Monetary Policy and Asset Prices

By Andrew J. Filardo

Despite the low inflation of recent years, some observers have wondered whether rapid gains in U.S. asset prices foreshadow rising inflationary pressures. Would U.S. monetary policy be improved if Federal Reserve policymakers reacted systematically to changes in the prices of widely held assets such as stocks and houses? Some monetary experts believe so. In particular, Charles Goodhart, a former member of the Bank of England's Monetary Policy Committee, argues that central banks should consider using housing prices, and perhaps, but to a much lesser extent, stock market prices to guide their policy decisions.

Goodhart has recommended that central banks replace conventional inflation measures—such as the CPI or PCE price index—with a broader measure that includes housing and stock market prices (weighted appropriately). This measure has the potential to improve macroeconomic performance if asset prices reliably predict future consumer price inflation. Other experts, however, question the ability of housing and stock prices to predict future inflation. And, even if asset prices help predict inflation, a central bank's reactions to such volatile asset prices might not necessarily improve macroeconomic performance.

This article evaluates the net benefits to the U.S. economy of adopting Goodhart's recommendation. The first section reviews the historical and theoretical motivation underlying the recommendation and discusses its monetary policy implications. The second section examines empirically whether U.S. housing and stock market prices help predict future consumer price inflation. Based on these findings, the third section simulates a macroeconomic model to explore the net benefits of a policy that responds to these asset prices. The article concludes that adopting Goodhart's recommendation would not improve U.S. economic performance.

I. BACKGROUND ON GOODHART'S RECOMMENDATION

Policymakers have renewed their interest in the relationship between asset prices and consumer price inflation in the last decade. This interest has been sparked in part by the behavior of international asset prices—especially housing and stock market prices—and inflation in Japan and the UK during the late 1980s and early 1990s.[1] Goodhart's recommendation has

Andrew J. Filardo is an assistant vice president and economist at the Federal Reserve Bank of Kansas City. *The author benefited from conversations with Charles Goodhart. Hank Hui, a research associate at the bank, helped prepare the article. This article is on the bank's web site at* **www.kc.frb.org**.

attracted particular attention because it offers a theoretically justified way for policymakers to interpret the inflation implications of a run-up of housing and stock market prices. This section presents the historical and theoretical motivation for Goodhart's recommendation and discusses its monetary policy implications.

International experiences

Economic developments in Japan and the UK during the late 1980s and early 1990s may provide important lessons for the United States. Both Japan and the UK were enjoying low, stable inflation rates in the face of rapid asset price appreciation.[2] Both nations eventually saw consumer price inflation rise significantly, however, followed in turn by a tightening of monetary policy, declining asset prices, and ultimately recession.

Japanese experience. In the late 1980s, Japan's economy was logging a stellar performance. Economic growth was solid, labor markets were tight, and investment spending was strong. Two factors that helped sustain this growth were easy credit conditions and low interest rates. But, accompanying this superior economic performance with essentially zero inflation was a tripling of both housing and stock prices from 1985 to 1990 (Chart 1). The favorable inflation performance was helped in part by strong investment spending that held down unit labor costs. It is not an exaggeration to say that Japanese economic conditions appeared so sound in the 1980s that Japan developed a reputation for economic invulnerability.

The economic performance began to sour in 1989. Inflation rose and monetary policy became tighter. Stock prices started their long retreat, followed by housing prices. By 1991, inflation peaked at nearly 4 percent. Since then, efforts to lower inflation have been associated with a period of lower asset prices and economic malaise.

UK experience. The UK experience parallels the Japanese experience in several important ways. In the late 1980s, the UK economy was expanding with strong consumption growth and high capacity utilization. From 1985 to 1987, the value of the stock market doubled, while housing prices nearly doubled (Chart 2). In 1988 alone housing price inflation reached an annual rate of roughly 35 percent. Despite this rapid rise in asset price inflation, UK consumer price inflation averaged just 4 percent. Following the acceleration in asset prices, though, inflation started to climb in early 1988, rising to 6 percent by the end of 1989 and nearly 9 percent in 1990.

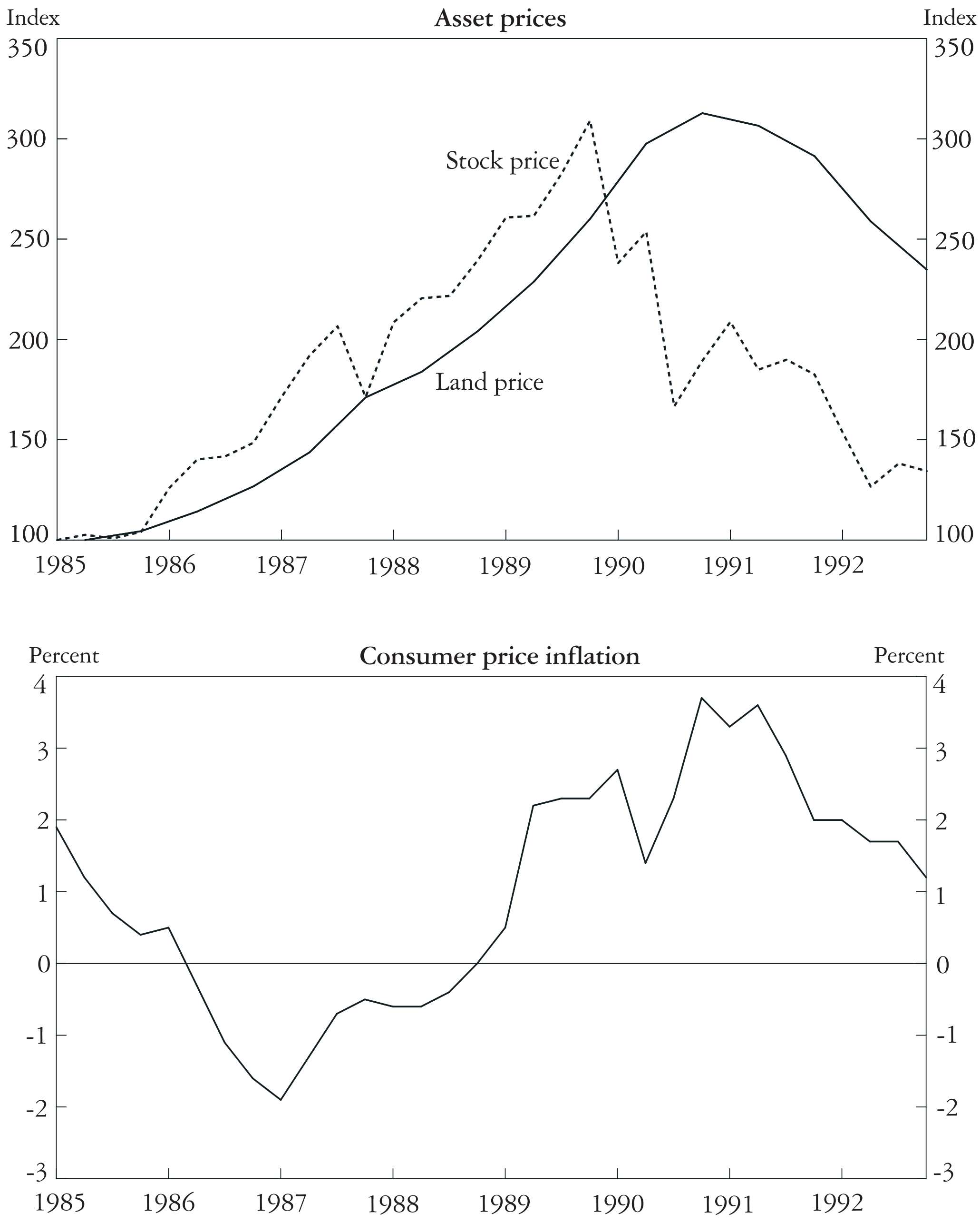
Goodhart (1995) singled out housing market developments during the period as early warning signs of underlying inflationary pressures. Bank credit expansion was particularly rapid, in part because of the financial liberalization of mortgage lending institutions in the 1980s.[3] The easier credit conditions fueled housing prices, and ultimately these pressures found their way into goods market prices. Higher interest rates and slower money growth eventually slowed inflation, but at the cost of a recession.

Déjà vu? In some respects, recent U.S. experience parallels the experiences in Japan and the UK. In particular, U.S. housing and stock market prices have soared over the last five years, while consumer price inflation has stayed remarkably stable (Chart 3). Given these parallels, it is not surprising that policymakers are concerned about the future of consumer price inflation. However, such international episodes might be dismissed as mere coincidence unless there are more fundamental factors at work.

