Asset Prices and Monetary Policy

Ichiro Fukunaga and Masashi Saito

How should central banks take into account movements in asset prices in the conduct of monetary policy? We provide an analysis to address this issue using a dynamic stochastic general equilibrium model incorporating both price rigidities and financial market imperfections. Our findings are twofold. First, in the presence of these two sources of distortion in the economy, central banks face a policy trade-off between stabilizing inflation and the output gap. With this trade-off, central banks could strike a better balance between both objectives if they took variables other than inflation, such as asset prices, into consideration. Second, these benefits decrease when central banks rely on limited information about the underlying sources of asset price movements and cannot judge which part of the observed asset price movements reflects inefficiencies in the economy.

Keywords: Asset prices; Monetary policy; Financial frictions; Policy trade-offs
JEL Classification: E44, E52

Ichiro Fukunaga: Research and Statistics Department, Bank of Japan (E-mail: ichirou.fukunaga@boj.or.jp)
Masashi Saito: Research and Statistics Department, Bank of Japan (E-mail: masashi.saitou@boj.or.jp)

This paper draws on Fukunaga and Saito (2008) and was written when the authors were affiliated with the Institute for Monetary and Economic Studies, Bank of Japan (BOJ). The authors would like to thank Henrik Jensen, Tomoyuki Nakajima, Kunio Okina, and seminar participants at the 2007 Central Bank Workshop on Macroeconomic Modeling and the BOJ for comments and suggestions. Views expressed in this paper are those of the authors and do not necessarily reflect the official views of the BOJ.

I. Introduction

Large swings in asset prices accompanied by economic disruption have frequently taken place in many countries, including Japan. In turn, central banks have often concerned themselves with how they should take into account movements in asset prices—comprising stock, land, and housing prices—in the conduct of monetary policy. Currently, price stabilization is explicitly the central objective of monetary policy, with measures for attaining it enhanced in many countries. However, central bankers have never reached consensus on the question of how monetary policy can best deal with movements in asset prices.

In this paper, we theoretically analyze this issue using a dynamic stochastic general equilibrium (DSGE) model. Rather than drawing a solid conclusion from a specific episode, our objective is to promote a more generally applicable understanding that will help us to organize the various views on how and under what conditions monetary authorities may benefit from taking movements in asset prices into account. In this context, we consider that our analysis serves as a complement to Okina and Shiratsuka (2002) and their review of the Japanese experience of the asset price boom and bust in the 1980s.

One advantage of DSGE models is that they allow us to compare the performance of alternative monetary policy rules in various economic environments. The model employed in this paper describes an economic environment where distortions in economic activity arise from two sources: frictions in price setting and financial market imperfections. Using a model including these realistic features, we can compare the performance of alternative monetary policy rules.

We base our analysis primarily on Gilchrist and Saito (2008), who consider the role of asset prices in monetary policy using a model incorporating both financial market imperfections and price-setting frictions.[1] In this paper, we flesh out how a monetary policy trade-off arises in the presence of financial market imperfections. Our analysis delivers two main findings similar to Gilchrist and Saito (2008). First, in the presence of financial market imperfections, economic welfare—measured *a priori* by the weighted average of the variances of the output gap and inflation—may improve when the central bank explicitly responds to asset prices in their monetary policy rule. This benefit could arise because in the model we consider, movements in asset prices closely relate to distortions in the economy arising from the financial market imperfections.[2] Second, these benefits are likely to decrease when the central bank relies on limited information about the underlying sources of asset price movements.

The paper is structured as follows. Section II provides a preliminary investigation of the role of monetary policy in dealing with economic distortions. We proceed in a systematic fashion by incorporating multiple sources of distortions. These include price and wage rigidities and financial market imperfections. We then discuss the

1. Bernanke and Gertler (1999) and Gilchrist and Leahy (2002) conduct a similar analysis using the "financial accelerator" model in Bernanke, Gertler, and Gilchrist (1999). More specifically, Bernanke and Gertler (1999) discuss bubbles in asset prices, while Gilchrist and Leahy (2002) shed light on the role of shocks to expectations by the private sector about future technology growth and the net worth of entrepreneurs.
2. Our model assumes a closed economy and does not consider exchange rate movements and foreign distortions.

importance of the central bank's information regarding the underlying mechanism and shocks behind the observed asset price developments when the central bank explicitly takes asset prices into account. In Section III, we apply a model incorporating financial market imperfections (a variant of the "financial accelerator" model) to illustrate the potential benefits and costs of monetary policy that explicitly responds to asset prices. Section IV concludes.

II. Distortions in Economic Activity and the Role of Monetary Policy

This section provides background to our main analysis in the following section. In particular, we describe several sources of distortion in economic activity and the role of monetary policy in attenuating these distortions. We also sketch out the bare bones of the financial accelerator model used in Section III.

A. Sources of Distortions in Economic Activity

How can monetary policy improve social welfare? A theoretical response to this broad question relies on the following: what factors give rise to distortions in economic activity, what economic variables closely relate to these distortions, and to what extent can we use monetary policy to deal with these distortions. In the model in the following section, we consider an environment where a monetary authority faces two types of short-run distortions to resource allocation: price stickiness and financial market imperfections. We find that it may be possible for central banks to better deal with both types of distortions through systematically responding to movements in asset prices, in addition to the more standard variables (i.e., inflation), when these movements are closely related to the distortions arising from financial market imperfections.

To confirm this argument, we first explain how distortions to resource allocation arise in the presence of frictions in price setting by firms. Many studies based on DSGE models assume similar frictions. We then consider frictions in setting nominal wages and the resulting stickiness in nominal wages as additional factors that give rise to distortions in the economy. With these factors in mind, we discuss how monetary policy should deal with multiple sources of distortions arising from stickiness in both goods prices and nominal wages.[3] Finally, we incorporate in the model financial market imperfections arising from asymmetric information between lenders and borrowers in financial markets, and discuss how movements in asset prices reflect distortions in economic activity from this particular type of friction.

1. Distortions from price-setting friction

Price stability is an explicit primary objective of monetary policy in many countries, and regarded as a prerequisite for sustainable economic growth. Once price stability is lost, distortions in resource allocation could arise from the outright loss of economic resources because of increased price volatility, the inefficient dispersion of relative

3. In fact, our model abstracts from stickiness in nominal wages. We consider this type of friction here to describe the policy problem in the presence of two types of friction.

prices among various goods and services, and greater uncertainty regarding the future price level.[4] Many DSGE models assume that only a fraction of firms can adjust the prices of their products in a certain period and consider the resulting welfare impact of price dispersion across firms. When some firms cannot adjust their prices, fluctuations in the general (aggregate) price level may also give rise to dispersion in relative prices across producers. These dispersions in relative prices may then not reflect economic fundamentals in terms of the balance of supply and demand in the markets for goods and services, and therefore lead to short-run distortions in the economy. In addition, when firms have monopoly power in a segmented market, firms set prices above marginal costs and the level of production could be below that achieved under perfect competition. This type of distortion could remain over a longer period where the real effects of monetary policy have completely tapered off. Importantly, monetary policy can only deal with the short-run distortions arising from price stickiness. This would suggest that other policies, such as fiscal policy, should take responsibility for dealing with the long-run distortions from monopolistic competition.

In standard models with price-setting friction, the welfare loss function for the economy depends on the fluctuations in both inflation and the output gap.[5] In this paper, we define the output gap as the difference between the *equilibrium* (or actual) output (the level of output in the presence of price rigidities and market power by firms) and the *efficient* output (the level of output that can be achieved under an efficient allocation of resources in a hypothetical economy with flexible prices and perfect competition). As a comparison, several studies define the output gap as that between actual and *natural* output (the level of output when prices are flexible with monopolistically competing firms). When price stickiness is the only source of short-run distortion in the economy, the gap between efficient and natural output exactly matches the long-run distortion arising from monopolistic competition and does not vary over time.[6] In this case, the two types of gap—that is, deviations from (1) the natural level and (2) the efficient level—always move together, and the desirable monetary policy actions to maximize welfare coincide under both definitions.

Under the standard assumptions of price stickiness, and when no other factors give rise to short-run distortion, the following New Keynesian Phillips curve describes the (short-run) relationship between inflation and the output gap (defined here as the gap between actual and natural output):

$$\pi_t = \kappa(y_t - y_t^n) + \beta E_t \pi_{t+1}, \tag{1}$$

where π_t is inflation in period t, $E_t\pi_{t+1}$ is the expectation of inflation in period $t+1$ conditional on the information available in period t, y_t and y_t^n are actual and natural

4. A direct loss of resources may arise due to menu costs in price adjustment or "shoe leather costs" in the presence of fluctuations in prices and nominal interest rates (the opportunity cost of holding money).

5. See Woodford (2003).

6. The gap between actual and natural output relates to the markup (the gap between prices and marginal costs). As shown in the next section, we can decompose the output gap into two components: (1) the gap between efficient and natural output, and (2) the gap between natural and actual output. The former represents long-run distortions from market power of firms and is constant over time in the simple environment considered here. The latter represents the short-run distortions arising from frictions in price setting by firms and varies over time.

output (expressed as the percentage deviation from the output level along a balanced growth path), and κ and β are parameters that take positive values ($\beta < 1$).

