Should the Federal Reserve Have Responded to Asset Prices?

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Determining strategies for taking into account movements in asset prices is a perennially important issue for central banks. In this paper, an analysis is provided to address this issue for the U.S. economy. To do so, an empirical model of the U.S. economy is constructed and estimated, and the estimated model is simulated with a set of alternative monetary policy rules. Comparing the stabilization performance of the rules, it is found that: i) by responding to a larger set of policy indicators and taking a more aggressive stance toward inflation and output gap in particular, the Federal Reserve could have achieved a much higher degree of stabilization; ii) had the Federal Reserve responded to its historical policy indicators differently, it could have conducted a near-optimal policy rule, even without taking into account movements in housing and stock prices; iii) the Federal Reserve could have likewise achieved close-to-optimal stabilization results by properly responding to movements in asset prices, on top of its historical policy scheme; and iv) stock price inflation contains more useful information that helps further stabilize the economy than does housing price inflation.

Keywords: Asset prices, Stabilization, Monetary policy

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I. Introduction

Since the mid 80s, asset prices in many countries have undergone major medium-term fluctuations, sometimes ending in abrupt corrections. In the U.S., the last two decades have witnessed significant and persistent increase in asset prices followed by sharp downward corrections. The rise in asset prices early in the last decade was mainly triggered by low interest rates, set by the Federal Reserve Board to diminish the blow caused by the collapse of the dotcom bubble and to combat deflation risk. In the wake of the subprime mortgage crisis, the recent downturn in the U.S. housing and stock market has caused multiple adverse effects on the financial and regulatory framework of the world economy.

Such large swings in asset prices brought about a debate over what the appropriate responses of the central bank are to asset price movements. Centered around this issue are the following questions: i) Should asset prices in the measure of inflation be targeted by monetary policy? ii) What can asset prices tell central banks about monetary policy? iii) What do asset prices add to other indicators that inform the central banks of the desirable monetary policy? This paper primarily aims to address the last two questions in the context of the U.S. economy, by asking *whether the monetary authority should respond to asset prices in order to stabilize output and inflation variability, and if so, by how much?*

There has been considerable debate on the role of asset prices in the formulation of monetary policy. As summarized by Eitrheim (2008), there have been three views on the policy implications of asset price movements. First, in the "benign neglect view" shared by Bernanke and Gertler (1999, 2001) and Bean (2003), effects of asset prices are sufficiently incorporated in a flexible inflation targeting regime. In particular, Bernanke and Gertler recommended that monetary policy should not respond to asset price fluctuations unless they flag changes in expected inflation. The second view is the "activist view," according to which macroeconomic performance can be improved by responding proactively to asset prices. The most recent contributors to this view are Cecchetti *et al.* (2000), who claimed finding strong support for including stock prices in the policy rule of the central bank. Moreover, Alchian and Klein (1973) and Goodhart (1995) stressed the importance of incorporating asset prices in a broader measure of inflation for central banks to respond to, because fluctuations in asset prices tend to affect expected inflation.[1] Finally, the "discretionary judgment view" advocated by Borio and Lowe (2002) and Bordo and Jeanne (2002) has it that some discretion should be entertained, acknowledging that abrupt changes in asset prices, followed by sharp unwinding of financial imbalances, may inflict substantial costs.

As aforementioned, this paper addresses the importance of asset prices in the conduct of the U.S. monetary policy. Our interest can be summarized by two questions. The first one is, "How well has the Federal Reserve executed its monetary policy since the 80s?" An answer to this question is sought by comparing the stabilization performance of the historically conducted policy against the optimal policy that can achieve the best stabilization results for output and inflation. In case the historical rule failed to achieve any close-to-optimal stabilization results, the second question comes into play: "Could the Federal Reserve have improved the stabilization performance of its policy, had it taken into account the movements in the asset prices?" The answer to this question can be sought by evaluating the extra contribution of the asset prices, on the top of the historical rule, to achieving better stabilization results.

With these questions in mind, an empirical model for the U.S. economy is constructed. Within the context of the empirical model, whether and how much the performance of monetary policy can be improved is examined by taking asset prices into account. Specifically, the estimated model is simulated with a set of alternative monetary policy rules and the stabilization performance of the rules compared against a performance metric comprising the weighted averages of variabilities in output gap and inflation.

Comparison results among alternative interest rate rules suggest there is plenty of room for further stabilization of inflation and output if the Federal Reserve shifts from the historical monetary policy rule to the optimal one. Improvements upon the historical rule can be achieved either by responding to additional policy indicators (especially the asset prices) in the optimal rule *per se*, or by responding solely to the historical policy indicators more aggressively than under the rule actually implemented. Likewise, as long as the Federal Reserve maintains appropriate reactions to the historical policy indicators, housing price

[1] In an empirical analysis for the U.S., Filardo (2000) finds little evidence that Goodhart's recommendation would reliably improve economic outcomes.

inflation turns out to have little extra information for further stabilization. Therefore, the Federal Reserve could have achieved close-to-optimal stabilization results by properly responding to movements in asset prices, on top of its historical policy scheme. Additionally, stock price inflation turns out to contain more useful information that helps further stabilize the economy than does housing price inflation.

The rest of the paper is organized as follows: Section 2 constructs and brings to data the workhorse model for the policy simulations. In Section 3, the stabilization performances of a series of alternative monetary policy rules are compared, during which interim conclusions on the role of asset price are drawn. Section 4 concludes the paper.