Theoretical foundation of Goodhart's recommendation

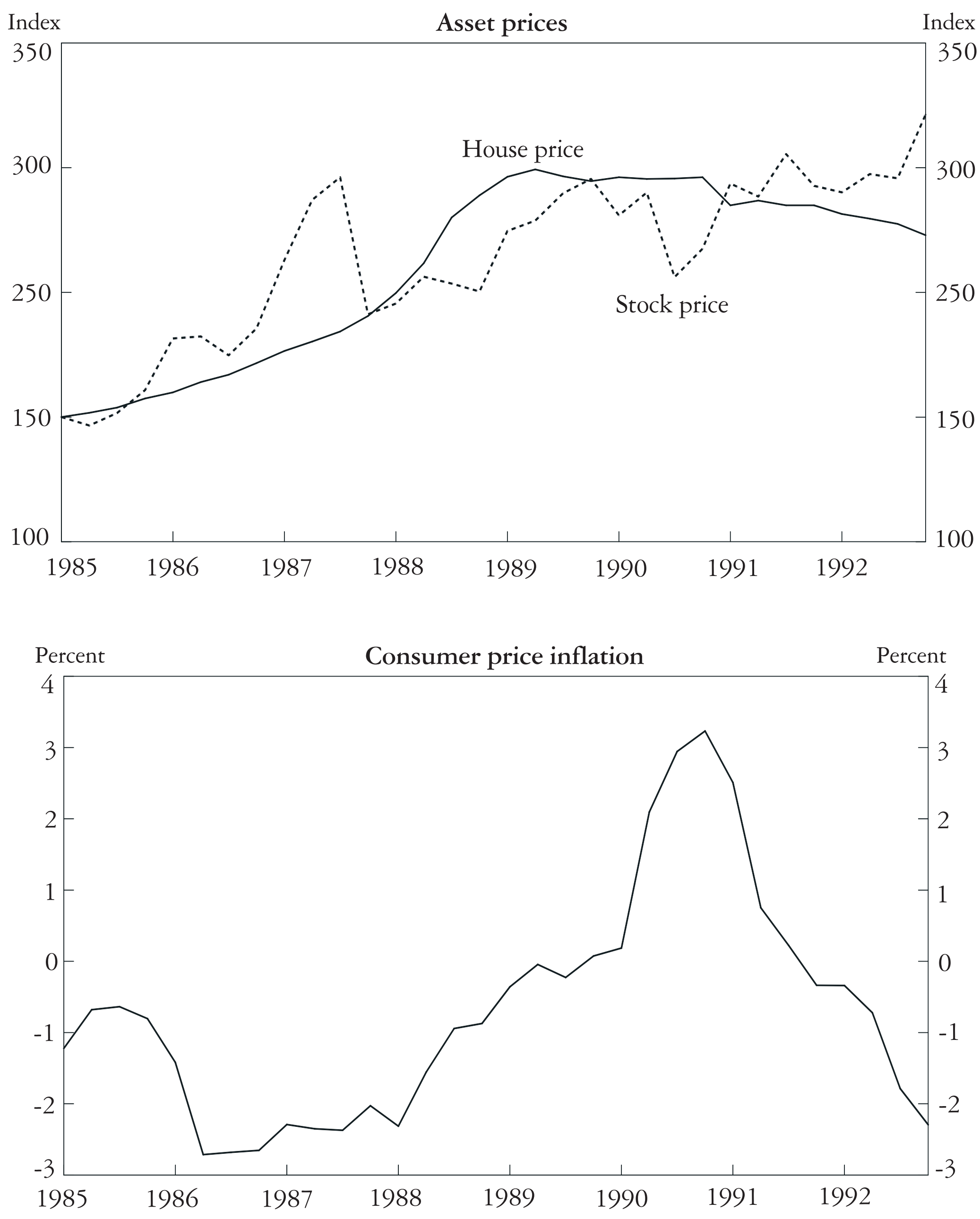
Part of Goodhart's contribution has been to sketch a theoretical rationale for using housing

Chart 1
JAPANESE ASSET PRICES AND CONSUMER PRICE INFLATION



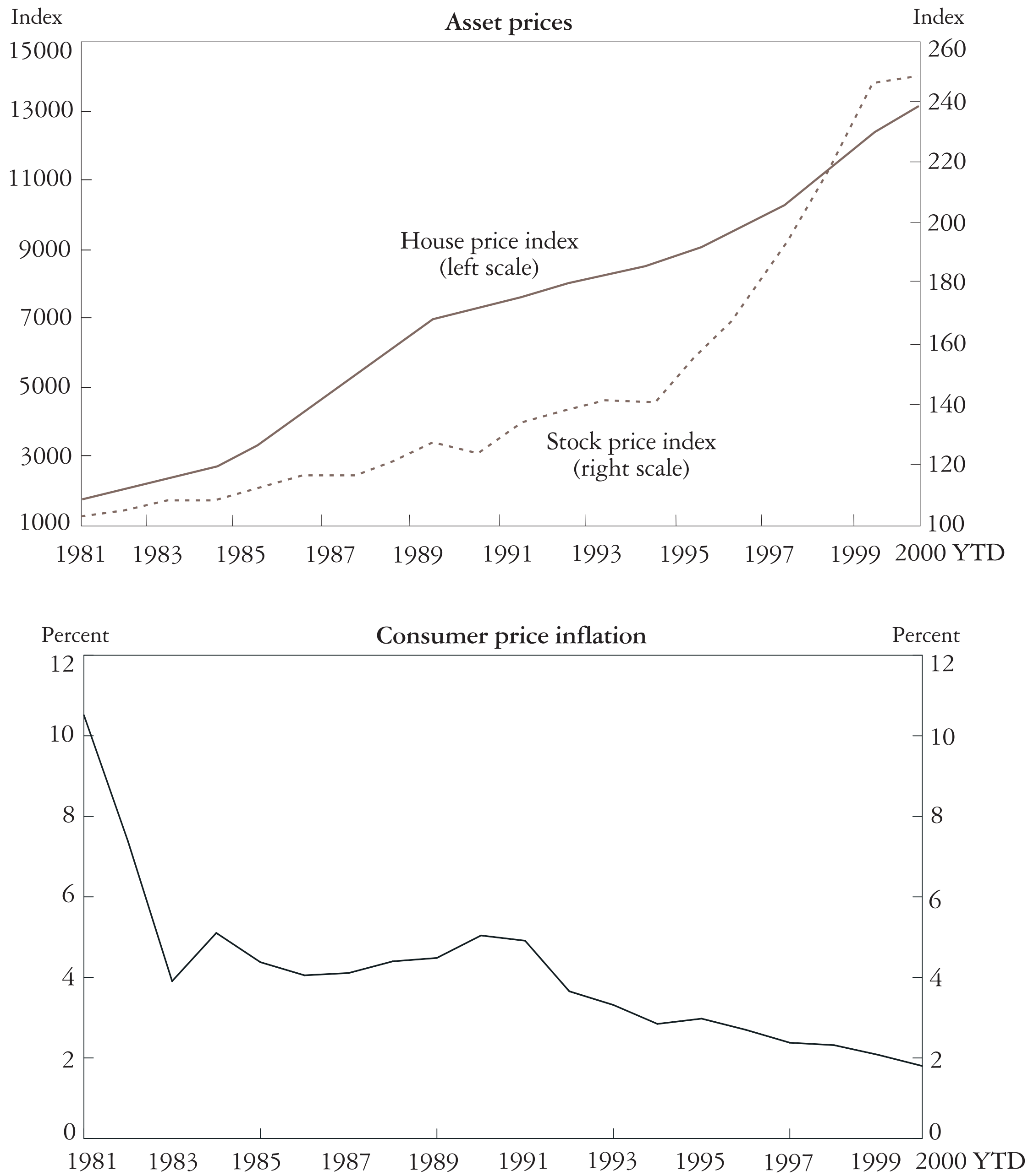
Sources: Nikkei 225 Index, Bloomberg; consumer price index (excluding perishables), Management and Coordination Agency; real estate price index of six big cities, all usage, Japan Real Estate Institute.

Chart 2
UK ASSET PRICES AND CONSUMER PRICE INFLATION



Sources: United Kingdom house price index (seasonally adjusted), Nationwide Building Society; retail price index (excluding mortgage interest payments), Monthly Digest of Statistics; FT-SE 100 index, Bloomberg.

Chart 3
U.S. ASSET PRICES AND CONSUMER PRICE INFLATION



Notes: Stock price index: Wilshire 5000. Wilshire 5000 total market index consists of over 7,000 U.S.-headquartered equity securities individually weighted by market capitalization. Housing price index: Office of Federal Housing Enterprise Oversight housing price index. This price index measures the value of single-family home sales in repeat sales or refinancing. Consumer price inflation: core CPI inflation.
Sources: Wilshire Associates Incorporated, Office of Federal Housing Enterprise Oversight, and Bureau of Labor Statistics.

and stock market prices to guide monetary policy decisions. Goodhart's view is based on the pioneering research on the theory of inflation measurement by Alchian and Klein. Nearly three decades ago, Alchian and Klein not only argued that a good measure of inflation should include asset prices, but they also discussed how to interpret the inflationary implications of a run-up of asset prices.

