude Materials	56.90	n.a	.002
Intermediate Goods	4.97	n.a.	.027
Finished Capital Equipment	2.02	n.a.	.065
Finished Consumer Goods	4.25	n.a.	.031

[a]Housing was broken into its component parts of Shelter, Fuel and Utilities, and Household Operations and Furnishings.

Table 4

Excess money estimation using alternate measures of money and prices

	Base		M2	
	CPI	Kalman	CPI	Kalman
β_0	0.09	0.15*	0.05	0.13*
β_1	0.05	0.09	0.04	0.05
β_2	0.10	0.07	0.07	0.05
β_3	0.04	0.05	0.03	0.04
β_4	-0.08	0.0	-0.04	-0.02
F^a	0.37	0.01	0.61	0.03

[a]Significance level of F-test on excess money coefficients.

* significant at 5% level

Table 5

Augmented Dickey-Fuller tests for unit roots

	value of T(ρ-1) for lags =			
	0	1	12	17
Kalman	-3.6	-13.8*	-21.7**	-24.4**
CPI	-139.5**	-15.4**	-12.2*	-14.1**
T-bill	-8.3	-14.7**	-7.4	-19.8**
Rcpi	-29.0**	-41.6**	-9.7	-9.6
Rkal	-9.6	-18.9**	-8.6	-10.8

** indicates significance at 5% level

* indicates significance at 10% level

Rcpi and Rkal are T-bill rate less measure of inflation.

Table 6

Distributions of real interest rates

Interest rate	Mean	Variance
Rcpi	1.3	10.2
Rkal	1.6	7.1
ΔRcpi	-0.0	1.9
ΔRcpi	-0.0	0.4

Figure 1

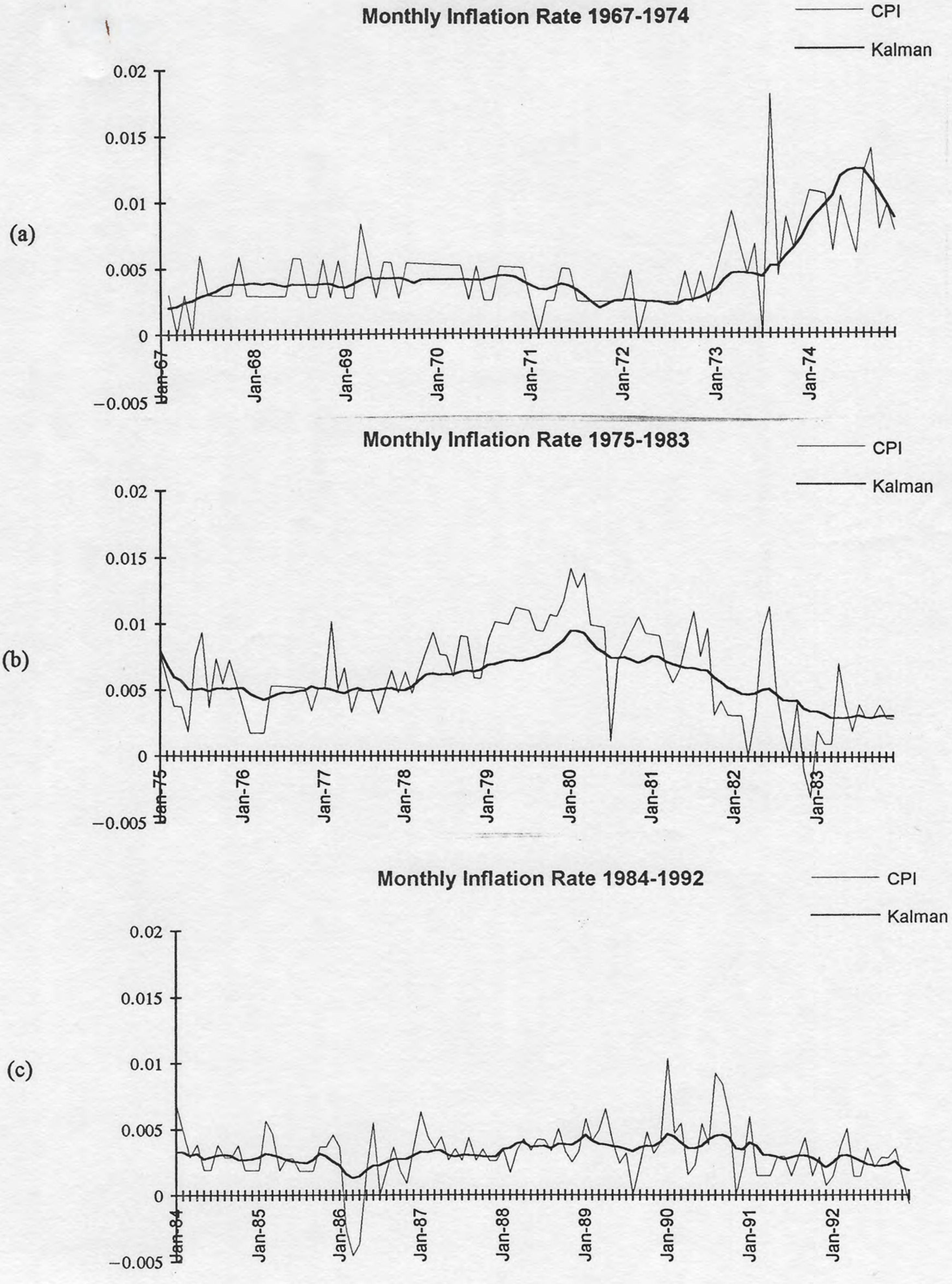
Monthly Inflation Rate 1967-1974
CPI
Kalman
(a)
0.02
0.015
0.01
0.005
0
−0.005
Jan-67
Jan-68
Jan-69
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Monthly Inflation Rate 1975-1983
CPI
Kalman
(b)
0.02
0.015
0.01
0.005
0
−0.005
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Monthly Inflation Rate 1984-1992
CPI
Kalman
(c)
0.02
0.015
0.01
0.005
0
−0.005
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92