Equation (1) indicates that it is possible to stabilize the gap between actual and natural output by stabilizing inflation (when both π_t and $E_t\pi_{t+1}$ are set to zero, the gap between y_t and y_t^n disappears). A few kinds of shocks, including the technology shocks we consider in the next section, affect both natural and efficient output. The gap between them, however, remains constant in the simple environment that we assume for the moment, and equation (1) holds, even when efficient output y_t^e replaces natural output y_t^n. In this case, monetary policy that stabilizes inflation can also stabilize the gap between actual and efficient output.

When there are shocks that affect the gap between efficient and natural output (such as one that changes the market power of firms), replacing y_t^n with y_t^e in equation (1) introduces an exogenous shock term u_t in the Phillips curve and changes (1) to

$$\pi_t = \kappa(y_t - y_t^e) + \beta E_t\pi_{t+1} + u_t. \tag{2}$$

When the shock u_t is included, as shown in (2), a monetary policy that stabilizes inflation cannot completely stabilize the output gap (the gap between actual and efficient output). Setting π_t and $E_t\pi_{t+1}$ to zero would then not necessarily result in a zero gap between y_t and y_t^e because of the presence of the term u_t. In this case, a central bank faces a trade-off between stabilizing inflation and stabilizing the output gap.[7]

2. Distortions from wage-setting friction

Several studies consider frictions in wage setting (some wages do not fully adjust in each period) in addition to the frictions in price setting considered above. In this case, there are two kinds of short-run distortions in resource allocation: one from frictions in setting wages and the other from frictions in setting prices. In addition to these short-run distortions, there are also two kinds of long-run distortion: one arising from the market power of households in setting wages and the other from the presence of market power in the firms setting prices.

In the presence of both price and wage rigidities, the following equations describe the relationship between price inflation, nominal wage inflation, the gap between actual and natural output, and the gap between the actual and natural level of real wages:

$$\pi_t = \kappa^p(y_t - y_t^n) + \xi^p(w_t - w_t^n) + \beta E_t\pi_{t+1}, \tag{3}$$

$$\pi_t^w = \kappa^w(y_t - y_t^n) + \xi^w(w_t - w_t^n) + \beta E_t\pi_{t+1}^w, \tag{4}$$

where w_t is the *equilibrium* (or *actual*) level of real wages (defined as the level of real wages in the presence of both frictions), w_t^n is the *natural* level of real wages (defined as real wages in a hypothetical economy with no rigidities in both prices and wages), π_t^w is nominal wage inflation (the rate of inflation in the equilibrium/actual level of nominal wages), and κ^p, ξ^p, κ^w, and ξ^w are positive parameters.

7. The model in the next section does not include this type of shock. However, we show that a monetary policy trade-off emerges in the presence of financial market imperfections, even when we abstract from the shock u_t.

In the presence of both frictions, a policy that fully stabilizes inflation does not ensure elimination of the gap between actual and natural output. This is because a policy that fully stabilizes inflation does not ensure a zero gap between actual and natural wages ($w_t - w_t^n$), and this is related to economic distortions arising from wage-setting frictions. In this case, setting π_t and $E_t \pi_{t+1}$ to zero does not necessarily ensure a zero gap between y_t and y_t^n, as we can see from equation (3).[8]

Even if both types of friction coexist in the economy described above, monetary policy can still manage the distortions in the economy by stabilizing the weighted average of price and nominal wage inflation (Erceg, Henderson, and Levin [2000]). More formally, the objective function of monetary policy (or the welfare loss function of the economy) in this case depends on the variance of price inflation, wage inflation, and the output gap. By defining "broadly defined inflation" as the weighted average of price and wage inflation, we can write the welfare loss function in terms of the variance of broadly defined inflation and the output gap.[9] In this case, central banks can achieve a zero gap between actual and natural output by stabilizing the broadly defined inflation rate. Moreover, when we abstract from exogenous shocks to the Phillips curve, the gap between efficient and natural output is constant over time. As a result, a policy that fully stabilizes broadly defined inflation can also stabilize the output gap (the gap between actual and efficient output).

We could also envision the case where real wages, rather than nominal wages, cannot flexibly adjust due to imperfections in the labor market. In the presence of rigidities in real wages, the gap between efficient and natural output is no longer constant and varies in response to shocks to the economy (Blanchard and Gali [2007]). In this case, the monetary authority faces a trade-off between stabilizing inflation and the output gap; that is, a policy that sets inflation (or a composite of price and wage inflation) to zero can stabilize the gap between actual and natural output, but not necessarily remove the output gap (the gap between actual and efficient output). In these cases, the objective function of monetary policy may take a more complex form than the simple case and may include variables other than inflation and the output gap. Moreover, economic welfare may improve when the monetary authority takes into account movements in real variables (such as unemployment) in addition to inflation, because these closely relate to distortions arising from labor market frictions (Blanchard and Gali [2009]).

In general, one policy instrument (for instance, nominal interest rates) is not sufficient to simultaneously deal with multiple short-run distortions. A policy that eliminates one type of distortion does then not necessarily eliminate other distortions at the same time. In the presence of multiple sources of distortion in economic activity, it is desirable to adopt a policy that strikes an appropriate balance between them. The model in the following section does not consider real wage rigidities or other forms of labor market friction. Instead, it incorporates financial market imperfections as an additional source of short-run distortion in economic activity alongside distortions arising from price-setting friction.

8. For simplicity, we assume that there is no exogenous shock to the Phillips curve (like u_t in equation [2]) and that the gap between efficient and natural level of output is constant over time.

9. By defining a broadly defined inflation rate, we can combine equations (3) and (4) and write them as a single equation with the same form as equation (1).

3. Distortions from financial market imperfections

Many existing dynamic general equilibrium models assume an economy with a complete financial market where there is little interaction between asset prices and real economic activity.[10] However, in the presence of financial market imperfections, richer dynamics (generally acknowledged as the financial accelerator mechanism) emerge.

In the absence of financial market imperfections, households and firms view all sources of funds as perfect substitutes.[11] In reality, however, transaction costs, taxes, and other structural factors (such as the asymmetric information between lenders and borrowers and limited commitment in financial contracts) may create differences in the costs and availability of the various financing sources. As a result, financing decisions may affect the spending behavior of both households and firms.

In the presence of financial market imperfections arising from asymmetric information or limited commitments in financial contracts, households and firms may incur additional costs in raising funds externally (borrowing from a bank or issuing corporate bonds) and, in some cases, external financing may be restricted. In at least some circumstances, collateral value or the net worth of the borrowers may determine these additional costs or the availability of external funding. In particular, when for some reason the value of the borrower's balance sheet falls, they face higher external financing premiums. In these cases, shocks that affect the financial positions of households and firms may have an additional impact on their spending behavior by affecting the costs of external financing or by directly limiting the availability of external funds.

Consequently, financial market imperfections may amplify the effects of shocks on real economic activity relative to the case of perfect financial markets (where the cost or availability of external funds does not depend on the balance sheet conditions of households and firms). This amplified response by the economy to shocks reflects distortions in economic activity induced by the presence of financial market imperfections (more fundamentally, distortions resulting from asymmetric information or limited commitments in financial contracts). In addition to those short-run distortions in economic activity, financial market imperfections also give rise to long-run distortions similar to the case of monopolistic competition in the goods market. Monetary policy cannot fully offset these long-run distortions, and so there may be a need for other policies, like prudential and fiscal policies. In the presence of both financial market imperfections and price stickiness, the monetary authority may need to aim at dealing with multiple short-run distortions arising from both types of friction.

In theory, the objective function of monetary policy (or the welfare loss function) in an economy with financial market imperfections may include variables other than inflation and the output gap (the gap between the actual and efficient output).[12] As the

10. For instance, the relationship between Tobin's Q and firm investment and the wealth effects on household consumption, considered even in a model with a complete financial market, do not themselves generate richer dynamics than they do in a model with an incomplete financial market.

11. In such cases, the value of a firm does not depend on its capital structure (the Modigliani-Miller Theorem).

12. In the environment considered here, *efficient* output is the level of output in the absence of financial market imperfections and price rigidities. *Natural* output, on the other hand, is the level of output in the presence of financial market imperfections but in the absence of price rigidities. *Equilibrium* (or *actual*) output is then the level of output in the presence of both financial market imperfections and price rigidities. The gap between efficient and natural output reflects both short-run distortions from financial market imperfections and long-run

formal welfare loss function in an economy with financial market imperfections has not been discussed thoroughly in existing work, we assume *a priori* that it depends on the variance of inflation and the output gap. In other words, we assume that the welfare loss function takes the same form where financial markets are perfect.[13] However, even if we assume the same objective function as with no financial market imperfections, the desirable form of monetary policy may vary. In particular, we need to bear in mind that in the presence of financial market imperfections, a policy that aims at minimizing distortions arising from price rigidities may not be the best policy to deal with the distortions from financial market imperfections. Monetary policy may then face a trade-off between stabilizing inflation and the output gap because of its overcapacity in coping with multiple short-run distortions with a single policy instrument. Moreover, when the movements in asset prices closely relate to the distortions in economic activity arising from financial market imperfections it may be desirable for the monetary authority to take account of these when making decisions on monetary policy. We stress that this argument remains, even if the stabilization of asset prices were not explicitly included in the objective function of monetary policy (or the welfare loss function of the economy).[14]

We now briefly describe how we incorporate financial market imperfections into our model, primarily based on Bernanke, Gertler, and Gilchrist (1999). The model assumes asymmetric information between borrowers (entrepreneurs) and lenders. We assume the lenders pay nonzero costs to audit the borrower's ability to repay the funds lent.[15] The key implication of financial market imperfections is that the premium on external funds (the difference between the cost of funds raised externally and the opportunity cost of internal funds) depends inversely on the net worth of borrowers,

$$\frac{E[R^K]}{R} = s\left(\frac{N}{K}\right), \quad s'(\cdot) < 0, \tag{5}$$

where R^K is the rate of return on borrowers' capital and R is the rate of return on risk-free assets. As the expected rate of return on capital is equal to the cost of external funds in equilibrium, the left-hand side of (5) represents the external finance premium

distortions arising from the market power of firms in setting prices as well as financial market imperfections. In the presence of financial market imperfections, the gap is not constant and varies in response to shocks.