II. Construction and Estimation of the Model

In this section, the workhorse model for evaluating alternative monetary policy rules is developed. Towards this end, we build on the monetary policy model of Ball (1999) and Rudebusch and Svensson (1999) by allowing an explicit role for asset prices. The model has three main components: macroeconomic block, asset price block, and monetary policy block. The specification of the model is first described, and then the estimation results are reported.

A. The Model Components

The macroeconomic block of the model is a standard IS-Phillip curve model, extended to include housing and stock price inflation. This block consists of the following equations:

$$\pi_t = \alpha_1 \pi_{t-1} + \alpha_2 y_{t-1} + \alpha_3 (e_{t-1} - e_{t-2}) + \alpha_4 \pi^h_{t-1} + \alpha_5 \pi^s_{t-1} + \varepsilon_{1t} \tag{1a}$$

$$\begin{aligned} y_t = {} & \beta_1 y_{t-1} + \beta_2 y_{t-2} + \beta_3 (i_{t-1} - \pi_{t-1}) + \beta_4 e_{t-1} + \beta_5 \pi^s_{t-1} + \beta_6 \pi^s_{t-2} \\ & + \beta_7 \pi^h_{t-1} + \beta_8 \pi^h_{t-2} \varepsilon_{2t} \end{aligned} \tag{1b}$$

$$e_t = \theta_1 (i_t - \pi_t) + \theta_2 (i_{t-1} - \pi_{t-1}) + v_t \tag{1c}$$

$$v_t = \rho v_{t-1} + \varepsilon_{5t} \tag{1d}$$

Equation (1a) is an accelerationist version of the Phillips curve, in which the general price inflation (π) depends on its lag, lagged real output gap (y), and the lagged change in the real exchange rate (e). The presence of stock price inflation (π^s) and housing price inflation (π^h) in (1a) is based on the arguments of Goodhart (1995) and Alchian and Klein (1973) that asset price inflation can signal inflationary pressure on general price level.

The second equation is a standard dynamic IS-type equation, linking real output gap (y) to its own lags, lagged real exchange rate (e), lags in housing price inflation, and lagged real interest rate as the difference of nominal interest rate (i) and inflation rate. The inclusion of asset price inflation in (1b) reflects the view that hikes in asset prices may boost aggregate demand.

Equations (1c)-(1d) provide a link between real exchange rate and real interest rate. To match the observed persistence in real exchange rate, the shock (v) to the real exchange rate equation, an AR(1) process, is specified.

Regarding the asset price block, the housing price inflation is assumed depending on its past values, lags in output gap, and lagged real interest rate:

$$\pi^h_t = \gamma_1 \pi^h_{t-1} + \gamma_2 \pi^h_{t-2} + \gamma_3 y_{t-1} + \gamma_4 y_{t-2} + \gamma_5 (i_{t-1} - \pi_{t-1}) + \varepsilon_{3t} \tag{2a}$$

where the effects of real interest rate are justified by the standard asset pricing theory. The behavior of stock price inflation is specified as a simple random walk

$$\pi^s_t = \varepsilon_{4t}. \tag{2b}$$

To close the model, it is necessary to describe the behavior of the central bank. It is assumed that the central bank sets the nominal interest rate in response to the state of the economy, following some Taylor-type monetary policy rule detailed in the next subsection.

B. Estimation Results

The data series used to estimate the model spans 1980:Q1 to 2008:Q2.[2] The measure of real output is the seasonally adjusted real GDP

[2] The sources of data series are as follows: real GDP, potential GDP, GDP deflators, federal funds rate; dollar exchange rates with regard to the Euro are obtained from the data base of the Federal Reserve Bank of St. Louis. Dow Jones Industrial Average index is taken from the BOK database. Taken from the statistics warehouse of the ECB is the GDP deflator series for the Euro area

in 2000 prices. As a measure of the price level, the GDP deflator is used with the year 2000 being the base year. Nationwide housing price index is used as proxy for the housing price, and Dow Jones Industrial Average index is used for stock price. The real exchange rate series is constructed using the nominal exchange rate between the Euro and the U.S. dollar and the GDP deflator in the two economies.[3] The nominal interest rate is proxied by the federal funds rate.

To estimate the model, the series of general price inflation, stock and housing price inflation, and output gap are needed. Output gap is constructed as the log-deviation of actual GDP from the potential GDP calculated by the Congressional Budget Office. The general price and housing price inflation rates are constructed as the year-on-year rates of change to circumvent the problem of seasonality, while stock price inflation rates are calculated relative to previous periods. Therefore, to maintain consistency across the model and data, CPI and housing price inflation series are all viewed as year-on-year. All data series are de-meaned prior to estimation.

Each equation in the model is separately estimated by OLS, except that Equations (1c)-(1d) are jointly estimated by Cochrane-Orcutt iteration. The empirical counterpart of the model is given in Table 1.

In the estimated Phillips curve Equation (1a′), the contemporaneous trade-off between inflation and output gap is quite small around 0.026. Most parameters, however, are significantly estimated with expected signs. The estimated coefficient, -0.012, on the changes in real exchange rate implies that the real appreciation of dollar leads to lower inflation, although that effect is not so significant. Housing price inflation turns out to convey an early (yet insignificant) signal for general price inflation.

The estimated IS curve (1b′) shows that higher real interest rate decreases real output, while higher stock price inflation tends to increase real output. Also, higher housing price inflation tends to boost output with a one-period lag, but such effect is reversed in the fol-

over 1995:Q1-2008:Q2. The German producer price index series over 1980:Q1-1994:Q4, available from the BOK database, is splined to the Euro GDP deflator series. The nationwide housing price index is available from the office of Federal Housing Enterprise Oversight.