Figure 2

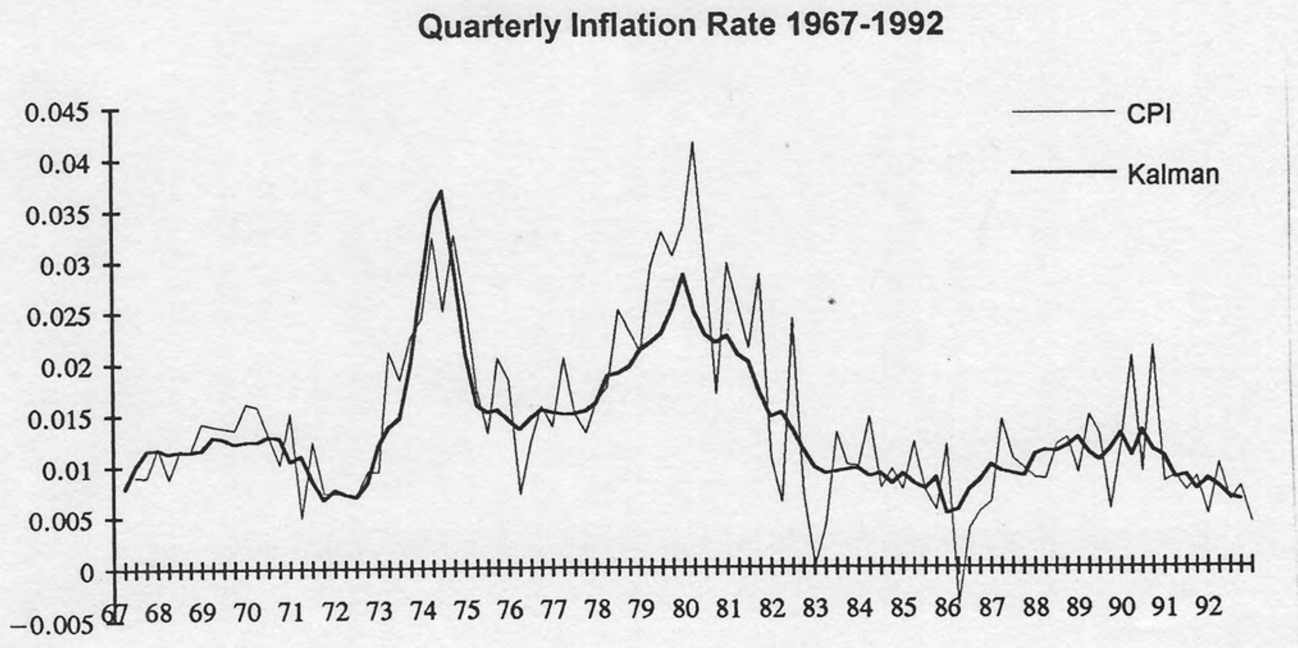

Figure 3