13. The formal welfare loss function may include financial variables in addition to inflation and the output gap. This strengthens our finding in the following section that monetary policy may benefit from taking into account information about asset prices in the presence of financial market imperfections. In addition, as the presence of financial market imperfections assumes, in many theories, the existence of heterogeneous agents in the economy, the formal welfare loss function may be a composite of the welfare functions of these agents.

14. In theory, variables other than asset prices may also relate closely to the distortions in economic activity arising from financial market imperfections. Taking into account these variables in the conduct of monetary policy may then also be beneficial. Despite this, in this paper we focus on whether we should consider asset prices in the conduct of monetary policy.

15. There are alternative ways to incorporate financial market imperfections into a model. The model developed in Carlstrom and Fuerst (1997) also assumes asymmetric information between borrowers and lenders, although it has a slightly different structure from Bernanke, Gertler, and Gilchrist (1999). Alternatively, Kiyotaki and Moore (1997) assume limited commitment in financial contracts. Iacoviello (2005) extends Kiyotaki and Moore (1997) and studies the relationship between housing prices, business cycles, and monetary policy. Faia and Monacelli (2007) study the role of asset prices in monetary policy using the model in Carlstrom and Fuerst (1997).

(the ratio of the cost of external funds and the opportunity cost of internal funds). N is the net worth of borrowers, and K is the capital stock (assets of borrowers in the model). Accordingly, N/K on the right-hand side of (5) represents the ratio of net worth to total assets of borrowers (the inverse of leverage). Equation (5) indicates that the external finance premium falls when the balance sheet conditions of borrowers improve. We note that an optimal contract between borrowers and lenders could underpin equation (5).

Equation (5) holds in both the short and long run (i.e., at the steady state). This indicates that the positive external finance premium does not dissipate, even in the long run. Consequently, in the steady state the amount of borrowing and the amount of investment in capital stock by entrepreneurs remains below the level that would prevail in the absence of financial market imperfections (i.e., when the external finance premium is zero). It is beyond the capacity of monetary policy to deal with this type of long-run distortion.

We can now rewrite equation (5) to obtain the following short-run relationship between the external finance premium and the financial conditions of borrowers,

$$E_t\left[\frac{R^K_{t+1}}{R_{t+1}}\right] = s\left(\frac{N_{t+1}}{Q_t K_{t+1}}\right), \tag{6}$$

where Q_t is the relative price of capital (the “asset price” in the model). This corresponds with Tobin’s Q and can vary endogenously.

Equation (6) points to a mechanism such that in the short-run financial market imperfections can amplify the effects of aggregate shocks on real economic activity. The outright source of this amplification mechanism lies in the inverse relationship between the external finance premium and borrowers’ balance-sheet conditions. As noted earlier, this amplification mechanism fundamentally reflects the short-run distortions in economic activity resulting from the financial market imperfections. We should also stress that monetary policy has the potential to deal with this type of short-run distortion.

The rate of return on capital R^K_{t+1} is defined by the following equation and fluctuates endogenously:

$$R^K_{t+1} = \frac{D_{t+1} + (1-\delta)Q_{t+1}}{Q_t}, \tag{7}$$

where δ denotes the depreciation rate and D_{t+1} is the marginal product of capital in period $t+1$.[16] Equation (6) is an *ex ante* relationship that holds before the aggregate shocks occur in period $t+1$, while equation (7) is an *ex post* relationship that holds after the aggregate shocks in period $t+1$.

In the presence of financial market imperfections, the effects of exogenous shocks on real economic activity amplify through procyclical movements in the balance-sheet condition of borrowers and countercyclical movements in the external finance premium.

16. Iterative substitutions in (7) yield $Q_t = \sum_{j=1}^{\infty}(1-\delta)^{j-1} D_{t+j} \big/ \left(\prod_{m=1}^{j} R^K_{t+m}\right)$. This implies that asset prices Q_t depend on the discounted values of future dividends. Note that in general equilibrium, both dividends and the discount rate R_{t+m} are determined endogenously. For example, when the growth rate of the economy increases following a shock to technology growth, the discount rate rises and this partly negates the positive effects of the increase in dividends on asset prices.

Put simply, the widely acknowledged financial accelerator mechanism is in action in this model. To see this point in detail, suppose there is an unexpected decline in asset prices Q_t in the wake of some adverse shock. Investment decreases along with the decline in asset prices. A lower than expected rate of return on capital R_t^K following the decline in asset prices then damages entrepreneurs' net worth N_{t+1}. This causes deterioration in the balance-sheet conditions of borrowers and the external finance premium increases. Prompted by the increase in the external finance premium, firms scale back their investment; ultimately, asset prices are likely to fall further. As discussed, a kind of multiplier effect is in action, and this amplifies the magnitude of the initial shock. The amplified response of the economy to exogenous shocks then reflects the presence of the distortions in economic activity arising from the financial market imperfections.

The financial accelerator mechanism described above tends to magnify fluctuations in inflation and the output gap. Because the movements in asset prices are closely related to this particular mechanism, taking into account movements in asset prices in the conduct of monetary policy may be beneficial in minimizing inefficient movements in inflation and the output gap. In the following section, we simulate the model to illustrate this point.

B. Mechanism and Shocks behind Asset Price Movements

In theory, and as described earlier and in detail in the following section, when fluctuations in asset prices closely relate to the short-run distortions arising from financial market imperfections, there may be potential benefits from taking into account the movements in asset prices in monetary policy. In practice, however, this may involve a number of difficulties, especially when the central bank does not have enough information about the nature and sources of asset price movements. Central banks may then wish to be well equipped with sufficient information on both the underlying shock and the mechanism that result in the observed asset price development.

Regarding the mechanism behind the asset price movements, many studies in the literature assume some sort of capital adjustment costs as central to generating the richer dynamics of asset prices (note that asset price here is the relative price of capital when firms' assets consist of capital stock only).[17] Some models explicitly include misalignment in asset prices in an attempt to create bubbles (e.g., Bernanke and Gertler [1999]). Our model includes the amplification mechanism from the financial accelerator, but does not assume the existence of bubbles. To understand better the relationship between the movements in asset prices and real economic activity, central banks require information about the mechanism that generates asset price movements. In practice, the uncertainty regarding the mechanism underlying asset price movements tends to be greater than that behind observed inflation or other variables usually of interest to central banks.

Information about the underlying shocks that drive asset prices plays an essential role for central banks when we assume that they are making monetary policy decisions

17. Similarly, several studies use a two-sector model including both a consumption goods sector and an investment goods sector to account for movements in the relative price of capital (asset prices in those models).

by taking account of the information contained in asset prices. In particular, when the central bank attempts to infer the efficient level of asset prices, they need to identify accurately the shocks to the economy, as any policy action based on imprecise estimates may destabilize the economy. In the next section, we consider an environment where there are two types of shocks to technology growth that only differ with respect to their persistence (one is transitory and the other is persistent) and assume the central bank is unable to distinguish between these shocks on a real-time basis. We illustrate that in such cases the potential costs may exceed the benefits of considering asset price movements in the conduct of monetary policy.

III. Benefits and Costs of Taking into Account Asset Price Movements

In this section, we simulate the model to illustrate the potential benefits and costs of considering movements in asset prices in the conduct of monetary policy. We base this on the model in Bernanke, Gertler, and Gilchrist (1999) that incorporates financial market imperfections in an otherwise standard DSGE model. See Gilchrist and Saito (2008) and Appendices 1 and 2 for a description. While our analysis draws on Gilchrist and Saito (2008), we discuss the monetary policy trade-offs arising from financial market imperfections in detail.

As a driving force behind macroeconomic fluctuations, we consider shocks to technology along with shocks to the net worth of entrepreneurs that have outright effects on their balance sheets.[18] An important difference between these shocks for the purpose of our analysis is the deviation in economic activity from its efficient level. To appreciate this point, we can see that even in the absence of nominal rigidities and real imperfections (such as financial market imperfections), the level of economic activity varies in response to technology shocks. However, net worth shocks have no impact on the efficient level of economic activity. This outcome reflects the fact that in the absence of financial market imperfections, balance-sheet conditions are irrelevant to economic activity (or the decisions of firms/investors).