[3] The real exchange rate is constructed as $P_{US} \cdot NER/P_{EURO}$, where the nominal exchange rate (NER) corresponds to the units of Euro (their equivalents for 1980:Q1-1998:Q4) per U.S. dollar. Therefore, higher real exchange rates constructed mean real appreciation of the U.S. dollar.

TABLE 1

ESTIMATED MODEL[4]

Macroeconomic Equations

$$\pi_t = \underset{(45.777)}{0.905}\pi_{t-1} + \underset{(1.901)}{0.026}y_{t-1} - \underset{(-1.484)}{0.012}(e_{t-1} - e_{t-2}) + \underset{(2.399)}{0.024}\pi^h_{t-1} + \underset{[0.002]}{\varepsilon_{1t}} \quad \text{(1a}'\text{)}$$

$$y_t = \underset{(12.305)}{0.469}(y_{t-1} - y_{t-2}) - \underset{(-0.176)}{0.050}(i_{t-1} - \pi_{t-1}) - \underset{(-1.827)}{0.009}e_{t-1} + \underset{(2.357)}{0.019}\pi^s_{t-1} + \underset{(-2.161)}{0.039}\pi^s_{t-2} \quad \text{(1b}'\text{)}$$
$$+ \underset{(1.978)}{0.175}\pi^h_{t-1} - \underset{(-2.015)}{0.179}\pi^h_{t-2} + \underset{[0.007]}{\varepsilon_{2t}}$$

$$e_t = \underset{(1.920)}{0.402}(i_t - \pi_t) - \underset{(-0.386)}{0.164}(i_{t-1} - \pi_{t-1}) + v_t \quad \text{(1c}'\text{)}$$

$$v_t = \underset{(30.090)}{0.966}v_{t-1} + \underset{[0.031]}{\varepsilon_{5t}} \quad \text{(1d}'\text{)}$$

Housing Price Inflation Equation

$$\pi^h_t = \underset{(14.163)}{1.310}\pi^h_{t-1} - \underset{(-4.124)}{0.387}\pi^h_{t-2} + \underset{(1.343)}{0.162}y_{t-1} - \underset{(-1.187)}{0.144}y_{t-2} - \underset{(-1.777)}{0.038}(i_{t-1} - \pi_{t-1}) + \underset{[0.008]}{\varepsilon_{3t}} \quad \text{(2a}'\text{)}$$

$$\pi^s_t = \underset{[0.065]}{\varepsilon_{4t}} \quad \text{(2b}'\text{)}$$

Monetary Policy Rule Equation

$$i_t = \underset{(9.322)}{1.013}i_{t-1} - \underset{(-1.453)}{0.118}i_{t-2} + \underset{(2.374)}{0.209}\pi_t + \underset{(4.250)}{0.502}y_t - \underset{(-3.692)}{0.390}y_{t-1} + \underset{[0.006]}{\varepsilon_{Rt}} \quad \text{(3)}$$

Note: The numbers in parentheses are t-values of estimates, and those in square brackets are standard deviations of the disturbances.

lowing period. Contrary to economic intuition, real appreciation causes the output gap to fall, although its magnitude is not significant.

According to real exchange rate Equation (1c′), higher real interest rate leads to real appreciation in the same period as theoretically predicted. The coefficient on the lagged real exchange rate implies, however, that the initial real appreciation is followed by real depreciation of moderate magnitude in the next period.

In Equation (1d′), the estimate 0.966 of ρ implies a considerable degree of inertia in the shock to the real exchange rate, reflecting the

[4] The final specification of estimated equations is reached after experimenting with inclusion/exclusion of variables and imposing restrictions, guided by the R-bar square criterion.

observed persistence in the real exchange rate. In Equation (2a′), the housing price inflation is estimated to increase, following higher output growth in the previous period, and decrease with higher real interest rate. The estimated standard error for the stock price inflation Equation (2b′) is larger than that for the housing price inflation by the factor of 8.

Finally, the estimated monetary policy rule (3′) is an extended Taylor-type rule, under which the nominal interest rate is adjusted in response to the set of policy indicators, $X_t^{HP}=[\pi_t\, y_t\, y_{t-1}\, i_{t-1}\, i_{t-2}]'$.[5] The estimated rule states that the Federal Reserve has raised the federal funds rate in response to higher inflationary pressure reflected in inflation and real output with a considerable degree of policy inertia.

III. Evaluation of Alternative Monetary Policy

A. Methodology and Strategy

Substituting real exchange rate terms *via* Equations (1c′) and (1d′), the estimated macro economy (1′)-(2′) can be cast into a state space form

$$X_{t+1}=AX_t+Bi_t+\varepsilon_{t+1} \tag{4}$$

where A and B are matrices of the model parameters, $X_t=[\pi_t\, \pi_{t-1}\, \pi_{t-2}\, y_t\, y_{t-1}\, i_{t-1}\, i_{t-2}\, \pi^h_t\, \pi^h_{t-1} \pi^s_t\, \pi^s_{t-1}\, v_t\, v_{t-1}]'$ is the vector of state variables, and $\varepsilon_t=[\varepsilon_{1t}\, 0\, 0\, \varepsilon_{2t}\, 0\, 0\, 0\, \varepsilon_{3t}\, 0\, \varepsilon_{4t}\, 0\, 0\, \varepsilon_{5t}\, 0]'$ is the conformably constructed vector of disturbances assumed to be a multivariate white noise.[6]

Given the structure of the macro economy in (4), comparing alternative monetary policies requires a criterion by which to evaluate the performance of each policy scheme. It is assumed that the monetary authority has preferences over variabilities in the two goal variables (*i.e.*, output gap and inflation). In particular, for a discount factor $\beta\in(0, 1)$, we consider the intertemporal loss function in period t,

[5] We experimented with the inclusion of asset price inflation in the policy reaction function of the Fed, but the results were not supportive of any significant responses from the Fed toward asset prices.