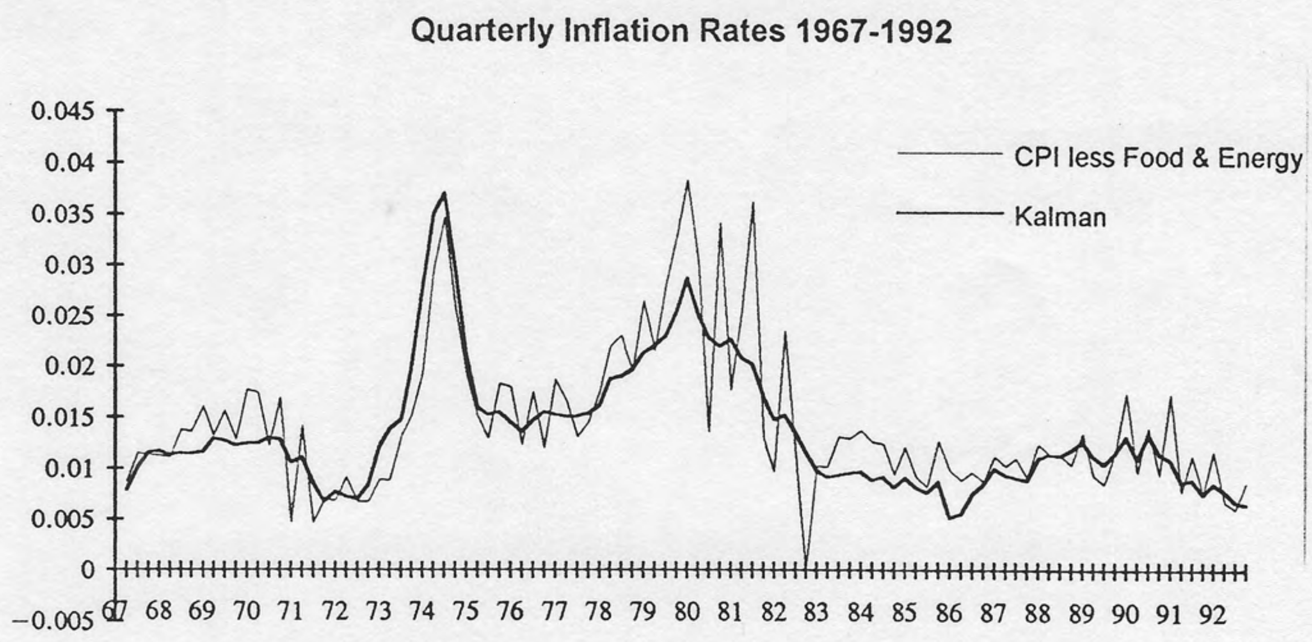

Figure 4

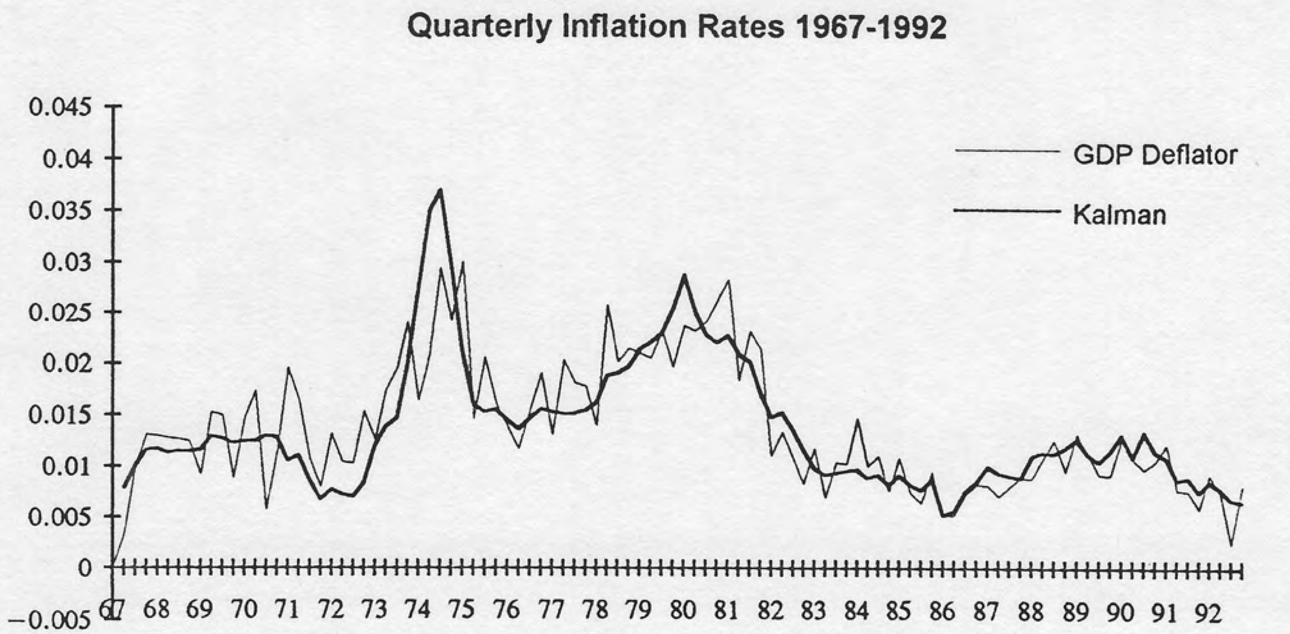