A. Monetary Policy Rules

We assume that the central bank relies on the short-term interest rate as its main policy instrument and follows an interest rate rule. We consider various interest rate rules and compare their performance as measured by the variance of inflation and the output gap.

The first policy rule that we consider is

$$\tilde{r}_t^n = \phi_\pi \tilde{\pi}_t,$$

where $\tilde{r}_t^n$ is the short-term nominal interest rate (the policy interest rate), $\tilde{\pi}_t$ is the inflation rate between period $t-1$ and period t, and ϕ_π is a response parameter that determines the extent to which the central bank adjusts interest rates to inflation.

18. Gilchrist and Leahy (2002) consider net worth shocks.

The second policy rule we consider includes both inflation and the "asset price gap." We define the asset price gap as the deviation of the *equilibrium* (or *actual*) level of asset prices from the *efficient* level. The equilibrium level of asset prices is the actual/observed level in the presence of both price rigidities and financial market imperfections. The efficient level of asset prices is then the level of prices that would materialize if the prices of goods and services could adjust flexibly and financial markets are perfect. With these concepts, the alternative rule is given by

$$\tilde{r}_t^n = \phi_\pi \tilde{\pi}_t + \phi_q (\tilde{q}_t - \tilde{q}_t^*),$$

where $\tilde{q}_t$ is the equilibrium level of asset prices in period t while $\tilde{q}_t^*$ denotes their efficient level in period t, both in terms of the percentage deviation from the balanced growth path. Accordingly, $\tilde{q}_t - \tilde{q}_t^*$ represents the asset price gap. ϕ_q is another response parameter of the central bank to the asset price gap.

B. Financial Market Imperfections and Monetary Policy Trade-Offs

We provide a few simulation results to illustrate that in the presence of financial market imperfections, complete inflation stabilization would not necessarily achieve a zero output gap, and thus the monetary authority faces a policy trade-off.

In the economy considered in this paper, we define *natural* output as the level of output in the absence of price stickiness but in the presence of financial market imperfections, and *efficient* output as the level of output in the absence of both price stickiness and financial market imperfections.[19] Note that controlling these two potential output levels lies beyond the capacity of monetary policy; that is, they are unaffected by changes in nominal interest rates.

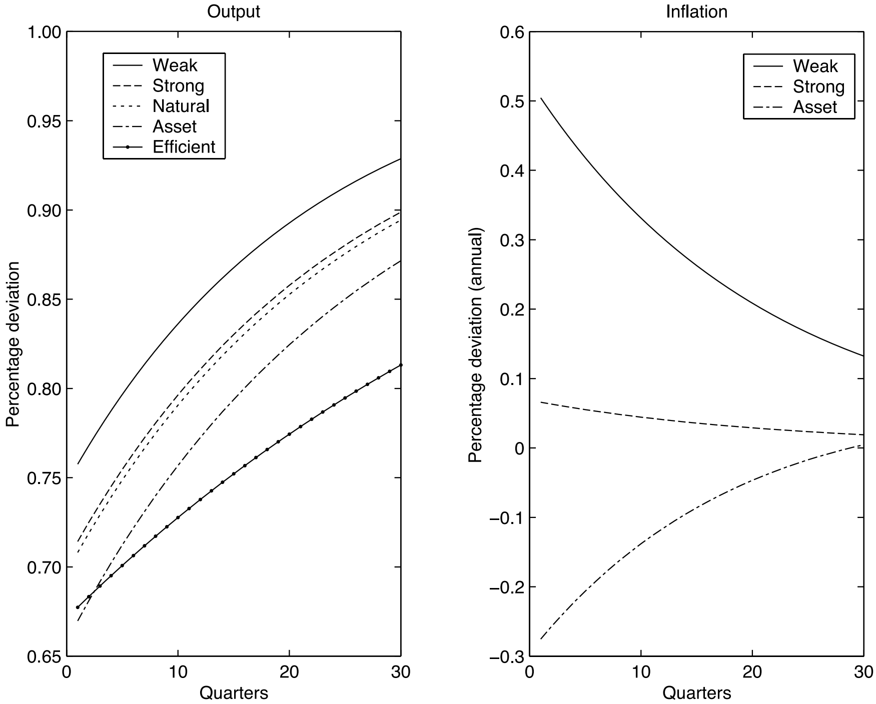
Let $\tilde{y}_t$, $\tilde{y}_t^n$, and $\tilde{y}_t^e$, respectively, denote equilibrium (or actual) output, natural output, and efficient output, each in terms of the percentage deviation from their balanced growth path. We can then decompose the percentage deviation in the output gap, where the output gap is the gap between actual and efficient output, into two components:

$$\tilde{y}_t - \tilde{y}_t^e = (\tilde{y}_t - \tilde{y}_t^n) + (\tilde{y}_t^n - \tilde{y}_t^e). \tag{8}$$

The first term on the right-hand side, $(\tilde{y}_t - \tilde{y}_t^n)$, denotes the gap between actual and natural output, and the second term, $(\tilde{y}_t^n - \tilde{y}_t^e)$, stands for the gap between natural and efficient output. In our model, which includes both price-setting frictions and financial market imperfections, the first term represents the distortion in resource allocation arising from price stickiness while the second term represents the distortion due to financial market imperfections. Note that in the presence of financial market imperfections or other forms of real imperfections/frictions, such as real wage rigidities, the second term endogenously fluctuates in response to exogenous shocks to the economy (such as technology shocks).

19. More generally, *natural* output is defined as the level of output in the economy without any nominal rigidities, but in the presence of some form of real imperfections (e.g., search frictions in the labor market, real wage stickiness, financial market imperfections). *Efficient* output is defined as the level of output in the economy without any nominal rigidities or real imperfections. See Woodford (2003) for a definition of natural and efficient output, and Blanchard and Gali (2007) for application of these concepts in an economy with real wage rigidities. See also Ravenna and Walsh (2008) for an analysis of an economy with labor market frictions.

Figure 1 Response of Output and Inflation to a Technology Shock



Notes: 1. The figures show the response of output (left-hand-side chart) and inflation (right-hand-side chart) to a technology shock, expressed as the percentage deviation from the balanced growth path.
2. "Weak," "strong," and "asset" all show the responses of an economy with price stickiness and financial market imperfections. The monetary policy rules are as follows: weak ($\tilde{r}_t^n = 1.1\tilde{\pi}_t$), strong ($\tilde{r}_t^n = 2.0\tilde{\pi}_t$), asset ($\tilde{r}_t^n = 2.0\tilde{\pi}_t + 0.5(\tilde{q}_t - \tilde{q}_t^*)$). "Natural" represents the response of the economy with flexible prices and financial market imperfections. "Efficient" represents the response of the economy with flexible prices and no financial market imperfections.
3. Response of inflation is not shown for flexible prices.

The first term on the right-hand side of (8) shrinks to zero under a monetary policy that fully stabilizes inflation, while the second term is unaffected by monetary policy actions and fluctuates in response to exogenous shocks to the economy. Consequently, in the presence of financial market imperfections, we cannot keep the output gap at zero under a policy that fully stabilizes inflation; the central bank then faces a trade-off between the stabilization of inflation and the output gap. We present several simulation results to highlight this point below.

Figure 1 presents the responses of equilibrium (or actual) output ($\tilde{y}_t$), natural output ($\tilde{y}_t^n$), efficient output ($\tilde{y}_t^e$), and inflation to a shock that temporarily raises technology growth by 1 percent. Each variable is expressed as the percentage deviation from the balanced growth path. The response of actual output ($\tilde{y}_t$) to the shock depends on the type of monetary policy rule adopted. We consider three types of monetary policy rules: namely, a policy rule that weakly responds to inflation ($\tilde{r}_t^n = 1.1\tilde{\pi}_t$), a policy rule with a strong response to inflation ($\tilde{r}_t^n = 2.0\tilde{\pi}_t$), and a policy rule that strongly responds to asset prices as well as inflation ($\tilde{r}_t^n = 2.0\tilde{\pi}_t + 0.5(\tilde{q}_t - \tilde{q}_t^*)$). Figure 1 labels these as "weak," "strong," and "asset," respectively. The labeled responses of natural and efficient output are "natural" and "efficient."

Figure 1 shows that by making the policy response to inflation stronger (by moving from "weak" to "strong"), both inflation and the gap between actual and natural output ($\tilde{y}_t - \tilde{y}_t^n$) can be broadly minimized. In the presence of financial market imperfections, however, a policy rule that completely stabilizes inflation does not necessarily ensure the elimination of the output gap between the actual and efficient level. The unfilled gap reflects the deviation of the natural output level from the efficient level, and as we discussed so far, we cannot remove this gap between these two notions of output by a monetary policy rule that fully stabilizes inflation.

Contrarily, in the absence of financial market imperfections (not shown), the gap between the natural and efficient level of output remains unchanged in response to technology shocks ($(\tilde{y}_t^n - \tilde{y}_t^e) = 0$) holds in equation (8).[20] In this case, a policy rule that responds strongly to inflation completely stabilizes both inflation and the output gap, and there is no policy trade-off.