[6] The forms of (A, B, Ψ) are provided in the appendix.

$$E_t\left[\sum_{\tau=0}^{\infty}\beta^{\tau}L_{t+\tau}\right] \tag{5a}$$

where the period expected loss is a weighted sum of the conditional variances

$$E_t[L_{t+\tau}]=\Phi_y \mathrm{var}_t(y_{t+\tau})+(1-\Phi_y)\mathrm{var}_t(\pi_{t+\tau}),\ 0<\Phi_y<1 \tag{5b}$$

which, in turn, can be calculated recursively given the evolution of the economy (4) and a linear feedback rule for the nominal interest rate.[7]

In subsequent policy evaluations, the five monetary policy rules summarized in Table 2 are considered. In the appendix, each of the five rules in Table 2 can be represented as a particular linear feedback instruments rule of the form $i_t=FX_t$. This being the case, the value of the loss as the infinite sum of conditional variances of the goal variables can be calculated for each rule.[8]

A few words are in order for the five rules under comparison. The rule HP (*i.e.*, historically performed) is the estimated rule in Section 2 that the Federal Reserve is believed to have implemented.[9] This rule is not likely to achieve the lower bound of the loss function (5), in that, i) the set X_t^{HP} of policy indicators for HP is, in effect, a subset of the whole state vector X_t, and that, ii) the coefficients in HP are not explicitly optimized, but fixed at their estimates. The rule UO (*i.e.*, unconstrained optimum), derived by solving the stochastic linear regulator problem (4)-(5), is the optimal rule minimizing the loss function.[10] The UO improves upon HP because the former allows the nominal interest rate to *optimally* respond to *the whole state vector* X_t, or equivalently to the vector $[\pi_t\ \pi_{t-1}\ \pi_{t-2}\ y_t\ y_{t-1}\ i_{t-1}\ i_{t-2}\ \pi^h_t\ \pi^h_{t-1}\ e_t\ e_{t-1}]'$.

In addition to the two rules above, three versions of constrained optimal rules are also considered. First, rule CO[I], minimizes loss among the rules, under which the nominal interest rate responds to X_t^{HP} only. Specifically, CO[I] differs from HP in that the former is

[7] The details involved are shown in the appendix.

[8] For practical purposes, the simple imposition of an interest rate non-negativity is regarded as non-binding. It should be noted, however, that such nonlinear constraints render our methods and results sensitive to the economy's average inflation rate, as discussed in Wolman (2006).

[9] For interpretational ease and fair comparison with other rules, the disturbance term in the estimated rule is ignored.

[10] See appendix for details on deriving the optimal rule.

TABLE 2

POLICY RULES UNDER COMPARISON

Rule	Policy Indicators	Reaction Coefficients
HP	X_t^{HP}	historical estimates
UO	X_t or $X_t^{HP} \cup \begin{Bmatrix} \pi_{t-1}, \pi_{t-2}, \\ \pi^h{}_t, \pi^h{}_{t-1}, \pi^s{}_t, \pi^s{}_{t-1} \end{Bmatrix}$	(unconstrained) minimizer of the loss
CO[I]	X_t^{HP}	(constrained) minimizer of the loss
CO[II]	$X_t^{HP} \cup \{\pi^h{}_t, \pi^h{}_{t-1}, \pi^s{}_t, \pi^s{}_{t-1}\}$	(constrained) minimizer of the loss
CO[III]	$X_t^{HP} \cup \{\pi^h{}_t, \pi^h{}_{t-1}, \pi^s{}_t, \pi^s{}_{t-1}\}$	X_t^{HP}: fixed at the historical estimates $\{\pi^h{}_t, \pi^h{}_{t-1}, \pi^s{}_t, \pi^s{}_{t-1}\}$: minimizer of the loss

equipped with optimized reaction coefficients while the latter is not. It can be readily deduced that, $\text{LOSS}_{\text{CO[I]}}$, the loss corresponding to CO[I], will lie between LOSS_{UO} and LOSS_{HP}, where the two losses are for UO and HP, respectively. Another constrained optimal rule, CO[II], minimizes loss in the class of rules that adjust the nominal interest rate in response $[\pi^h{}_t, \pi^h{}_{t-1}, \pi^s{}_t, \pi^s{}_{t-1}]$, as well as X_t^{HP}. Finally, rule CO[III] is considered, under which the nominal interest rate optimally responds to $[\pi^h{}_t, \pi^h{}_{t-1}, \pi^s{}_t, \pi^s{}_{t-1}]$, while the reaction coefficients on X_t^{HP} are fixed at their historical estimates in (3′).

Having described the features of the rules under consideration, we briefly explain the strategy for comparing the performance of these rules. We set off by comparing HP and UO, from which the firsthand idea can be obtained on the maximum possible improvements, LOSS_{HP} - LOSS_{UO}, by the optimal feedback rule.