Alchian and Klein argued that conventional measures of inflation yield an incomplete picture of inflation conditions. The picture is incomplete because consumers care not only about the changes in prices of goods that they buy in a given year but also about changes in the prices of goods they are likely to buy in the future. If consumer prices are expected to rise at 3 percent in the future rather than 2 percent, consumers will perceive a worsening of inflation conditions. Conventional measures of inflation do not pick up this deterioration, though, because they largely reflect past price pressures.

Alchian and Klein also argued that asset prices can serve as good proxies for the inflation information left out of conventional measures. If consumers anticipate higher inflation in the future, economic theory suggests that, all else the same, housing and stock market prices would rise immediately. Hence, asset prices can reflect expected inflation that has not yet shown up in conventional measures. Alchian and Klein offered a broader measure of inflation that adds asset prices to the conventional inflation measures. (For a detailed discussion of the differences between Alchian and Klein's inflation measure and conventional inflation measures, see Appendix 1.)

The role of asset price inflation in Alchian and Klein's inflation measure can be approximated in a simple yet practical way. Shibuya shows that Alchian and Klein's inflation measure can be summarized as a weighted sum of conventionally measured inflation (π) and asset price inflation (π_{AP}):

$$\pi_{AK} = \alpha\pi + (1-\alpha)\pi_{AP},$$

where α is the weight on conventionally measured inflation and $1-\alpha$ is the weight on asset price inflation. This equation illustrates that Alchian and Klein's inflation measure is broader than conventional measures like the CPI or the PCE price index. Because conventionally measured inflation and asset price inflation can differ substantially, Alchian and Klein's inflation measure may differ substantially from conventional measures.

Potential implications for monetary policy

If a central bank were to follow Goodhart's recommendation and use this broader measure of inflation, an increase in asset price inflation could prompt tighter monetary policy even if conventionally measured inflation were low and stable. In this case, the higher asset price inflation would signal expectations of higher future inflation. By tightening monetary policy, the central bank can rein in those expectations. For example, if Japanese and UK monetary authorities had focused on this broader measure of inflation, they might have tightened monetary policy earlier, thereby reducing inflation pressures and averting economic downturns.[4]

In addition, Alchian and Klein's inflation measure may provide guidance on how tight monetary policy should be in the face of increased asset price inflation. A central bank should tighten policy sufficiently to bring expectations of higher consumer price inflation (as reflected in asset prices) in line with inflation goals.[5] For example, if a central bank preferred 2 percent inflation and consumer price inflation were running at 2 percent, then asset price inflation above 2 percent would call for tighter policy and asset price inflation below 2 percent would call for easier policy.

This simple policy implication depends,

however, on the strong assumption that asset price inflation accurately reflects future consumer price inflation. There are two reasons the relationship between asset price inflation and consumer price inflation may be somewhat imprecise. First, housing and stock prices are not perfectly reliable indicators because these prices are not the ideal proxies suggested by Alchian and Klein's theory. The theory suggests that the best proxy would be an aggregate index of all assets held by consumers. Housing and stock market assets, though widely held, are only a fraction of all consumer assets. Consumers also hold their wealth in the form of consumer durable goods (such as cars, household appliances, and clothing), owners' equity in noncorporate businesses, collectibles, foreign assets, and human capital. In 1999, U.S. housing and stock market wealth represented about one-half of U.S. tangible and financial wealth.[6]

The second reason the relationship between asset price inflation and consumer price inflation may be imprecise is that housing and stock prices may change for reasons that are unrelated to changing inflation expectations. For example, stock prices may rise because of improved expectations for corporate earnings rather than expectations of higher consumer prices in the future. Another example is the asset price consequence of changing investor preferences for risk taking. If investors were to perceive reduced risks of holding stocks or real estate, these asset prices would rise without an increase in inflationary expectations. In these examples, movements in stock prices would send faulty signals about future inflation.[7] Such problems complicate the use of housing and stock market prices as indicators of future consumer price inflation.

II. HOW WELL DO ASSET PRICES FORECAST INFLATION?

Although there are theoretical reasons why Goodhart's recommendation may fail, housing and stock prices might still be useful policy guides. Empirical evidence is needed to determine the usefulness of asset prices in predicting future inflation. This section uses simple correlations and a more sophisticated regression analysis to evaluate whether housing and stock prices help predict future consumer price inflation.[8]

Are housing and stock price inflation correlated with future consumer price inflation?

Simple correlations between asset price inflation and future consumer price inflation give mixed results. On the one hand, housing price inflation is positively correlated with future core CPI inflation. The repeat sales housing price index's correlation is 21 percent after one year, rising to a high of nearly 40 percent after three years (Table 1). This housing price index is one of the best measures of quality-adjusted housing values, but is only available over the last two decades. Housing wealth data from the Flow of Funds Accounts allow a longer perspective of four decades.[9] The correlations exceed those using the repeat sales index. For the first three years, the annual correlations are greater than 50 percent.[10] Thus, the housing price data support the notion that asset price inflation reflects the likely direction of future consumer price inflation.[11]

On the other hand, stock market price inflation tends to be negatively correlated with future consumer price inflation. Table 1 shows the correlations for the Wilshire 5000 index, a broad measure of U.S. stock prices, and the Standard and Poor's 500 index, a measure of stock prices for the largest U.S. corporations. Such correlations are somewhat surprising given economic theory suggests nominal asset returns should vary one for one with consumer price inflation.[12] The negative correlation suggests that the relationship between stock prices and consumer price inflation may be more

Table 1

ARE ASSET PRICE INFLATION AND CONSUMER PRICE INFLATION CORRELATED?

	Correlation with future inflation				
	1 year	2 year	3 year	4 year	Time period
Housing price inflation					
Repeat sales index	.21	.34	.39	.35	1981-99
Housing wealth	.61	.73	.59	.37	1961-99
Stock market price inflation					
Wilshire 5000	-.13	-.08	-.07	.24	1981-99
S&P 500	-.31	-.21	-.20	-.20	1961-99

Notes: The column heading indicates the number of years that asset price inflation leads core CPI inflation.

complicated than can be captured by the simple correlations.

Do housing and stock price inflation help predict consumer price inflation?

Although the simple correlations provide useful insights, these measures may be biased for two reasons. First, the housing price correlations may be spurious. Some experts argue that asset prices have very little, if any, statistical correlation with short-run inflation after other business cycle indicators are taken into account (Gertler). Second, the stock market correlations may simply reflect statistical noise that can be eliminated with a more sophisticated statistical method.

Regression analysis can eliminate these biases (Table 2). In particular, the regression equation uses one lag of consumer price inflation, one lag of the output gap, and a lag of either housing price inflation or stock market price inflation to predict future consumer price inflation.[13] The output gap is the difference between actual output and potential output. This business cycle indicator is generally thought to be a good proxy for resource utilization pressures on inflation. The core CPI again measures consumer prices.

The regression results confirm the findings of the simple correlation analysis in Table 1. Housing price inflation helps predict future consumer price inflation. The correlations between housing price inflation and consumer price inflation range from 20 to 35 percent over the first three years using the repeat sales index, and are somewhat lower using the housing wealth data.[14] Further analysis into housing price inflation's predictive value, however, reveals some limitations. While housing price inflation is correlated with future consumer price inflation, the marginal improvement in forecasting accuracy is fairly small.[15] Thus, although housing price inflation is informative about future consumer price inflation, the relationship is admittedly weak.

The regression analysis of stock price inflation reveals no hidden relationship between this asset price and consumer price inflation.

Table 2

DO HOUSING AND STOCK MARKET PRICES HELP PREDICT FUTURE INFLATION?

	Partial correlation with future inflation				
	1 year	2 year	3 year	4 year	Time period
Housing price inflation					
Repeat sales index	**.22**	**.30**	**.35**	.20	1981-99
Housing wealth	**.16**	**.19**	.06	.01	1961-99
Stock market price inflation					
Wilshire 5000	.00	-.01	-.01	**.04**	1981-99
S&P 500	.01	.00	-.02	-.01	1961-99

Notes: The partial correlation estimate is defined as the correlation between consumer price inflation and asset price inflation after controlling for the influence of business cycle conditions. In particular, the coefficients in this table come from a regression of (annual) core CPI inflation on a constant, one lag of core CPI inflation, one lag of the Congressional Budget Office's estimate of the output gap, and a lag of asset price inflation. The column heading indicates the lag length of the asset price inflation. The bold entries indicate statistical significance at the 95 percent confidence level.

The regression coefficients are small and generally statistically insignificant. Hence, stock market price inflation does not predict future consumer price inflation.[16]

In sum, the statistical evidence provides qualified support for the assumptions underlying Alchian and Klein's theory. Housing price inflation, but not stock market price inflation, appears to be a reasonable proxy for asset prices in Alchian and Klein's inflation measure. Practical implications of using housing price inflation in Alchian and Klein's inflation measure for the United States are discussed in the box.