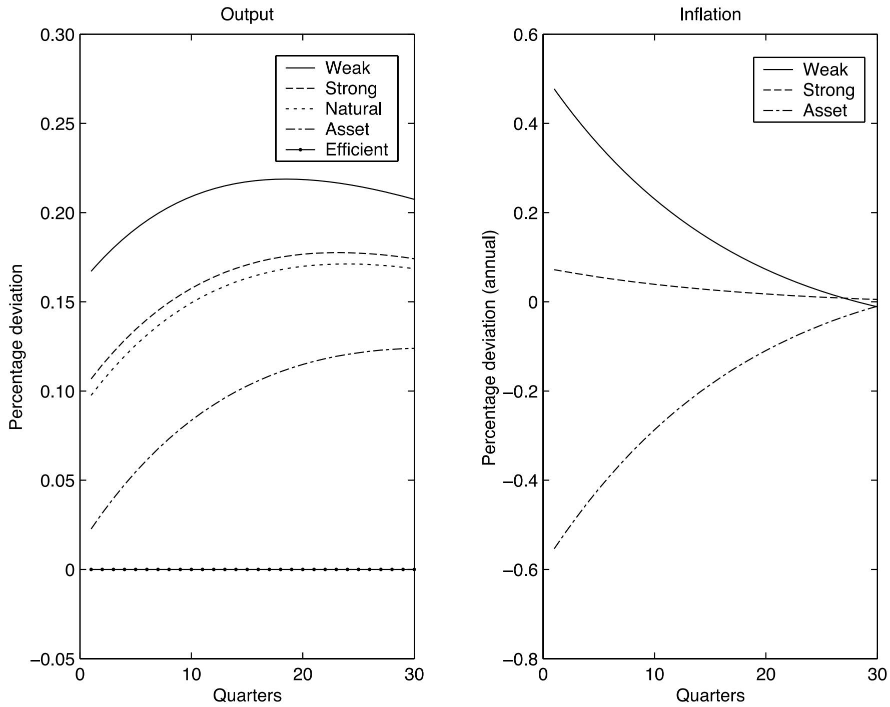
Figure 1 also includes the response of output and inflation when the policy rule explicitly responds to the asset price gap (labeled as "asset"). The output gap can be reduced under this policy, but this comes at the cost of increasing the deviation of inflation from zero (the target inflation rate). This result reconfirms that monetary policy faces a trade-off between stabilizing inflation and the output gap in the presence of financial market imperfections. In this particular case, the "asset" rule outperforms the "strong" rule in terms of output gap stabilization while it fails to minimize the variance of inflation.[21]

We obtain similar results in our model where we simulate shocks to net worth. Figure 2 presents the response of output and inflation to a positive shock to the net worth of entrepreneurs. As in the case of technology shocks, by strengthening the policy response to inflation (from "weak" to "strong"), the response of output can broadly mimic the path of natural output and the response of inflation can be brought closer to zero (the target inflation rate). However, we cannot reduce the gap between natural and efficient output by monetary policy action alone. In this case, a policy rule

20. In the absence of financial market imperfections, the difference between natural and efficient output is due to the presence of markups introduced by imperfect competition. When prices are flexible, markups remain unchanged in response to shocks (although not zero), and as a result the gap between the natural and efficient output remains unchanged. In this case, the percentage deviation in natural output from its balanced growth path ("natural" in the figure) coincides with the deviation in efficient output ("efficient" in the figure).

21. Here, we focus on a particular policy rule that includes the asset price gap (in addition to inflation). We obtain similar results when we consider a policy rule that includes the output gap. A general point is that by letting the monetary authority respond to variables other than inflation, economic outcomes may improve. This additional variable can be the asset price gap (as in our simulation), the output gap, the external finance premium, or the leverage of entrepreneurs. We focus on the additional role of asset prices in monetary policy here. One important avenue for future research is to consider under what conditions asset prices provide useful information for the central bank that it cannot obtain from other variables, such as the output gap.

Figure 2 Response of Output and Inflation to a Net Worth Shock



Notes: 1. The figures show the response of output (left-hand-side chart) and inflation (right-hand-side chart) to a shock to the net worth of entrepreneurs, expressed as the percentage deviation from the balanced growth path.
2. "Weak," "strong," and "asset" all show the responses of an economy with price stickiness and financial market imperfections. The monetary policy rules are as follows: weak ($\tilde{r}_t^n = 1.1\tilde{\pi}_t$), strong ($\tilde{r}_t^n = 2.0\tilde{\pi}_t$), asset ($\tilde{r}_t^n = 2.0\tilde{\pi}_t + 0.5(\tilde{q}_t - \tilde{q}_t^*)$). "Natural" represents the response of the economy with flexible prices and financial market imperfections. "Efficient" represents the response of the economy with flexible prices and no financial market imperfections.
3. Response of inflation is not shown for flexible prices.

that stabilizes inflation completely does not necessarily ensure the elimination of the output gap (the gap between actual and efficient output).

In a similar vein, and as in the case of technology shocks, when the monetary authority takes into account movements in asset prices in addition to movements in inflation ("asset" in the figure), the output gap can better be stabilized, but again this comes partly at the cost of losing inflation stability.

We have so far discussed one-off shocks to technology or net worth. We now conduct stochastic simulations using the same model to see whether we can essentially reconfirm the conclusion that we have reached so far, even in the situation where shocks are hitting the economy continuously.

Table 1 Variance of Output Gap and Inflation under Technology Shocks

	Output gap variance	Breakdown of output gap variance			Inflation variance	Welfare loss
	$\mathrm{var}(\tilde{y}_t - \tilde{y}_t^e)$	$\mathrm{var}(\tilde{y}_t - \tilde{y}_t^n)$	$\mathrm{var}(\tilde{y}_t^n - \tilde{y}_t^e)$	$2\,\mathrm{cov}(\tilde{y}_t - \tilde{y}_t^n, \tilde{y}_t^n - \tilde{y}_t^e)$	$\mathrm{var}(\tilde{\pi}_t)$	
Monetary policy rule with inflation only: $\tilde{r}_t^n = \phi_\pi \tilde{\pi}_t$						
$\phi_\pi = 1.1$	0.689	0.054	0.393	0.241	0.074	0.381
$\phi_\pi = 2.0$	0.430	0.003	0.393	0.033	0.006	0.218
Monetary policy rule with inflation and asset price gap: $\tilde{r}_t^n = \phi_\pi \tilde{\pi}_t + \phi_q(\tilde{q}_t - \tilde{q}_t^*)$						
$\phi_\pi = 2.0$, $\phi_q = 0.1$	0.385	0.002	0.393	−0.011	0.004	0.195
$\phi_\pi = 2.0$, $\phi_q = 0.5$	0.272	0.020	0.393	−0.141	0.031	0.151
$\phi_\pi = 2.0$, $\phi_q = 1.0$	0.202	0.056	0.393	−0.246	0.083	0.143
$\phi_\pi = 2.0$, $\phi_q = 1.5$	0.165	0.091	0.393	−0.319	0.132	0.149
$\phi_\pi = 2.0$, $\phi_q = 2.0$	0.142	0.123	0.393	−0.373	0.176	0.159
Monetary policy rule with strong response to inflation: $\tilde{r}_t^n = \phi_\pi \tilde{\pi}_t$						
$\phi_\pi = 5.0$	0.403	0.001	0.393	0.009	0.001	0.201

Notes: 1. The breakdown of the output gap variance is based on the following equation: $\mathrm{var}(\tilde{y}_t - \tilde{y}_t^e) = \mathrm{var}(\tilde{y}_t - \tilde{y}_t^n) + \mathrm{var}(\tilde{y}_t^n - \tilde{y}_t^e) + 2\,\mathrm{cov}(\tilde{y}_t - \tilde{y}_t^n, \tilde{y}_t^n - \tilde{y}_t^e)$.
2. The welfare loss is calculated as (output gap variance) $\times\ 0.5\ +$ (inflation variance) $\times\ 0.5$.
3. Both the private sector and the central bank are assumed to have perfect information regarding technology shocks.

Note that we can decompose the variance of the output gap ($\mathrm{var}(\tilde{y}_t - \tilde{y}_t^e)$) into three components as in equation (9) below: (1) the variance of the gap between actual and natural output ($\mathrm{var}(\tilde{y}_t - \tilde{y}_t^n)$); (2) the variance of the gap between natural and efficient output ($\mathrm{var}(\tilde{y}_t^n - \tilde{y}_t^e)$); and (3) the (doubled) covariance between the gap between actual and natural output and the gap between natural and efficient output ($2\,\mathrm{cov}(\tilde{y}_t - \tilde{y}_t^n, \tilde{y}_t^n - \tilde{y}_t^e)$).

$$\mathrm{var}(\tilde{y}_t - \tilde{y}_t^e) = \mathrm{var}(\tilde{y}_t - \tilde{y}_t^n) + \mathrm{var}(\tilde{y}_t^n - \tilde{y}_t^e) + 2\,\mathrm{cov}(\tilde{y}_t - \tilde{y}_t^n, \tilde{y}_t^n - \tilde{y}_t^e). \tag{9}$$

We can interpret the first term on the right-hand side of equation (9) as representing the distortions in economic activity arising from nominal rigidities. Likewise, we can interpret the second term as representing the distortions due to financial imperfections. In the absence of price rigidities, the first term is zero, while in the absence of financial market imperfections, the second term is zero. The third term on the right-hand side of equation (9) collapses to zero if either prices are flexible or financial markets are perfect.