We then examine how CO[I] compares with UO and HP. The motivation here is as follows: if CO[I] stands in comparison with the optimal rule UO, then it can be deduced that the set of historical policy indicators X_t^{HP} in CO[I] is a good proxy for the whole state vector. Therefore, *the selection of policy indicators per se* by the Federal Reserve has been satisfactory enough. From the difference between CO[I] and HP, either in the reaction coefficients or in their minimized losses, whether or not *the policy stance* reflected by the coefficients in HP was appropriate in stabilizing output and inflation can be determined.

The next piece of evaluation exercise is centered around the usefulness of asset price inflation in stabilizing the economy. This issue is addressed *via* two comparisons: CO[I] *vs*. CO[II], and HP *vs*. CO[III]. In

TABLE 3

PROPERTIES OF ALTERNATIVE MONETARY POLICY RULES

Rule	Φ_y	Coefficients												
		π_t	π_{t-1}	π_{t-2}	y_t	y_{t-1}	i_{t-1}	i_{t-2}	π^h_t	π^h_{t-1}	π^s_t	π^s_{t-1}	e_t	e_{t-1}
HP		0.209	0	0	0.502	-0.390	1.013	-0.118	0	0	0	0	0	0
UO	0	282.430	1.444	0	40.255	-14.041	-1.485	0	33.146	-12.988	1.015	1.008	-10.846	3.750
	0.25	56.664	1.054	0	33.027	19.484	-1.159	0	22.137	-14.963	1.079	2.556	-6.032	0.738
	0.5	12.275	0.289	0	15.673	12.714	-0.342	0	8.210	-6.629	0.575	1.292	-1.498	0.149
	0.75	4.052	0.093	0	11.393	10.556	-0.133	0	4.951	-4.551	0.444	0.958	-0.358	0.040
	1	1	0	0	9.380	9.380	-0.033	0	3.500	-3.580	0.380	0.796	0.180	0
CO [I]	0	31.662	0	0	1.693	4.466	-1.084	-0.294	0	0	0	0	0	0
	0.25	24.289	0	0	6.052	9.480	-0.631	-0.099	0	0	0	0	0	0
	0.5	11.579	0	0	11.163	8.683	-0.158	-0.006	0	0	0	0	0	0
	0.75	3.744	0	0	12.570	17.745	-0.343	-0.029	0	0	0	0	0	0
	1	-4.106	0	0	14.655	18.923	-0.269	-0.018	0	0	0	0	0	0
CO [II]	0	48.865	0	0	13.934	-10.619	0.985	-0.242	7.776	-4.059	1.135	-1.576	0	0
	0.25	16.136	0	0	3.838	6.497	0.100	-0.003	5.875	-4.635	0.656	-0.238	0	0
	0.5	11.447	0	0	9.429	10.756	-0.204	-0.010	4.307	-2.729	0.264	0.234	0	0
	0.75	4.236	0	0	9.528	10.149	-0.098	-0.002	4.065	-3.631	0.384	0.655	0	0
	1	0.852	0	0	10.180	9.940	-0.051	-0.001	3.770	-3.912	0.408	0.975	0	0
CO [III]	0	0.209	0	0	0.502	-0.390	1.013	-0.118	3.676	-2.509	0.471	-0.240	0	0
	0.25	0.209	0	0	0.502	-0.390	1.013	-0.118	3.799	-3.594	0.159	0.059	0	0
	0.5	0.209	0	0	0.502	-0.390	1.013	-0.118	4.201	-3.972	0.160	0.131	0	0
	0.75	0.209	0	0	0.502	-0.390	1.013	-0.118	4.081	-3.787	0.136	0.218	0	0
	1	0.209	0	0	0.502	-0.390	1.013	-0.118	4.097	-3.772	0.095	0.304	0	0

the former, the focus is on gauging how useful the asset price inflation is if the central bank is already optimally responding to the variables in X_t^{HP} by following CO[I]. In the latter comparison, the purpose is to see by how much asset price inflation further stabilizes inflation and output, on top of what the historical policy stance has already achieved.

B. Comparison I: HP vs. UO

The results of policy evaluations are provided in Table 3 and Table 4. Table 3 summarizes the policy reaction coefficients of the rules, where five different preferences over the policy goal are considered if applicable. In Table 4, minimized losses and volatilities of the two goal variables are reported.

The first row of Table 3, labeled HP, replicates the estimated rule. The next five rows concern the optimized rule UO for Φ_y=(0, 0.25, 0.50, 0.75, 1). The reaction coefficients for the two rules exhibit several features detailed below.

TABLE 4
VOLATILITIES UNDER ALTERNATIVE POLICY RULES

Weight	Volatility	Rule				
		HP	UO	CO[I]	CO[II]	CO[III]
$\Phi_y=0$	Total[1)]	**0.2900**	**0.0381**	**0.0635**	**0.0418**	**0.0699**
	y[2)]	1.0443	0.7618	0.7542	0.7647	0.7581
	π[3)]	0.2900	0.0381	0.0635	0.0418	0.0699
$\Phi_y=0.25$	Total	**0.5794**	**0.3196**	**0.3220**	**0.3206**	**0.3252**
	y	1.0443	0.5377	0.5365	0.5377	0.5415
	π	0.2900	0.1995	0.2057	0.2017	0.2080
$\Phi_y=0.50$	Total	**0.7664**	**0.3606**	**0.3623**	**0.3612**	**0.3673**
	y	1.0443	0.3471	0.3480	0.3455	0.3597
	π	0.2900	0.3736	0.3760	0.3761	0.3747
$\Phi_y=0.75$	Total	**0.9160**	**0.3084**	**0.3100**	**0.3085**	**0.3204**
	y	1.0443	0.1779	0.1818	0.1772	0.2051
	π	0.2900	0.5345	0.5342	0.5353	0.5332
$\Phi_y=1$	Total	**1.0443**	**0.0716**	**0.0850**	**0.0718**	**0.1264**
	y	1.0443	0.0716	0.0850	0.0718	0.1264
	π	0.2900	0.6831	0.6794	0.6827	0.6800