III. CAN ASSET PRICES IMPROVE THE CONDUCT OF U.S. MONETARY POLICY?

According to the logic underlying Goodhart's recommendation, a central bank might be able to improve macroeconomic performance by responding to the forward-looking signs of inflation captured in asset prices. However, if these asset prices send erroneous signs, then the central bank may end up worsening economic conditions. This unintended consequence is possible because asset prices are highly volatile and may respond to factors other than expected inflation. This section sorts out the net benefits of using housing price inflation in the conduct of monetary policy. Building on the empirical results in the previous section, a macroeconomic model is simulated with a hypothetical monetary policy that responds to housing price inflation. The output, consumer price inflation, and interest rate consequences of such a policy determine the efficacy of Goodhart's recommendation for the United States.

Macroeconomic model

To assess the attractiveness of Goodhart's

AN ALTERNATIVE INFLATION MEASURE

This box describes how to construct a version of Alchian and Klein's inflation measure using the empirical results of this article and how to interpret its practical implications. Chart B1 plots the time-series to core CPI inflation over the last two decades.

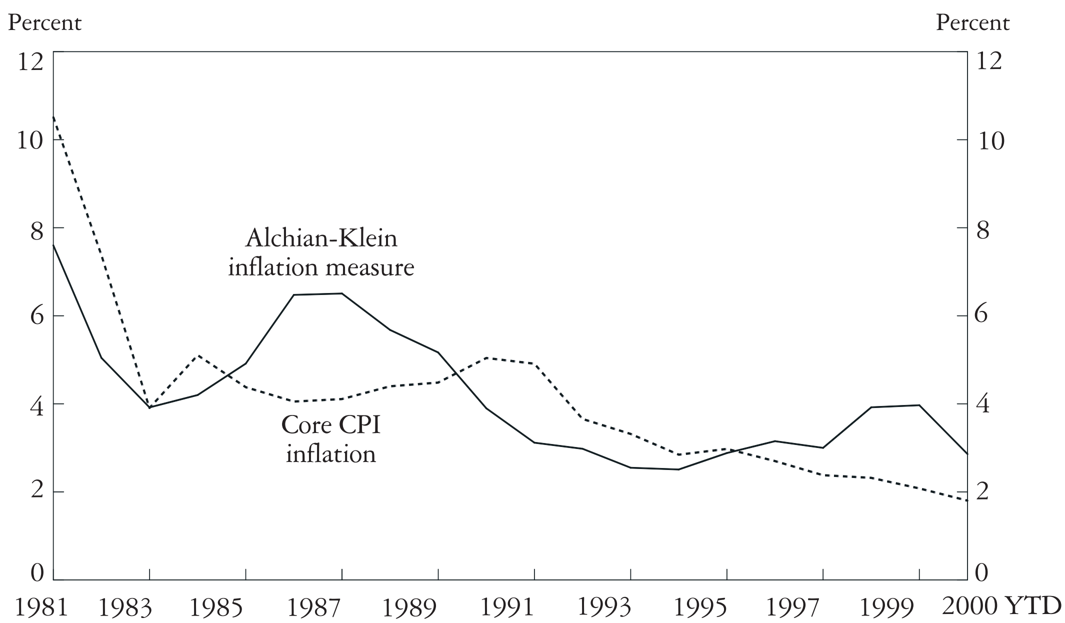
Alchian and Klein's inflation measure, π_{AK}, is a weighted average of core CPI inflation and housing price inflation:

$$\pi_{AK} = 1/2\pi_{coreCPI} + 1/2\pi_{housing}.$$

Housing price inflation is defined as the annual percent change in the repeat sales housing price index. The weight of 1/2 on core CPI and housing inflation was chosen to maximize the ability of Alchian and Klein's measure to predict future consumer price inflation. In particular, regressions of annual core CPI inflation on weighted averages of lagged core CPI and housing price inflation yielded estimates of the weight close to 1/2.[17] Statistical tests confirm the estimate of 1/2 cannot be rejected at standard levels of statistical significance.

Chart B1

U.S. INFLATION MEASURE ADJUSTED FOR ASSET PRICES



Notes: The Alchian and Klein inflation measure is $\pi_{AK} = 1/2\pi_{coreCPI} + 1/2\pi_{housing}$. See box for details.

Two interesting patterns emerge in Chart B1. First, as theory would predict, Alchian and Klein's inflation measure moves together with core CPI inflation, with movements in Alchian and Klein's measure generally leading the movements in core CPI inflation. For example, π_{AK} (dark line) turns up in 1983, roughly two years prior to the upturn in core CPI inflation; then π_{AK} turns down in 1987, three years prior to the downturn in 1990. Second, Alchian and Klein's inflation measure has been higher than core CPI inflation for the last several years, and the gap between the two lines has been growing.[18]

The size of the gap can be used to assess the potential inflation threat. For example, in the past when Alchian and Klein's inflation measure was above core CPI inflation, core CPI inflation rose, such as in the mid-1980s. And, when Alchian and Klein's measure was below core CPI inflation, core CPI inflation tended to fall, as in the early 1990s. In 1999, π_{AK} had been roughly 4 percent, while core CPI inflation was about 2 percent. According to the logic of Goodhart's recommendation, this difference would suggest that core CPI inflation would have been expected to rise significantly in the future in the absence of tighter monetary policy. In 2000, however, Alchian and Klein's inflation measure has come down. One interpretation is that the tighter monetary policy over the last year has reduced the prospects of higher consumer price inflation.

recommendation, this section uses a conventional macroeconomic model calibrated to the behavior of the U.S. economy. The model has two main components: a model of inflation and output and an equation describing monetary policy. In the model, output is inversely related to interest rates, and inflation varies positively with aggregate demand. The model also assumes the central bank sets the interest rate to minimize output and inflation variability as well as to smooth interest rates across time.

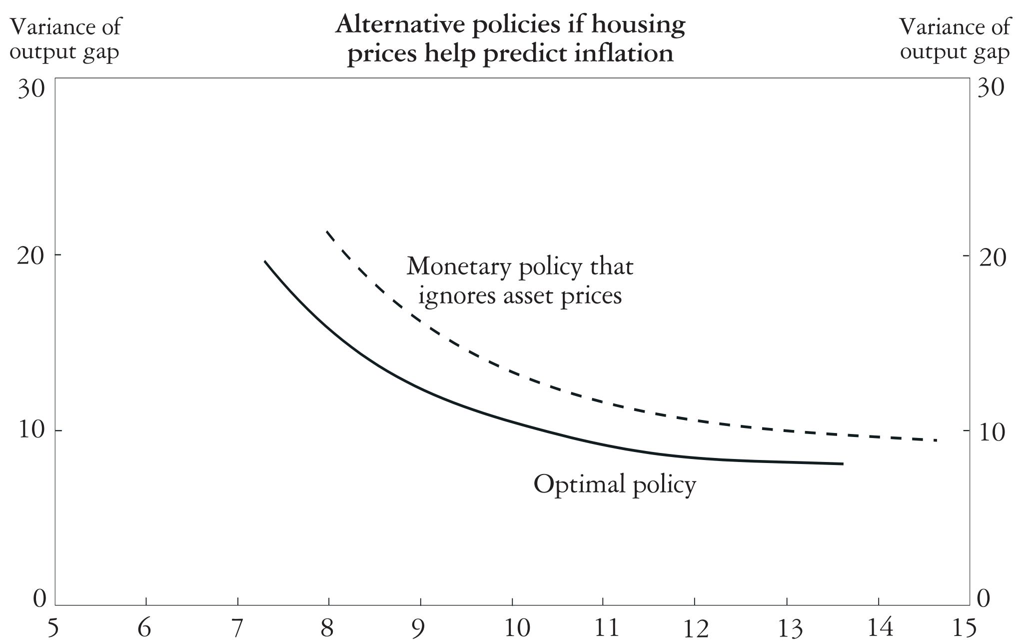
Housing price inflation enters the model in two ways. First, housing price inflation is included in the consumer price inflation equation because housing prices are assumed to help predict future consumer price inflation. Second, housing prices enter the equation that describes monetary policy because the central bank might find it useful to react to changing asset price inflation. The second appendix describes the details of the model.[19]