Table 1 shows the simulated variance of the output gap and inflation together with their decompositions according to equation (9) in the model economy with stochastic technology shocks. Clearly, the variance of the gap between natural and efficient output ($\mathrm{var}(\tilde{y}_t^n - \tilde{y}_t^e)$) does not vary across the three monetary policy rules as the value stays constant at 0.393 under all policy rules considered.

The upper two rows of Table 1 show that both the variance of the gap between actual and natural output ($\mathrm{var}(\tilde{y}_t - \tilde{y}_t^n)$) and the variance of inflation can be reduced by raising the policy response parameter to inflation. When the policy response to inflation is extremely strong (the bottom row in Table 1), we can reduce both the variance of the gap between actual and natural output and the variance of inflation to nearly zero. However, as noted earlier, monetary policy cannot address the gap between natural and efficient output, and the output gap defined as the gap between the actual and efficient output cannot be completely stabilized under a policy that achieves the full stabilization of inflation. More specifically, Table 1 suggests that it is not possible to reduce the variance of the output gap below the variance of the gap between natural and efficient output (0.393) under a monetary policy rule that responds only to inflation.

Equation (9) indicates that when the covariance ($\mathrm{cov}(\tilde{y}_t - \tilde{y}_t^n, \tilde{y}_t^n - \tilde{y}_t^e)$) takes a negative value, it may be possible to reduce the variance of the output gap ($\mathrm{var}(\tilde{y}_t - \tilde{y}_t^e)$) to a level below the variance of the gap between actual and natural output ($\mathrm{var}(\tilde{y}_t - \tilde{y}_t^n)$). The lower part of Table 1 shows that the covariance may take a negative value under a policy rule that responds to the asset price gap.[22] Moreover, the covariance decreases as the interest rate responds more strongly to the asset price gap. A policy rule with an interest rate responding to both inflation and the asset price gap can then reduce the output gap variance relative to where the policy responds only to inflation. However, this benefit comes at the cost of increasing the volatility of inflation. These results reinforce our finding that the central bank faces a trade-off between the stabilization of inflation and the output gap in the presence of financial market imperfections. Table 1 also shows the welfare loss defined as the weighted average of the inflation and output gap variance. Under the parameter values set in our model, if the monetary policy moderately responds to the asset price gap (with a coefficient on the asset price gap of around 1.0), it would be welfare improving.

The results are similar in the case of net worth shocks. Table 2 presents the variance of the output gap (as well as its decomposition) and the variance of inflation in an economy with net worth shocks. As in the case of technology shocks, we can stabilize inflation by a policy rule that responds strongly to inflation. In the presence of financial market imperfections, however, we cannot reduce to zero the variance of the output gap under such a policy rule. Table 2 also indicates that by including the asset price gap in the policy rule, the variance of the output gap can decrease, but again this comes at the cost of increasing the variance of inflation. These results suggest that in line with the earlier simulation results, monetary authorities face policy trade-offs in the presence of financial market imperfections. Table 2 also indicates, as in the case of technology shocks, a moderate response to the asset price gap could improve economic welfare.

22. The impulse response in Figure 1 shows that this covariance is indeed negative. Under a policy rule with the asset price gap ("asset"), the response of the equilibrium (or actual) output to a technology shock is smaller than the response of the natural output to the same shock (($\tilde{y}_t - \tilde{y}_t^n$) takes a negative value), while the response of natural output exceeds that of efficient output (($\tilde{y}_t^n - \tilde{y}_t^e$) takes a positive value). As a result, the covariance between ($\tilde{y}_t - \tilde{y}_t^n$) and ($\tilde{y}_t^n - \tilde{y}_t^e$) is negative.

Table 2 Variance of Output Gap and Inflation under Net Worth Shocks

	Output gap variance	Breakdown of output gap variance			Inflation variance	Welfare loss
	$\mathrm{var}(\tilde{y}_t-\tilde{y}^e_t)$	$\mathrm{var}(\tilde{y}_t-\tilde{y}^n_t)$	$\mathrm{var}(\tilde{y}^n_t-\tilde{y}^e_t)$	$2\,\mathrm{cov}(\tilde{y}_t-\tilde{y}^n_t, \tilde{y}^n_t-\tilde{y}^e_t)$	$\mathrm{var}(\tilde{\pi}_t)$	
Monetary policy rule with inflation only: $\tilde{r}^n_t=\phi_\pi\tilde{\pi}_t$						
$\phi_\pi=1.1$	1.734	0.073	1.213	0.448	0.109	0.922
$\phi_\pi=2.0$	1.281	0.002	1.213	0.066	0.002	0.642
Monetary policy rule with inflation and asset price gap: $\tilde{r}^n_t=\phi_\pi\tilde{\pi}_t+\phi_q(\tilde{q}_t-\tilde{q}^*_t)$						
$\phi_\pi=2.0$, $\phi_q=0.1$	1.134	0.002	1.213	−0.082	0.004	0.569
$\phi_\pi=2.0$, $\phi_q=0.5$	0.787	0.094	1.213	−0.520	0.134	0.461
$\phi_\pi=2.0$, $\phi_q=1.0$	0.601	0.258	1.213	−0.871	0.362	0.481
$\phi_\pi=2.0$, $\phi_q=1.5$	0.517	0.415	1.213	−1.112	0.574	0.545
$\phi_\pi=2.0$, $\phi_q=2.0$	0.476	0.554	1.213	−1.291	0.756	0.616
Monetary policy rule with strong response to inflation: $\tilde{r}^n_t=\phi_\pi\tilde{\pi}_t$						
$\phi_\pi=5.0$	1.231	0.0001	1.213	0.017	0.0001	0.615

Notes: 1. The breakdown of the output gap variance is based on the following equation: $\mathrm{var}(\tilde{y}_t-\tilde{y}^e_t)=\mathrm{var}(\tilde{y}_t-\tilde{y}^n_t)+\mathrm{var}(\tilde{y}^n_t-\tilde{y}^e_t)+2\,\mathrm{cov}(\tilde{y}_t-\tilde{y}^n_t,\tilde{y}^n_t-\tilde{y}^e_t)$.
2. The welfare loss is calculated as (output gap variance) $\times 0.5+$ (inflation variance) $\times 0.5$.

C. Costs of Considering Asset Price Movements

So far, we have assumed that the central bank can correctly calculate the efficient level of asset prices ($\tilde{q}^*_t$) and use this as an input in monetary policy decisions. In reality, however, the central bank may not possess all the information required to calculate the efficient level of asset prices. In such situations, monetary policy rules that rely on the central bank's inferences about the asset price gap—the gap between actual asset prices and the central bank's inference about the efficient level of asset prices—may not perform well.

In order to illustrate this point, Gilchrist and Saito (2008) consider an economy where there are two types of shocks to technology growth (one transitory and the other persistent) and the central bank does not observe these shocks separately. They further assume that the central bank makes inferences about the realization of the transitory and persistent shocks to technology growth using a Kalman filter, infers the efficient level of asset prices, and then uses it as an input to monetary policy. The central bank is assumed to adopt a monetary policy rule of the form $\tilde{r}^n_t=\phi_\pi\tilde{\pi}_t+\phi_q(\tilde{q}_t-\tilde{q}^*_t)$ where $\tilde{q}^*_t$ now represents the central bank's inferences about the efficient level of asset prices.

Table 3 presents simulation results similar to those contained in Gilchrist and Saito (2008). As shown in the left-hand-side columns in the table (those labeled "economy with price stickiness only"), when the central bank has limited information about

Table 3 Performance of Monetary Policy Rules When the Central Bank Has Imperfect Information about the Source of Asset Price Movements

	Economy with price stickiness only			Economy with price stickiness and financial market imperfections		
	Output gap Variance	Inflation variance	Welfare loss	Output gap variance	Inflation variance	Welfare loss
$\phi_q = 0.1$	0.001	0.005	0.003	0.385	0.006	0.195
$\phi_q = 0.5$	0.001	0.007	0.004	0.272	0.035	0.154
$\phi_q = 1.0$	0.001	0.010	0.005	0.203	0.089	0.146
$\phi_q = 1.5$	0.002	0.011	0.006	0.166	0.139	0.152
$\phi_q = 2.0$	0.002	0.012	0.007	0.143	0.182	0.163

Notes: 1. The monetary policy rule is $\tilde{r}_t^n = 2.0\tilde{\pi}_t + \phi_q(\tilde{q}_t - \tilde{q}_t^*)$.
2. The welfare loss is calculated as (output gap variance) $\times\, 0.5 +$ (inflation variance) $\times\, 0.5$.

the efficient level of asset prices, there is no gain from including the asset price gap in the monetary policy rule in the absence of financial market imperfections. In fact, the welfare loss, calculated as the weighted average of the inflation and output gap variance, becomes larger when the central bank takes into account movements in the asset price gap. This is because the central bank's inferences about the asset price gap are inaccurate when the central bank has limited information about the underlying sources of asset price movements (exogenous shocks in the economy).