Notes: Losses and volatilities are calculated for $\beta=0.99$.
1) Square root of the minimized loss.
2) Square root of the discounted sum of the conditional variance of output gap.
3) Square root of the discounted sum of the conditional variance of inflation.

First, while HP is characterized by a considerable degree of inertia in adjusting the nominal interest rate, the five versions of UO are not. Specifically, the long-run AR coefficient on the nominal rate for HP amounts to 0.895, but those for UO range below zero. This suggests that the Federal Reserve may have been overly inertial in adjusting nominal interest rate, responding too smoothly to changes in economic conditions.

Second, optimal adjustments of the federal funds rate require much more aggressive responses toward contemporaneous inflation and output gap. For example, the contemporaneous response coefficients for inflation and output gap under HP are 0.209 and 0.502, respectively. However, corresponding numbers under UO are 12.275 and 15.673, respectively, when the Federal Reserve gives equal weight to volatilities in inflation and output.

Third, the optimal conduct of monetary policy requires the Federal

Reserve to respond to asset price inflation, although the degrees of responses are smaller than those directed toward price inflation and output gap. For example, the sum of coefficients on housing price inflation is 5.847 on average, lower than 71.861 for price inflation and 29.564 for output gap. The sum of coefficients on stock price inflation is 2.021, smaller than on housing price inflation. This feature is reminiscent of Brainard (1967), who recommended extra caution in responding to more volatile, hence uncertain, movements in stock price inflation.

It is worthwhile to see how differences in the two rules are reflected in their stabilization performance. The two columns labeled HP and UO in Table 4 show that UO *does* improve upon the historical rule HP. On average, total volatility under HP is 3.270 times as high under UO. Even when the Federal Reserve is solely concerned with output stabilization, putting $\Phi_y = 1$, the volatility of inflation under UO is lower than that under HP.

From the comparison results in this subsection, the first interim conclusion can be drawn: by responding to a larger set of policy indicators and taking a reaction scheme more aggressive yet less inertial than the historical one, the Federal Reserve could have achieved a much higher degree of stabilization.

C. Comparison II: CO[I] vs. UO & HP

The next task is to delve into the reason why UO outperforms HP: is it because UO responds to a larger set of policy indicators, or because UO takes a policy stance inherently different from the historical counterpart? To answer this question, UO is compared with CO[I]. The intuition here is: the closer CO[I] is to UO, the more likely it is that UO outperforms HP, not due to additional policy indicators, but owing to the better stabilizing adjustment scheme for nominal interest rate.

The results for CO[I] in Table 3 show that, once the Federal Reserve revises its historical policy stance for better stabilization, the resulting rule exhibits a resemblance to the unconstrained optimal rule UO. For example, as under UO, response coefficients on inflation and output gap under CO[I] are much higher than those under HP. Again, as under UO, the nominal interest rate is not subject to too much inertia.

In terms of policy performance, the proximity of CO[I] to UO is more conspicuous. A casual look at the columns for UO and CO[I] in Table 4 confirms that the performance of the two rules are very similar, especially for modest weights on output volatility. The interpretation of this finding is that, even if the central bank is constrained to use the historical policy indicators in X_t^{HP} only, an appropriate policy stance can ensure close-to-optimal stabilization results.

Results in this subsection posit the second interim conclusion: had the Federal Reserve responded to its historical policy indicators differently, it could have conducted a near-optimal policy rule, even without taking into account the movements in asset prices.

D. Comparison III: CO[I] vs. CO[II], and HP vs. CO[III]

From the results thus far, a direct question rises: once the policy stance with respect to other variables (especially those in X_t^{HP}) are taken appropriately, how much extra information does asset price inflation have for further stabilization? This question is addressed by comparing CO[I] and CO[II]. In Table 3, reaction coefficients of the two rules are quite similar, setting aside those for asset price inflation. In Table 4, the stabilization performance of the two rules are almost impossible to distinguish. This suggests that, as long as the Federal Reserve responds appropriately to its historical policy indicators, not much additional stabilization gains are obtained from additionally responding to asset price inflation.

Another question that remains is: if the central bank commits itself to the historical policy scheme toward X_t^{HP}, how useful would asset price inflation be in the conduct of monetary policy? The answer to this question is found by comparing HP and CO[III]. In Table 3, the central bank in such a situation would have to change the nominal rate actively in response to asset price inflation. Interestingly, the magnitudes of responses toward stock price inflation are much smaller than those concerning housing price inflation, similar for UO. More interesting is that the performance of CO[III] is comparable to CO[I]. This provides another interim conclusion for this subsection: the Federal Reserve could also have achieved close-to-optimal stabilization results by properly responding to movements in asset prices on top of its historical policy scheme.