Figure 5

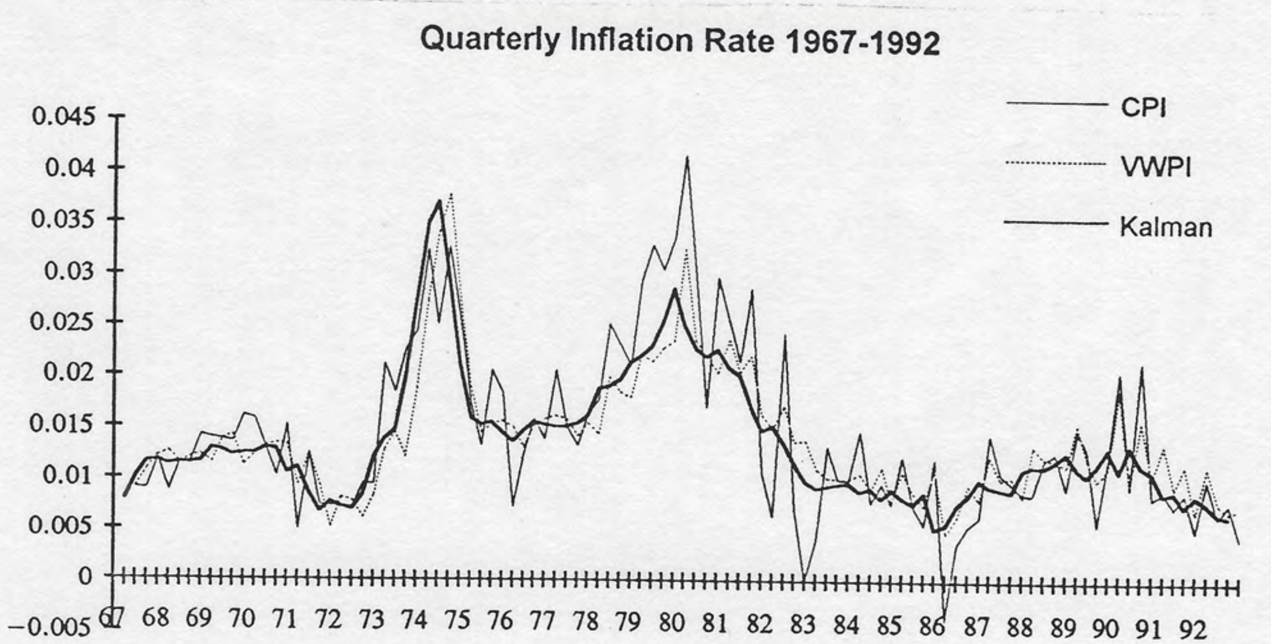

Figure 6 Real interest rates