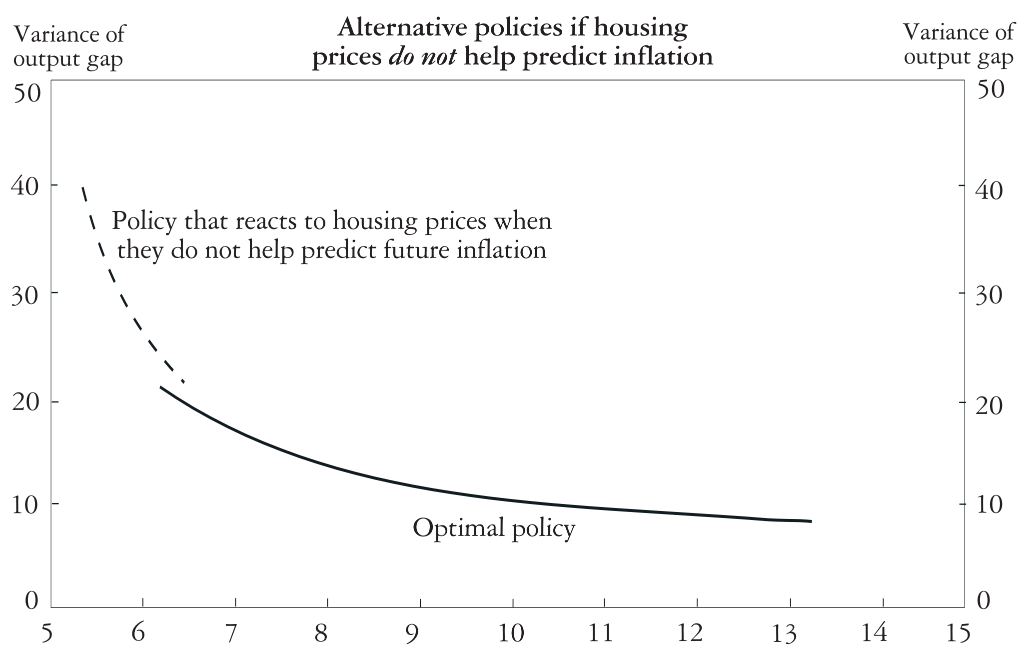
Policy evaluation yardstick

To evaluate the policy simulations from this type of model, policies can be ranked by their implications for output and inflation variability. A policy that produces low output variability and low inflation variability is clearly preferred to a policy that produces high output and inflation variability. Not all policies, however, can be ranked this easily. When policy alternatives offer a tradeoff between output variability and inflation variability, the rankings depend on the relative aversion of the central bank to the two types of variability. For example, a central bank that is relatively inflation averse would tend to prefer policies that keep inflation variability low at the expense of higher output variability.

With this yardstick and the macroeconomic model, a monetary policy that responds to asset prices can be simulated and its implications for output and inflation variability can

Chart 4
MONETARY POLICY CONSEQUENCES OF USING HOUSING PRICES





be assessed. The potential benefits of the proposal arise from the value of forward-looking asset price information. The size of the benefit depends on how reliably housing price inflation predicts future consumer price inflation. In general, better forward-looking information improves the central bank's control of both output and inflation. Hence, the central bank may be able to lower the variability of output and inflation. The potential costs arise from the possibility that the central bank may react to spurious housing price movements.

Potential benefit. A monetary policy that reacts to housing prices would be beneficial if it could reduce both inflation and output variability. The upper panel of Chart 4 illustrates the potential benefit of Goodhart's recommendation in a model calibrated to behave like the U.S. economy. The solid line corresponds to a monetary policy that incorporates housing price inflation when setting short-term interest rates. The dashed line corresponds to the monetary policy that ignores housing price inflation. The southwest location of the solid line relative to the dashed line shows that the central bank can deliver lower inflation and output variability by following a policy that reacts to housing price inflation. In general, a southwestern shift in the inflation-output variability tradeoff indicates an unambiguous improvement in policy.

Potential cost. A monetary policy that responds to housing prices could be harmful if housing prices contain unreliable information about future inflation. In particular, a central bank would overreact to movements in housing prices when they do not reflect changes in expectations of future inflation.

The consequences of such central bank actions for output and inflation variability are demonstrated in the bottom panel of Chart 4. In this chart, housing price inflation is assumed not to play a role in inflation or output determination. The solid line shows the inflation-output tradeoff of the optimal monetary policy. In this case, the central bank is assumed to know that housing price inflation is uninformative and therefore puts no weight on it. In contrast, the dashed line shows the consequences for inflation and output variability if the central bank mistakenly reacts to housing prices. The northwest location of the curve indicates that this policy generates considerably higher output variability but lower inflation variability.

The drop in the variability of inflation may seem counterintuitive. One might think that if a central bank responded to a variable that had no predictive power for future inflation, inflation variability would increase. But the simulations show the opposite. The explanation arises from the central bank's misperception of economic conditions combined with its aversion to inflation variability. When the central bank incorrectly assumes that housing prices are good predictors of consumer price inflation, it will find that its ability to forecast inflation will drop. In other words, the central bank will see bigger forecast errors of inflation and hence perceive a greater threat of higher inflation variability. This threat, albeit misperceived, causes the central bank to alter its policy relative to the baseline case where the central bank forecasts inflation more accurately. In particular, the central bank will tend to respond more aggressively to the factors that would tend to cause inflation variability to rise. As a result, the aggressive policy will lower inflation variability relative to the baseline case. However, the misperception is not costless. The central bank's extra efforts to contain inflation variability cause output variability to increase more than would be optimal, producing the northwest shift of the policy curve in Chart 4.[20]

Evaluating the potential costs of the proposal is complicated because it requires assumptions about the preferences of the central bank. For example, a central bank could

Table 3

HYPOTHETICAL COST-BENEFIT ANALYSIS OF GOODHART'S RECOMMENDATION

Central bank's preferences	Housing prices signal future inflation		Housing prices **do not** signal future inflation		
	Potential benefit	Probability	Potential cost	Probability	Expected net benefit
		percent		percent	
Equally averse to inflation and output variability	2	50	7	50	-2.5
Relatively averse to inflation variability	3	50	5	50	-1

Notes: The cost and benefit estimates represent the change in the central bank's loss function from implementing the recommendation; and, the expected net benefit is calculated assuming a 50-50 chance that asset price inflation helps predict future consumer price inflation. With this information, the expected net benefit in row 1 is 2*(.5)-7*(.5)=-2.5.

find the risks of being wrong about the information role of asset prices acceptable if it puts low enough weight on output variability relative to inflation variability. In contrast, a central bank that puts low weight on inflation variability relative to output variability could find the risk of being wrong unacceptable.[21]

Net benefit. Table 3 compares the net benefits of Goodhart's recommendation for two types of central banks: one that is equally averse to inflation and output variability, and another that is relatively inflation averse. The expected net benefit equals the probability of achieving the potential benefit times the size of that benefit less the probability of the potential cost times the size of the cost. For simplicity, the comparison assumes a 50-50 chance that asset price inflation accurately reflects future consumer price inflation.

The results using a model calibrated to the U.S. economy indicate that the expected net benefit of Goodhart's recommendation is negative, regardless of the central bank's preferences. Even a central bank that is relatively averse to inflation variability (weight on inflation variability is five times as high as on output variability) would find the net benefits of the proposal to be negative. The results suggest that Goodhart's recommendation would not be expected to improve U.S. economic performance. Moreover, if the probability that housing price inflation reliably predicts consumer price inflation is below 50 percent, the net benefits would be even more negative.

The results must be qualified somewhat because there may be circumstances when the probability of achieving the potential benefits would far outweigh the probability of the potential costs. For example, there may be times when a central bank is particularly confident that asset prices are sending reliable inflationary signals. If the probability of achieving the potential benefit rises sufficiently, the net benefits of following Goodhart's recommendation could turn positive. Moreover, if in the future economists discover better methods to extract reliable inflation information from asset price inflation, Goodhart's recommendation may play an important and valuable role in monetary policymaking.

IV. CONCLUSION

Although the recommendation to include asset prices in policymakers' inflation measures has a theoretical basis, it is not likely to improve U.S. economic performance. To be sure, there have been periods when asset price inflation has given early warning of future consumer price inflation. But, the empirical analysis in this article finds little evidence that Goodhart's recommendation would reliably improve economic outcomes. Housing price inflation shows some power to predict future inflation, but stock market price inflation exhibits no power to help predict future consumer price inflation. As a consequence, the prospect of using these asset prices to improve the conduct of monetary policy is not promising. Policy simulations of Goodhart's recommendation confirm this conclusion.

APPENDIX 1

THEORY BEHIND ALCHIAN AND KLEIN'S MEASURE

This appendix describes the theoretical foundations of Alchian and Klein's inflation measure. The first part outlines the index number theory underlying the measure. The second part explains why asset prices may be good proxies for futures prices, thereby transforming Alchian and Klein's theoretical measure into a practical tool for policymaking. The third part contrasts Alchian and Klein's approach with more conventional models linking asset prices and consumer price inflation.