E. Comparison IV: Which Asset Price to Respond to?

The final question addressed now is: which asset price should the Federal Reserve choose for better stabilization results? In other words, which asset price contains more useful information for the Federal

TABLE 5
VOLATILITIES UNDER CONSTRAINED POLICY RULES

Weight	Volatility	Rule		
		CO[III]	CO[III]-S	CO[III]-H
$\Phi_y=0$	Total[1]	**0.0699**	**0.1087**	**0.0792**
	y[2]	0.7581	0.7573	0.7462
	π[3]	0.0699	0.1087	0.0791
$\Phi_y=0.25$	Total	**0.3252**	**0.3375**	**0.3284**
	y	0.5415	0.5573	0.5745
	π	0.2080	0.2198	0.1838
$\Phi_y=0.50$	Total	**0.3673**	**0.3825**	**0.4231**
	y	0.3597	0.3842	0.5652
	π	0.3747	0.3807	0.1963
$\Phi_y=0.75$	Total	**0.3204**	**0.3435**	**0.4990**
	y	0.2051	0.2491	0.5648
	π	0.5332	0.5347	0.1979
$\Phi_y=1$	Total	**0.1264**	**0.1915**	**0.5648**
	y	0.1264	0.1915	0.5648
	π	0.6800	0.6778	0.1985

Notes: 1) Square root of the minimized loss.
2) Square root of the discounted sum of the conditional variance of output gap.
3) Square root of the discounted sum of the conditional variance of inflation.

Reserve trying to stabilize the economy? To answer this question, two variants of CO[III] are compared. The first one, CO[III]-S, allows the Federal Reserve to optimally respond to stock price inflation only while the reaction coefficients on X_t^{HP} are fixed at their historical estimates. Similarly, the second variant, CO[III]-H, requires optimal responses to housing price inflation only. Stabilization results of the two rules are reported in Table 5. Unless the Federal Reserve is solely concerned with stabilizing inflation, CO[III]-S outperforms CO[III]-H. A direct interpretation of this finding is that stock price inflation contains more useful information that helps stabilize the economy further than does housing price inflation. Responding to movements in stock price, therefore, can be a firsthand shortcut for the Federal Reserve in improving its stabilization performance.

IV. Conclusion

This paper provides an empirical investigation tailored for the U.S. economy on the role of asset prices in the conduct of monetary policy. We constructed an empirical model, simulated the estimated model with a set of alternative monetary policy rules, and compared the stabilization performance of the rules against a performance metric comprising weighted averages of variabilities in output gap and inflation.

Comparison results among alternative interest rate rules cast some light on the question, "Should the Federal Reserve have reacted to the fluctuations in asset prices for better stabilization performances?" The findings are summarized as follows: First, by responding to a larger set of policy indicators and taking a more aggressive stance toward inflation and output gap compared to the historical indicator, the Federal Reserve could have achieved a much higher degree of stabilization. Second, had the Federal Reserve responded to its historical policy indicators differently, it could have conducted a near-optimal policy rule, even without taking into account the movements in housing and stock prices. Third, the Federal Reserve could also have achieved close-to-optimal stabilization results by properly responding to movements in asset prices, on top of its historical policy scheme. Finally, stock price inflation contains more useful information that helps further stabilize the economy than does housing price inflation.

Future research may help increase our understanding of housing price and monetary policy, as the results are rather tentative at the current stage. First of all, the results are based on the model in this paper which, along many dimensions, is quite simple and limited. In particular, resorting to purely backward-looking specifications of key structural equations, the results obtained should be interpreted subject to a caution in the spirit of the Lucas critique. Along another dimension, the issue of monetary policy and asset prices may be better understood if the role of financial market fragility is incorporated into the model and empirically examined.

Another key issue to address in future research is whether the monetary authority should respond in any way to asset price *bubbles*, as discussed in Filardo (2004) for example. A more sophisticated approach that can address these issues is left for future research.

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Appendix I. Derivation of the Optimal Rule UO

The problem is how to choose a decision rule for i_t that minimizes

$$E_t \sum_{\tau=0}^{\infty} \delta^t \{X'_{t+\tau} R X_{t+\tau}\},\ 0 < \delta < 1$$

subject to the law of motion

$$X_{t+1} = AX_t + Bi_t + \varepsilon_{t+1}, \tag{A1}$$

where $Y_t = \begin{bmatrix} y_t \\ \pi_t \end{bmatrix}$, $C = \begin{bmatrix} e_4 \\ e_1 \end{bmatrix}$, $K = \begin{bmatrix} \Phi_y & 0 \\ 0 & 1-\Phi_y \end{bmatrix}$, $R = C'KC$, e_1 and e_4 denote 1×11 row vectors whose elements are all 0s, with the first and fourth elements being 1, respectively.

As in Ljungqvist and Sargent (2000), the optimal instrument rule is the vector F that satisfies

$$F = -(B'PB)^{-1} B'PA, \tag{A2}$$

where the matrix P solves the Ricatti equation

$$P = -R + \delta A'PA - \delta^2 A'PB(\delta B'PB)^{-1} B'PA. \tag{A3}$$

When actually solving for P, the RHS of (A3) is used to get an updated P in the LHS in a recursive manner, starting with $P_0 = -R$.

The optimal rule described above may appear infeasible, prescribing the nominal interest rate as a linear function of the state vector X_t that contains unobservable v_t and v_{t-1}. As shown in Appendix [III], however, the optimal rule can be translated into an equivalent rule in which the nominal rate responds to Z_t.