As discussed earlier, including the asset price gap in the monetary policy rule can be beneficial in the presence of financial market imperfections. We can see this, at least partially, from the right-hand-side columns in Table 3 (the columns labeled "economy with price stickiness and financial market imperfections"). The variance of the output gap decreases as the policy response to the asset price gap becomes larger. The benefits arise because by responding to the asset price gap, the central bank can at least partially deal with the inefficiencies in the economy due to the presence of financial market imperfections. However, these benefits reduce to the extent that the central bank's inferences about the efficient level of asset prices are inaccurate. We can see this by comparing Table 1 (where the central bank can correctly calculate the efficient level of asset prices) and Table 3 (the situation of limited information held by the central bank). When the central bank has limited information in calculating the efficient level of asset prices, both the variance of inflation and the variance of the output gap are larger when compared with the case where the central bank is not subject to such an information problem. When the central bank has limited information, a policy rule that does not require the central bank's inferences about the efficient level of asset prices may perform better. Such policy rules may include the growth rate of observed asset prices instead of the asset price gap.[23]

23. See Gilchrist and Saito (2008) for further discussion.

D. Future Directions

There are at least two outstanding issues related to the analysis in this section. The first is theoretical. We assumed throughout this section that the welfare loss is measured by the weighted average of the output gap variance and the inflation variance.[24] In theory, the welfare loss function may include other variables, and no one has thus far derived a formal welfare function for an economy with the type of financial frictions considered in this paper.[25] In addition, the weights attached to the variance of inflation and the variance of the output gap in the welfare loss function is arbitrarily set at 0.5 in our analysis. In theory, the weights can differ from the values we imposed. Using the appropriate welfare loss function and weights on the arguments is important in evaluating, at least in theory, how large the monetary policy response to the movements in asset prices should be.

The second issue is empirical. We have illustrated that a desirable form of monetary policy rule differs depending on whether financial markets are perfect or imperfect. It is thus important to assess the degree of financial market imperfections in the actual economy. In particular, it is interesting to see how the degree of financial market imperfections differ across countries and change over time in a certain country,[26] and connect these observations to differences in the desirable form of monetary policy rule across countries, and how these change over time within a country.

IV. Conclusion

This paper discusses the role of asset prices in the conduct of monetary policy using a dynamic general equilibrium model with financial market imperfections. Many previous studies on this topic have emphasized the costs rather than the benefits arising from lean-against-the-wind type monetary policies.[27] In fact, no central bank appears to adjust interest rates in response to movements in asset prices in a systematic manner. The analysis in this paper suggests that when movements in asset prices closely relate to inefficiencies in the economy, which is the case in the presence of financial market imperfections, there may be potential benefits from taking into account movements in asset prices in the conduct of monetary policy. We also find that the benefits decrease when the monetary authority has limited information in judging which part of the observed movements in asset prices reflects these inefficiencies.

24. Bernanke and Gertler (1999) use a similar approach.
25. See Faia and Monacelli (2007), Curdia and Woodford (2009a, b), and Carlstrom, Fuerst, and Paustian (2009) for recent research developments in this area.
26. Christiano, Motto, and Rostagno (2008) and Queijo von Heideken (2008) estimate a DSGE model with financial market imperfections similar to that used in this paper using both U.S. and euro area data. Queijo von Heideken (2008) in particular finds that financial frictions are greater in the euro area.
27. There are pros and cons to this argument. Some studies argue that when the central bank does not recognize bubbles in asset prices in a timely manner and there are some uncertainties in the effects of monetary policy on bubbles, it may not be desirable for monetary policy to respond excessively to asset price movements (Bernanke and Gertler [1999] and Kohn [2006]). Others, however, advocate the potential benefits of lean-against-the-wind policies and more generally stress the importance of the stability in financial system in the context of monetary policy (Borio and White [2004]).

APPENDIX 1: THE FINANCIAL ACCELERATOR MODEL

This section presents the equilibrium conditions of the model and the parameter values.[28]

A. Equilibrium Conditions

In the model, technology is nonstationary, and accordingly, macroeconomic variables such as consumption and investment are nonstationary. We can show that along the balanced growth, consumption (C), investment (I), output (Y), capital stock (K), and the net worth of entrepreneurs (N) grow at the same rate as technology. As a result, these variables divided by the level of technology are stationary. Let c, i, y, k, and n denote consumption, investment, output, capital stock, and the net worth of entrepreneurs, each divided by the level of technology (A). These variables are constant along the balanced growth path. Writing the percentage deviations of the normalized variables from the balanced growth path as $\tilde{c}$, $\tilde{i}$, $\tilde{y}$, $\tilde{k}$, and $\tilde{n}$, the percentage deviation of technology growth from the balanced growth path as $\tilde{z}$, and the deviation of inflation rate from 0 percent as $\tilde{\pi}$, we can write the equilibrium conditions of the model as (A.1)–(A.11) below.[29] Variables with subscript t denote the variables observed in period t. Variables with conditional expectations operator (E_t) denote the expected values conditional on information available in period t. Variables without time subscript denote constant values along the balanced growth.

Equation (A.1) is the Euler equation for households:

$$-\tilde{c}_t = -E_t\tilde{c}_{t+1} - E_t\tilde{z}_{t+1} + \tilde{r}^n_{t+1} - E_t\tilde{\pi}_{t+1}, \tag{A.1}$$

where $\tilde{r}^n_{t+1}$ is the nominal interest rate that is set by the central bank in period t (see Section III for a description of the monetary policy rules).

Equation (A.2) states that the expected rate of return on capital ($E_t\tilde{r}^k_{t+1}$) is the sum of marginal product of capital and capital gains:

$$E_t\tilde{r}^k_{t+1} = \frac{mc(1-\alpha)\frac{y}{k}z}{mc(1-\alpha)\frac{y}{k}z + (1-\delta)}(E_t\tilde{y}_{t+1} - \tilde{k}_{t+1} + E_t\tilde{z}_{t+1} + E_t\tilde{m}c_{t+1})$$

$$+ \frac{1-\delta}{mc(1-\alpha)\frac{y}{k}z + (1-\delta)}E_t\tilde{q}_{t+1} - \tilde{q}_t, \tag{A.2}$$

where $\tilde{q}_t$ is asset prices and $\tilde{m}c_t$ is the real marginal cost (the inverse of markup), both in deviations from the balanced growth path.

Equation (A.3) defines the external finance premium ($\tilde{s}_t$) as the difference between the expected rate of return on capital and the expected rate of return on risk-free assets:

$$\tilde{s}_t = E_t\tilde{r}^k_{t+1} - (\tilde{r}^n_{t+1} - E_t\tilde{\pi}_{t+1}). \tag{A.3}$$

28. See Gilchrist and Saito (2008) for details.
29. We assume that the rate of inflation on the balanced growth path is 0 percent.

Equation (A.4) states that the external finance premium is increasing in the leverage of entrepreneurs:

$$\tilde{s}_t = \chi(\tilde{q}_t + \tilde{k}_{t+1} - \tilde{n}_{t+1}), \tag{A.4}$$

where χ is a positive parameter.

Equation (A.5) describes the evolution of the net worth of entrepreneurs:

$$\tilde{n}_{t+1} = \frac{k}{n}\tilde{r}_t^k - \left(\frac{k}{n} - 1\right)E_{t-1}\tilde{r}_t^k + \tilde{n}_t - \tilde{z}_t + \varepsilon_{nw,t}. \tag{A.5}$$

Net worth at the end of period t ($\tilde{n}_{t+1}$) is the net worth at the end of period $t-1$ ($\tilde{n}_t$) plus the return on capital from period $t-1$ to period t ($\tilde{r}_t^k$) minus the repayment on the loan ($E_{t-1}\tilde{r}_t^k$). $\varepsilon_{nw,t}$ is a shock to net worth (similar to that considered in Gilchrist and Leahy [2002]). This shock is assumed to be i.i.d. with a normal distribution.

Equation (A.6) expresses the relationship between investment and asset prices (relative price of capital, or Tobin's Q):

$$\tilde{q}_t = \eta_k(\tilde{i}_t - \tilde{k}_t + \tilde{z}_t), \tag{A.6}$$

where η_k is a positive parameter.

Equation (A.7) states that the aggregate demand for goods and services consists of consumption ($\tilde{c}_t$) and investment ($\tilde{i}_t$):

$$\tilde{y}_t = \frac{c}{y}\tilde{c}_t + \frac{i}{y}\tilde{i}_t. \tag{A.7}$$

Equation (A.8) is the production function that relates the aggregate supply of goods and services to labor input ($\tilde{h}_t$), capital stock, and total factor productivity:

$$\tilde{y}_t = \alpha\tilde{h}_t + (1-\alpha)\tilde{k}_t - (1-\alpha)\tilde{z}_t, \tag{A.8}$$

where α is a positive parameter.

Equation (A.9) is the equilibrium condition in the labor market:

$$\tilde{y}_t + \tilde{m}c_t - \tilde{c}_t = (1+\gamma)\tilde{h}_t, \tag{A.9}$$

where γ is a positive parameter that is the inverse of the labor supply elasticity.