Index theory justifying Alchian and Klein's inflation measure

The key difference between Alchian and Klein's price index and conventional ones is the definition of the consumption basket.[22] Alchian and Klein argue that conventional price indexes ignore important prices that help determine overall inflation conditions. Conventional price indexes, such as the CPI, measure changes in the cost of a "typical" basket of consumption goods purchased in a year. Changes in the index capture changes in the *yearly cost of living*. Alchian and Klein, in contrast, develop their index using the notion of a *lifetime cost of living*. A lifetime cost of living includes not only the prices of goods purchased in a particular year but also expected prices of future purchases.[23]

Conventional price indexes define the consumption basket as the goods purchased by consumers in a given year. Such a basket would include items such as food, shelter, and entertainment. Algebraically, the consumption basket can be represented as $c_t = \{c_{1,t}, c_{2,t}, \ldots, c_{n,t}\}$, where $c_{i,t}$ is good i consumed during period t. Given this basket and its associated prices, a conventional price index is defined as the ratio of the cost of living in a given year relative to the cost of living in a particular base year:

$$P_t^{conventional} = \frac{\sum_{i=1}^{N} P_{i,t} c_{i,t}^0}{\sum_{i=1}^{N} p_{i,t}^0 c_{i,t}^0}.$$

The denominator is the yearly cost of purchasing the base year basket (the base year is denoted with the *0* superscript) using base year prices; the numerator is the cost of purchasing the base year basket using current prices.[24]

In contrast, Alchian and Klein's price index expands the definition of the consumption basket to include expected future consumption. For example, expected future consumption represents such items as expected shelter purchases in three years or a planned vacation in two years. This consumption basket can be written as

$$C_t = \{\{c_{1,t}, c_{2,t}, \ldots, c_{n,t}\}, \ldots, \{c_{1,T} c_{2,T}, \ldots, c_{n,T}\}\},$$

where period T would represent the length of life for the average consumer. The associated prices of the expected future consumption are future prices; that is, the price you would pay today for the good to be deliv-

APPENDIX 1 *continued*

Table A1

DATA FROM HYPOTHETICAL ECONOMY

	Base year		Year following base year	
	Price	Quantity	Price	Quantity
Current consumption	100	30	102	40
Future consumption	102	970	106	960

Implied inflation	
Conventional index	2 percent
Alchian-Klein index	3 percent

ered at a later date. In this case, the price index is

$$P_t^{AK} = \frac{\sum_{j=0}^{T}\left(\sum_{i=1}^{N} P_{i,t+j}\, c_{i,t+j}^{0}\right)}{\sum_{j=0}^{T}\left(\sum_{i=1}^{N} p_{i,t+j}^{0}\, c_{i,t+j}^{0}\right)} = \frac{\sum_{j=0}^{T} p_{t+j}\, c_{t+j}^{0}}{\sum_{j=0}^{T} p_t^{0}\, c_{t+j}^{0}},$$

which is the ratio of the lifetime cost of living evaluated at current prices to the lifetime cost of living evaluated in base year prices. Alchian and Klein's price index can be written as the ratio of the sum of the cost of all goods consumed in a lifetime, or as the ratio of the sum of the cost of an aggregate consumption bundle for each time period.

An example helps clarify the difference between Alchian and Klein's price index and conventional price indexes. To simplify the calculations, assume goods are lumped into two categories: consumption today and all future consumption. Table A1 summarizes the relevant data on prices and quantities from a hypothetical economy.[25]

Table A1 also summarizes the inflation rates in the hypothetical economy. Alchian and Klein's inflation measure is 3 percent whereas the conventional measure is 2 percent. The higher inflation rate reflects an expectation of higher consumer price inflation in the future. Hence, a central bank interested in keeping consumer price inflation below 3 percent might use this information to justify tighter monetary policy.

Using Alchian and Klein's inflation measure without future prices

Alchian and Klein understood the practical limitations of their proposed index due a dearth of readily available futures prices. However, they offered a possible

APPENDIX 1 *continued*

solution to this problem by using asset prices as a proxy for futures prices. [26]

Alchian and Klein showed how changes in asset prices could reflect changes in future prices. The consumer's lifetime budget constraint can be written in terms of current and future consumption: [27]

$$\text{Consumer's lifetime budget constraint} = p_t c_t + \sum_{j=1}^{T} p_{t+j} c_{t+j}.$$

This equation can also be rewritten to highlight the fact that consumers allocate their wealth into current consumption and asset holdings ($p_A A_t$) in each time period:

$$\text{Consumer's lifetime budget constraint} = p_t c_t + p_A A_t.$$

Subtracting the second equation from the first yields the following link between asset prices and future prices:

$$p_A A_t = \sum_{j=1}^{T} p_{t+j} c_{t+j}.$$

Hence, p_A is related to future prices; if A_t and future consumption choices were known, then asset price changes would reflect changing future prices.

Shibuya exploits this link and further simplifies Alchian and Klein's abstract theory for practical purposes. He shows that Alchian and Klein's inflation measure can be summarized as a weighted-sum of consumer price inflation and asset price inflation:

$$\pi_{AK} = \alpha\pi + (1-\alpha)\pi_{AP},$$

where π is a conventional measure of inflation and π_{AP} is a measure of asset price inflation.

A more conventional justification

Alchian and Klein's theoretical justification for the links between asset prices and consumer price inflation is different from that used in conventional macroeconomic models. Conventional models typically specify tight links among asset prices, aggregate demand, and consumer price inflation. In contrast, Alchian and Klein's theory is something of a "black box" that does not describe the channels of cause and effect.

Despite the different theoretical justifications, Alchian and Klein's model and conventional models are not necessarily inconsistent with each other. In the case when the links from asset prices to aggregate demand to consumer price inflation are operative and reliable, Alchian and Klein's model and conventional models should yield broadly similar inflation implications. Asset price inflation rises, followed by an increase in consumer price inflation.

However, there are cases when one model would be preferred over the other. For example, when the links between asset prices and aggregate demand and between aggregate

APPENDIX 1 *continued*

demand and consumer price inflation are thought to be reliable, conventional models may be more helpful in monetary policy deliberations. In such a situation, both models would provide similar signals about the direction of consumer price inflation, but conventional models would provide better information about the typical lags between asset price inflation and consumer price inflation. In contrast, Alchian and Klein's model would provide little guidance to policymakers about the expected lag between an increase in asset prices and increases in consumer price inflation. Asset price inflation alone does not indicate whether consumer price inflation is likely to rise in one year or in five years.

In the case where the links assumed in conventional models are unreliable, Alchian and Klein's model may prove to be more helpful to monetary policymakers.[28] In this situation, conventional models would provide faulty signals about the likely effects of asset price changes. The errors might provide an incorrect inference that the links between asset price inflation and consumer price inflation had been broken. In contrast, Alchian and Klein's model may provide more accurate inflation implications. This is because Alchian and Klein's model is more likely to be robust to long and variable lags between asset price inflation and consumer price inflation.[29]

APPENDIX 2

MONETARY POLICY MODEL WITH ASSET PRICE INFLATION

Recent advances in monetary policy modeling have yielded powerful tools to evaluate Goodhart's recommendation for U.S. monetary policymaking. By extending the approach of Ball and Rudebusch and Svensson, this article examines the macroeconomic performance of an economy where the central bank responds to changes in forward-looking inflation information contained in asset price inflation.

The model comprises three key components: 1) a system of equations describing the key aspects of the macroeconomy, 2) a monetary policy interest rate equation, and 3) preferences of the central bank.

A system of equations was estimated to describe important macroeconomic variables in the U.S. economy. This system represents a standard macroeconomic model that has been augmented to include asset price inflation:[30]

$$
\begin{aligned}
(IS)\ y_t &= -.34 r_{t-1} + .62 y_{t-1} + \varepsilon_t \\
(PC)\ \pi_t &= \pi_{t-1} + .17 y_{t-1} + .17 \pi_{AP,t-1} + \eta_t \\
(AP)\ \pi_{AP,t} &= \pi_{t-1} + .12 y_{t-1} + \nu_t
\end{aligned}
$$

In this fictitious economy, aggregate output (y) is modeled as an IS equation; output is determined by the past interest rate and a lag of output. The PC equation describes inflation as a function of lagged consumer price inflation, the strength of the economy as measured by lagged output, and lagged asset price inflation. In the PC equation, asset price inflation serves as a proxy for expectations of future consumer price inflation. Technically, the inflation equation resembles a Phillips curve specification with an asset price inflation term. The final equation in this system is the asset price inflation equation (*AP*). Asset price inflation is specified as a function of past consumer price inflation and output. Each equation of the system also includes an error term. The variables $\varepsilon, \eta,$ and ν denote unexpected changes in aggregate demand, consumer price inflation, and asset price inflation, respectively.[31]

An interest rate equation describes monetary policy in the fictitious economy. The central bank is assumed to respond to changing economic conditions. This specification is similar to equations of the type investigated in Taylor (1999), where the central bank is assumed to set the interest rate in response to changing output, consumer price inflation, and asset price inflation:

$$r_t = a_1 \pi_t + a_2 y_t + a_3 \pi_{AP,t}.$$

The interest rate equation resembles a standard Taylor-type interest rate rule with an additional housing price inflation term. The central bank chooses coefficients a_1, a_2, and a_3 to achieve its goals for inflation and output stability.