Appendix II. Calculation of the Loss Function

Calculating the value of loss function for a rule of the form $i_t = FX_t$ is now explained. Plugging in the rule into the state space representation of the economy, we get

$$X_t = MX_{t-1} + \varepsilon_t, \text{ with } M = A + BF$$

Given the covariance matrix Σ^{ε} of the white noise error term ε_t, the conditional variance Σ_t^X of X_t evolves as

$$\Sigma_{t+1}^X = M \Sigma_t^X M' + \Sigma^{\varepsilon},\ t \geq 0 \tag{A4}$$

where we assume $\Sigma_o^X = 0_{11\times 11}$.

From the relationship $Y_t = C'X_t$, the conditional variance matrix Σ_t^Y for the goal variable vector Y_t is given by

$$\Sigma_t^Y = C' \Sigma_t^X C, \tag{A5}$$

from which values of the period losses are easily calculated. Recursive use of (A4) and (A5) and summing up the discounted period losses yield the results wanted.

Appendix III. (A, B, Ψ) Matrices

$$A=\begin{bmatrix}
\alpha_1-\alpha_3\theta_1 & -\alpha_3(\theta_2-\theta_1) & \alpha_3\theta_2 & \alpha_2 & 0 & \alpha_3(\theta_2-\theta_1) & -\alpha_3\theta_2 & \alpha_4 & 0 & 0 & 0 & \alpha_3 & -\alpha_3 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\beta_3-\beta_4\theta_1 & -\beta_4\theta_2 & 0 & \beta_1 & \beta_1 & \beta_4\theta_2 & 0 & \beta_7 & \beta_8 & \beta_5 & \beta_6 & \beta_4 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\gamma_5 & 0 & 0 & \gamma_3 & \gamma_4 & 0 & 0 & \gamma_1 & \gamma_2 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
\end{bmatrix}$$

$$B=\begin{bmatrix} \alpha_3\theta_1 \\ 0 \\ 0 \\ \beta_3+\beta_4\theta_1 \\ 0 \\ 1 \\ 0 \\ \gamma_5 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \qquad \varepsilon_t=\begin{bmatrix} \varepsilon_{1,t+1} \\ 0 \\ 0 \\ \varepsilon_{2,t+1} \\ 0 \\ 0 \\ 0 \\ \varepsilon_{3,t+1} \\ 0 \\ \varepsilon_{4,t+1} \\ 0 \\ \varepsilon_{5,t+1} \\ 0 \end{bmatrix}$$

References

Alchian, A., and Klein, B. "On a Correct Measure of Inflation." *Journal of Money, Credit, and Banking* 5 (No. 1 1973): 173-91.

Ball, Laurence. "Policy Rules for Open Economies." In John B. Taylor (ed.), *Monetary Policy Rules.* Chicago: University of Chicago Press, 1999.

Bean, Charles R. "Asset Prices, Financial Imbalances and Monetary Policy: Are Inflation Targets Enough?" In Anthony Richards and Tim Robinson (eds.), *RBA Annual Conference Volume.* Asset Prices and Monetary Policy Reserve Bank of Australia, 2003.

Bernanke, Ben, and Gertler, Mark. "Monetary Policy and Asset Price Volatility." *Economic Review,* Federal Reserve Bank of Kansas City (Fourth Quarter 1999): 17-51.

__________. "Should Central Banks Respond to Movements in Asset Prices?" *American Economic Review Papers and Proceedings* 91 (No. 2 2001): 253-7.

Bordo, M., and Jeanne, O. Boom-Busts in Asset Prices, Economic Instability, and Monetary Policy. NBER Working Paper No. 8966, May, 2002.

Borio, C., and Lowe, P. Asset Prices, Financial and Monetary Stability: Exploring the Nexus. Paper Presented at the BIS Conference on Changes in Risk through Time: Measurement and Policy Options, BIS Working Papers No. 114, July, 2002.

Brainard, William. "Uncertainty and the Effectiveness of Policy." *American Economic Review Papers and Proceedings* 57 (No. 2 1967): 411-25.

Cecchetti, Stephen G., Genberg, Hans, Lipsky, John, and Wadhwani, Sushil. *Asset Prices and Central Bank Policy*. London: International Center for Monetary and Banking Studies, 2000.

Eitrheim, Øyvind. Discussion of 'Asset Price Bubbles and Monetary Policy: A Multivariate Extension.' by Andew Filardo, in Workshop on 'Fundamental and Non-Fundamental Asset Price Dynamics: Where do We Stand?' Venastul, February 14-15, 2008.

Filardo, Andrew J. "Asset Prices and Monetary Policy." *Economic Review,* Federal Reserve Bank of Kansas City (Third Quarter 2000): 11-37.

__________. Monetary Policy and Asset Price Bubbles: Calibrating the Monetary Policy Trade-Offs. BIS Working Paper No. 155, June, 2004.

Goodhart, Charles A. "Price Stability and Financial Fragility." In Charles A. Goodhart (ed.), *The Central Bank and the Financial System.* Cambridge: MIT Press, 1995.

Ljungqvist, Lars, and Sargent, Thomas J. *Recursive Macroeconomic Theory*. Cambridge: MIT Press, 2000.

Rudebusch, Glenn D., and Svensson, Lars E. O. "Policy Rules for Inflation Targeting." In John B. Taylor (ed.), *Monetary Policy Rules*. Chicago: University of Chicago Press, 1999.

Wolman, Alexander L. "The Zero Bound and the Term Structure in a Nonlinear Macroeconomic Model." *Seoul Journal of Economics* 19 (No. 1 2006): 147-70.