The preferences for the inflation and output goals fit conveniently in a standard specification of a central bank's preferences (Taylor 1994). The central bank dislikes variability in output and inflation. As

APPENDIX 2 *continued*

well, the central bank dislikes disrupting financial markets with interest rate variability. These preferences are represented in the loss function

$$L = \text{var}(y) + \mu\,\text{var}(\pi) + .1\,\text{var}(r - r_{-1}),$$

where var(y) is the variance of output, var(π) is the variance of inflation, var$(r - r_{-1})$ is the variance of interest rate changes. The coefficients $(\mu, .1)$ reflect the central bank's relative preference for its goals. If μ is close to zero, then the central bank puts little weight on output variability relative to the variability of inflation and interest rate changes. In contrast, a higher μ signifies more weight on output fluctuations relative to variability in inflation and interest rate changes. Finally, the coefficient 0.1 on the variability of interest rate changes captures the empirical fact that central bankers smooth interest rates in the pursuit of inflation and output stabilization (Mishkin).

The model is simulated in three steps to solve for optimal monetary policy.[32] First, the monetary policy rule is substituted into the IS-PC-AP system of equations. Second, the system is simulated with random numbers that represent shocks to output, consumer price inflation, and asset price inflation. Third, with 5,000 simulations from this fictitious economy, the coefficients a_1, a_2, and a_3 are numerically chosen to minimize the central bank's loss function L.

Chart 4 shows inflation-output tradeoffs from four different simulations. The two inflation-output tradeoffs in the top panel were generated from the system of equations described above. The difference between the two curves arises from different assumptions about monetary policy. The "optimal policy" curve corresponds to the case where the central bank can freely choose values of a_1, a_2, and a_3 to minimize the loss function L. In contrast, the second curve corresponds to the case where the monetary policy ignores asset price inflation; in other words, coefficient a_3 is constrained to be zero. The positions of the curves show that ignoring useful information about inflation will produce higher inflation and output variability.[33]

The two inflation-output tradeoffs in the bottom panel were generated assuming that housing price inflation does not help predict inflation; the *PC* equation is assumed to have a coefficient on π_{AP} of zero instead of 0.17. When this coefficient is set to zero, housing price inflation has no role in determining consumer price inflation. The "optimal policy" curve corresponds to the case where the central bank correctly knows the structure of the economy. If the central bank knew that asset price inflation had no predictive power for consumer price inflation, its optimal policy would be an interest rate rule with a zero weight on π_{AP}. However, the central bank might mistakenly believe that asset price inflation helps predict future consumer price inflation. As a result of this incorrect assumption, a central bank would respond to changing housing price inflation. The policy consequence of

APPENDIX 2 *continued*

responding to housing price inflation when it should not is a shift in the inflation-output curve in the northwest direction. In this case, the central bank was assumed to respond to housing price inflation in the way that the central bank optimally does in the top panel.

Evaluating the net benefit of Goodhart's recommendation requires a comparison of shifts in the top and the bottom panels. The top panel illustrates the benefit of using asset price inflation when it can help predict future consumer price inflation. The bottom panel illustrates the costs of being wrong about the usefulness of asset price inflation. The net benefit is simply calculated by weighting the outcomes from the two scenarios. The weights, however, are difficult to estimate because they depend on the probability that housing price inflation provides reliable information about future consumer price inflation. In practice, this probability should reflect statistical evidence of the relationships among housing prices, the output gap, and consumer price inflation as well as judgments (or prior beliefs) of the central bank about the usefulness of asset prices in forecasting future consumer price inflation.

Despite the difficulty of precisely estimating the key probability, conclusions can be drawn about the attractiveness of a policy option. For example, instead of using a precise estimate of the probability, one can use a conservative guess of the probability and then verify that the results from the cost-benefit analysis are robust to more likely values. This method provides useful information as long as the conclusion from the cost-benefit analysis is robust to reasonable estimates of the probability. For this article, a 50 percent probability is a fairly conservative, albeit subjective, estimate of the probability that housing price inflation reliably predicts future consumer price inflation. This estimate likely underestimates the skepticism often expressed in policy debates about the ability of asset price inflation (and housing price inflation specifically) to forecast future consumer price inflation.[34] Using this estimate of the probability, Table 3 works out the cost-benefit analysis, and shows the net benefits of Goodhart's recommendation to be negative. If the probability were lower, then the conclusion of the cost-benefit analysis would be even stronger because the expected costs grow and the expected benefits drop as the probability decreases.

ENDNOTES

[1] Housing prices include both land and structure prices.

[2] The rapid rise in asset prices has not been isolated to the United States, the UK, and Japan. Most OECD countries have experienced wide swings in stock market and real estate prices over the last several decades, especially in the Scandinavian countries (Borio, Kennedy, and Prowse and Capel and Houben). The International Monetary Fund (1999) finds that Finland, Ireland, and Norway have recently experienced asset price swings that suggest these countries may be now facing some of the same monetary policy issues as the United States.

[3] Breedon and Joyce also attribute the extraordinary strength in UK housing prices to demographics and market expectations. Borio, Kennedy, and Prowse conclude that easy credit conditions have been a distinguishing feature of most episodes of sustained asset price inflation in OECD countries.

[4] Why didn't Japanese officials respond to asset prices sooner? Gertler and Bernanke argue that Japan could have prevented the outbreak of inflation by raising interest rates earlier. However, Yamaguchi has noted that this advice seems more reasonable with hindsight than it was at the time. Japanese monetary officials were concerned about the inflationary implications of the unprecedented run-up in asset prices. They had been warning the public about the potential inflationary conditions. However, there were structural changes under way that could have helped to explain the asset price behavior. And, in an environment of zero (or lower) inflation, the central bank faced the practical problem of justifying tighter monetary policy even if they thought it was the correct policy. Okina, Shirakawa, and Shiratsuka echo these same sentiments in a systematic analysis of economic conditions and prevailing views about the links between asset prices and monetary policy at the time. See Mori, Shiratsuka, and Taguchi for a discussion of the monetary policy implications of the asset price reversal in Japan during the early 1990s. Schinasi attributes part of the delayed monetary policy reaction to the long lag between asset price movements and consumer price inflation.

[5] Bernanke and Woodford point out that extracting reliable information from asset prices depends critically on market assumptions about future monetary policy. In this case, the central bank can tighten current policy or credibly commit to tighter future policy. Either response will rein in inflationary expectations and presumably show up in current asset prices.

[6] Asset wealth is measured by the market capitalization of the Wilshire 5000 index and consumer housing wealth as a percentage of the total assets of households and nonprofit organizations from the Flow of Funds, Table B.100 for 1999. In addition, when human capital is added to the total, the share falls to roughly a fifth of all assets. The estimate of the human capital stock is based on the income share of human capital being roughly double that of physical capital.

[7] In the current U.S. context, if recent gains in productivity growth are sustainable, then future real corporate earnings will be higher, and stock values should rise even if inflation is not expected to pick up. Likewise, faster productivity growth might imply higher future real incomes for U.S. households, increasing demand for housing and bidding up housing prices without a more general increase in the inflation rate.

In general, there are many other reasons that housing and stock market prices may rise that are unrelated to expected future consumer price inflation. Stock market prices may be affected by variation in future earnings, risk preferences of investors, discount rates of future dividends, and taxes. Housing prices can vary for similar reasons, but the factors are typically labeled as variation in rental (or owner-occupied housing) returns, risk preferences of homeowners and real estate investors, discount rates of future returns, and taxes. See Shiller, Siegel, and Shen for further discussion of the difficulty in interpreting the factors responsible for asset price fluctuations.

[8] This section uses annual data to minimize the effect of transitory movements in asset prices on the correlations. Transitory movements may arise from the practical problems in using housing and stock market prices as proxies for the ideal asset price measure suggested in Alchian and Klein's theory.

[9] Alchian and Klein's theory would suggest the use of housing prices rather than housing wealth. The results using housing wealth data (long sample) appear to be largely consistent with the results from the housing price data (short sample). From 1981 to 1999, the housing wealth correlations are .36, .34, .15, and .14 for years one to four, respectively. This evidence suggests that most of the wealth variation reflects fluctuations in prices rather than fluctuations in holdings of assets. Therefore, it seems reasonable to consider the housing wealth data as a good proxy to test Alchian and Klein's theory for the United States.

[10] One possible reason for the higher correlation is that the housing wealth index is a better asset price measure. Another possible reason is that the correlation between housing price and consumer price inflation has fallen in the last two decades compared with the previous two decades. This latter explanation is consistent with the data. The correlation between housing wealth inflation and consumer price inflation over the last two decades is largely consistent with the repeat sales index correlations.

[11] The qualitative findings using core CPI inflation are largely consistent with those using the core PCE inflation.

[12] This finding is consistent with Quan and Titman's study of real estate prices and inflation. Using data from 17 countries including the United States, they find that real estate prices provide a good hedge against long-term inflation. Stock market prices do not seem to be a good hedge despite the fact that there is a widely held view that rising stock market prices boost aggregate demand, thereby increasing consumer price inflation. The differential hedging value of stock market inflation and real estate price inflation is not particularly surprising. Ibbotson and Siegel and Hartzel find low correlations between changes in stock market prices and real estate prices.

[13] The imprecision may be due to the fact that Alchian and Klein's theory implies little about the timing and magnitude of asset price changes on consumer price inflation. In the presence of long and variables lags between asset price inflation and consumer price inflation, regression estimates would tend to be imprecise.

[14] These findings are largely consistent with recent cross-country studies by Goodhart and Hofmann (2000A, B) that find housing prices predict future consumer price inflation in many countries. The results are also supportive of conclusions in Cecchetti, Genberg, Lipsky, and Wadhwani. They explore the potential benefits of adding stock market prices and housing prices into the Bryan-Cecchetti dynamic factor index model of inflation measurement. While stock market prices are unreliable predictors of future consumer price inflation, housing prices show some favorable characteristics in helping capture U.S. inflation trends. They conclude: "While there may be justification for including equity prices, their inclusion is likely to create more problems than they solve…Housing [prices], though, need to be considered more carefully. Here, we believe that there is clear room for improvement in the price indices."

[15] The marginal improvement in the R^2 of including housing price inflation is about 10 percent. In addition, the regression results assume that consumer price inflation is I(0). In the case when consumer price inflation is assumed to be I(1), the predictive power of housing price inflation falls further. It should also be noted that the results are from an in-sample predictive analysis; the length of the annual dataset does not allow a meaningful out-of-sample analysis.

[16] Monetary condition indexes have been developed by various private sector institutions to help track inflation pressures. The results in this article suggest that the lack of predictive power of stock market indexes may cause these indexes to send faulty signals about future inflation prospects.

[17] In theory, the weights in Alchian and Klein's measure should reflect the share of current consumption as a percentage of discounted lifetime consumption. Shibuya calculated an estimate of the weight, α, that reflects the share of yearly consumption as a percentage of the discounted value of lifetime consumption. His estimate of α is 3 percent.

Shibuya and Shiratsuka, however, point out important drawbacks of Alchian and Klein's theoretical measure and argue that empirical estimates for α may be much higher because of asset price volatility. Shiratsuka shows that theoretical measures of α can be severely downwardly biased. To avoid this problem, this article uses regression-based estimation methods. The weight α is chosen to maximize the correlation with future consumer price inflation. The approach is similar in spirit to Christoffersen, Schinasi, and Lim. They chose the weight to maximize the correlation between Alchian and Klein's inflation measure and a measure of monetary conditions (measured by M2 growth plus CDs less real GDP growth).

[18] Cecchetti et al. raise the possibility that core CPI may have been biased downward in recent years because of the methodology used to calculate shelter prices by the Bureau of Labor Statistics (BLS). The BLS measures shelter prices using rental market data rather than prices of existing homes. In recent years, housing prices have been rising faster than rental prices because the rental vacancy rate has been relatively high as homeownership rates have risen. This may help to explain why the inflation index consistent with Alchian and Klein's theory has been exceeding the core CPI in recent years.

[19] In a recent study, Bernanke and Gertler address similar issues as in this paper but use a different model. Asset prices are assumed to affect consumer price inflation through an aggregate demand channel. In particular, asset prices can influence aggregate demand and hence consumer price inflation in two ways. First, higher asset prices raise consumer wealth which, in turn, raises consumption demand. Second, higher asset prices reduce financing costs which raises investment demand. In addition, the empirical results about the ability to predict consumer price inflation do not necessarily apply to their study. Models based on an aggregate demand channel would imply different tests than are used in the previous section. These models would suggest using assets that are highly correlated with changes in aggregate demand. The benefit of using such asset prices will not only depend on how well they predict changes in aggregate demand but also on how well aggregate demand predicts inflation.

Bernanke and Gertler also explore the implications of asset price movements that arise from fundamentals as well as those that arise from asset price bubbles. This article does not address the differences between fundamental and bubble behavior of asset prices because most experts (including Bernanke and Gertler) agree that it is exceedingly difficult, if not impossible, to distinguish between the two in practice.

[20] The central bank makes an incorrect assumption and hence perceives more uncertainty in the economy. Although a change in uncertainty might cause the central bank to respond in a less aggressive way (Brainard), this possibility is hard to explore in the model and is not examined in this article.

[21] Bernanke and Gertler argue that the potential costs of responding to asset price movements can be quite large. Their evidence supports the conclusion that by responding to stock prices, a central bank would worsen economic outcomes, a finding that reflects their view that stock prices are too volatile relative to their information content to be useful. Vickers draws a similar conclusion in an analysis without using a formal macroeconomic model.

The conclusion has recently been challenged by Cecchetti, Genberg, Lipsky, and Wadhwani. They argue that Bernanke and Gertler may have unduly restricted the ability of the central bank to respond to asset prices in the simulations. Cecchetti et al. use a similar model and find evidence that economic conditions can be improved by a central bank that responds to asset prices. Their conclusion does not depend on whether the central bank reacts to asset prices or the part of asset prices attributable to asset price bubbles.

[22] Pollak provides a more rigorous foundation for Alchian and Klein's price index. Alchian and Klein's measure is an example of a broader class of prices indexes sometimes referred to as the intertemporal cost of living index or dynamic equilibrium price index. Carlson shows that Alchian and Klein's price index is closely related methodologically to various conventional price indexes.

[23] As Gavin and Jordan point out, Alchian and Klein's measure of inflation is firmly rooted in modern macroeconomic theory. The hallmark of modern macroeconomic theory is that economic decisions depend on the forward-looking behavior of economic agents—be they consumers, investors, workers, or producers. Forward-looking consumers would need to know prices of today's goods as well as expected prices of future goods. Alchian and Klein's price index incorporates this type of information.

[24] Technically, this equation approximates the procedure used to construct conventional price indexes such as the CPI and PCE price indexes. See Clark for details on the construction of these conventional price indexes.

[25] The quantity of current consumption is much smaller than the discounted value of all future consumption. The difference is consistent with the calculations of Shibuya.

[26] Wynne shows how to use forecasts of future inflation instead of asset price inflation to construct the price index.

[27] This assumes the present value of future labor income is captured in the value of human capital.

[28] Few will deny the theoretical underpinning of the conventional view, but the links may be subject to large uncertainty. One reason arises from the uncertainty about the relationship between rising wealth and rising consumption in both its timing and magnitude (Poterba 2000). Another reason is that the empirical Phillips curve, which is a model of the link between aggregate demand and inflation, has proven to be quite unstable at times (Akerlof, Perry, and Dickens).

[29] Shibuya argues that this model is consistent with a Wicksellian view of economic activity. If interest rates dropped below Wicksell's natural interest rate, equity prices would rise above their long-run sustainable level as would economy activity. These imbalances would ultimately exhibit themselves as higher inflation. However, the timing of the transmission to inflation could be long and variable.

[30] The coefficient estimates in the equations were estimated using annual data on the output gap, core CPI inflation, and housing price inflation (using repeat sales housing data). The IS equation was estimated from 1961 to 1999. The standard errors of the regression coefficients are 0.08 and 0.10, respectively. The estimates are consistent with the output gap falling one percentage point for every percentage point increase in the interest rate. The *PC* equation was estimated over 1981 to 1999 because of data availability constraints. The standard errors of the regression coefficients are 0.16 and 0.16, respectively. The low statistical significance of the coefficients reflects the short data sample and the simple lag structure (which simplifies the simulations). As discussed in the second section of this article, the positive relationship between inflation and housing price inflation (after controlling for the output gap) is fairly robust. Moreover, the implied sacrifice ratio from this model is about 5. The *AP* equation is imprecisely estimated. The standard error of the coefficient is 0.29. The positive relationship between housing price inflation and output, however, is consistent with the cross-country study of Case, Goetzmann, and Rouwenhorst. It should be noted that the qualitative results found in Chart 4 are fairly robust to other possible calibrations consistent with the time series properties of the U.S. economy.

[31] Estimates of the variances of the error terms $\varepsilon, \eta,$ and ν are (2.2, 2.1,18.7), respectively.

[32] The policy is optimal in that no other policy will reduce the loss function *L*. The optimality of such interest rate rules arises from the linear-quadratic form of the model.

[33] This result may seem counterintuitive because some economists may conjecture that asset price volatility causes monetary policy volatility. However, as Ball points out, optimal monetary policy in the type of model used in this article does not depend on the variance of the error terms. In technical terms, the model exhibits a certainty equivalence property that is shared by all linear macroeconomic models with quadratic preferences for the central bank. Intuitively, these models allow a hypothetical central bank to improve macroeconomic performance (on average) by responding to all variables that truly help to predict future consumer price inflation.

[34] Conventional statistical analysis of the *PC* equation indicates that there is roughly a 60 percent probability that the regression coefficient for housing price inflation is not equal to zero. Further scrutiny of the regression, however, indicates that this probability estimate may be an optimistic assessment of the ability of housing price inflation to forecast future consumer price inflation. The marginal R2 of adding the housing price inflation variable to the *PC* equation is small. And, even though out-of-sample forecasting results are hard to interpret because of the short sample period over which the regression is run, the out-of-sample forecasting performance of the *PC* equation is weak.

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