Equation (A.10) is the Phillips curve that describes the price-setting behavior of firms:[30]

$$\tilde{\pi}_t = \kappa\tilde{m}c_t + \beta E_t\tilde{\pi}_{t+1}, \tag{A.10}$$

where κ is a positive parameter and β is a positive parameter associated with the subjective discount factor of households.

30. The deviation of the real marginal cost from the balanced growth path corresponds to the output gap (the gap between actual output and natural output). Equation (A.10) corresponds to equation (1) in Section II.

Equation (A.11) describes the evolution of the capital stock:

$$\tilde{k}_{t+1} = \frac{1-\delta}{z}(\tilde{k}_t - \tilde{z}_t) + \left(1 - \frac{1-\delta}{z}\right)\tilde{i}_t, \tag{A.11}$$

where δ is the depreciation rate.

We assume that two types of shocks to technology growth occur in each period. One has a transitory impact on technology growth (ε_t), and the other has a persistent impact on technology growth (ν_t). We characterize the process of technology growth by the following equations:

$$\tilde{z}_t = \tilde{d}_t + \varepsilon_t, \qquad \varepsilon_t \sim \text{i.i.d. } N(0, \sigma_\varepsilon^2),$$

$$\tilde{d}_t = \rho_d \tilde{d}_{t-1} + \nu_t, \quad \nu_t \sim \text{i.i.d. } N(0, \sigma_\nu^2),$$

where $\tilde{z}_t$ is the growth rate of technology and $\tilde{d}_t$ is the persistent component of technology growth, both in terms of percentage deviations from the balanced growth path. Several other studies use a similar characterization of the stochastic process of technology growth.[31]

In addition to the equations listed above, the monetary policy rule constitutes the system of equilibrium conditions (see Section III for a description of the monetary policy rules).

B. Parameters

The labor share (α) is 0.642. The subjective discount factor (β) is 0.995. The preference parameter (γ) is chosen so that the labor supply elasticity ($1/\gamma$) is 2.7373 ($\gamma = 0.3654$).[32] The depreciation rate of capital (δ) is 2.1 percent per quarter ($\delta = 0.021$), and the parameter related to capital adjustment costs is $\eta_k = 0.25$ as in Bernanke, Gertler, and Gilchrist (1999).

The parameter related to the market power of firms is set so that the price markup along the balanced growth is 10 percent ($\varepsilon = 11$), while the parameter related to the price stickiness is set so that price adjustments occur with a probability of 25 percent every quarter ($\nu = 0.75$), as in Bernanke, Gertler, and Gilchrist (1999). The former relates to the distortion in long-term resource allocation introduced by the market power of firms. The latter relates to the distortion in the short-term resource allocation due to price rigidities. $\nu = 0$ corresponds to the special case of flexible prices. The resource allocation in the flexible price economy is identical to the allocation when the real marginal costs remain unchanged ($\tilde{mc}_t = 0$).[33]

Regarding the parameters related to financial market imperfections, the sensitivity of the external finance premium to the entrepreneur's leverage is $\chi = 0.05$, as in Bernanke, Gertler, and Gilchrist (1999). The ratio of capital stock to the net worth of entrepreneurs on the balanced growth path (k/n) is set to 1.982 based on Japanese

31. See, for instance, Edge, Laubach, and Williams (2007).

32. These parameter values are from Fukunaga (2002), who calibrates a similar model for the Japanese economy.

33. When prices are flexible, we replace equation (A.10) with $\tilde{mc}_t = 0$.

data.[34] $\chi = 0$ corresponds to the special case of no financial market imperfections, in which case the external finance premium is constant at zero ($\tilde{s}_t = 0$), as we can see from equation (A.4).

Regarding the parameters related to the stochastic process of technology, the standard deviations of technology shocks are set to the same values as those in Gilchrist and Saito (2008). The standard deviation of the shocks to the persistent component of technology growth (σ_v) is 0.001, while the standard deviation of the shocks to the transitory component (σ_ε) is 0.01. The autocorrelation of the persistent component of technology growth (ρ_d) is 0.5. Under these parameterizations, the Kalman gain (λ) is 0.0131. Finally, the standard deviation of net worth shocks (σ_{nw}) is 0.01.

APPENDIX 2: FINANCIAL MARKET IMPERFECTIONS AND POLICY TRADE-OFFS

In Section III, we saw that in the presence of both price rigidities and financial market imperfections the central bank faces a trade-off between stabilizing inflation and the output gap. We can see this from the following two equilibrium conditions in the model:

$$\tilde{\pi}_t = \kappa \tilde{mc}_t + \beta E_t \tilde{\pi}_{t+1}, \tag{B.1}$$

$$\begin{aligned} &\tilde{s}_t + \tilde{r}^n_{t+1} - E_t \tilde{\pi}_{t+1} \\ &= \frac{mc(1-\alpha)\frac{y}{k}z}{mc(1-\alpha)\frac{y}{k}z + (1-\delta)}(E_t \tilde{y}_{t+1} - \tilde{k}_{t+1} + E_t \tilde{z}_{t+1} + E_t \tilde{mc}_{t+1}) \\ &\quad + \frac{1-\delta}{mc(1-\alpha)\frac{y}{k}z + (1-\delta)} E_t \tilde{q}_{t+1} - \tilde{q}_t. \end{aligned} \tag{B.2}$$

Equation (B.1) is the Phillips curve (the same as equation [A.10] in Appendix 1), and equation (B.2) is derived from equations (A.2) and (A.3) in Appendix 1.

Note that when prices are flexible, there are no fluctuations in the markup and the real marginal cost ($\tilde{mc}_t = 0$). Note also that in the absence of financial market imperfections, the external finance premium is constant at zero ($\tilde{s}_t = 0$).

As we can see from equation (B.1), the real marginal cost completely stabilizes under a policy rule that achieves the complete stabilization of inflation. Stabilizing the real marginal cost completely, however, does not necessarily ensure the complete stabilization of the external finance premium and the output gap.[35] We can see this from equation (B.2): even if prices and the real marginal cost completely stabilize, fluctuations in the external finance premium (deviations in $\tilde{s}_t$ from zero) lead to deviations in real variables (such as output) from their efficient levels (the levels that would prevail in the absence of price rigidities and in the absence of financial market imperfections).

34. Bernanke, Gertler, and Gilchrist (1999) use a slightly smaller value ($k/n = 1.8$).

35. For example, in the presence of financial market imperfections, the external finance premium varies in response to technology shocks, even when prices are flexible.

In other words, even if $\tilde{mc}_t$ is zero, the level of output in the presence of financial market imperfections (the level of output when $\tilde{s}_t$ is not zero in equation [B.2]) would be different from that in the absence of financial market imperfections (the level of output when $\tilde{s}_t$ is zero). Accordingly, in the presence of financial market imperfections (that is, when the external finance premium varies in response to shocks), complete stabilization of inflation does not necessarily ensure the elimination of the output gap (the gap between actual and efficient output).

References

Bernanke, Ben S., and Mark Gertler, "Monetary Policy and Asset Price Volatility," *New Challenges for Monetary Policy,* Federal Reserve Bank of Kansas City, 1999.

———, ———, and Simon Gilchrist, "The Financial Accelerator in a Quantitative Business Cycle Framework," in John B. Taylor and Michael Woodford, eds. *Handbook of Macroeconomics,* Volume 1C, Amsterdam: Elsevier Science, North-Holland, 1999.

Blanchard, Olivier, and Jordi Gali, "Real Wage Rigidities and the New Keynesian Model," *Journal of Money, Credit and Banking,* 39 (1), 2007, pp. 35–66.

———, and ———, "Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment," *American Economic Journal: Macroeconomics,* 2009 (forthcoming).

Borio, Claudio, and William R. White, "Whither Monetary and Financial Stability? The Implications of Evolving Policy Regimes," *Monetary Policy and Uncertainty: Adapting to a Changing Economy,* 2004, pp. 131–211.

Carlstrom, Charles C., and Timothy S. Fuerst, "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review,* 87 (5), 1997, pp. 893–910.

———, ———, and Matthias Paustian, "Optimal Monetary Policy in a Model with Agency Costs," mimeo, 2009.

Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, "Shocks, Structures or Monetary Policies? The Euro Area and US after 2001," *Journal of Economic Dynamics and Control,* 32 (8), 2008, pp. 2476–2506.

Curdia, Vasco, and Michael Woodford, "Credit Frictions and Optimal Monetary Policy," BIS Working Paper No. 278, Bank for International Settlements, 2009a.

———, and ———, "Credit Spreads and Monetary Policy," mimeo, 2009b.

Edge, Rochelle M., Thomas Laubach, and John C. Williams, "Learning and Shifts in Long-Run Productivity Growth," *Journal of Monetary Economics,* 54, 2007, pp. 2421–2438.

Erceg, Chris J., Dale W. Henderson, and Andrew T. Levin, "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics,* 46, 2000, pp. 281–313.

Faia, Ester, and Tommaso Monacelli, "Optimal Interest Rate Rules, Asset Prices, and Credit Frictions," *Journal of Economic Dynamics and Control,* 31 (10), 2007, pp. 3228–3254.

Fukunaga, Ichiro, "Financial Accelerator Effects in Japan's Business Cycles," Bank of Japan Working Paper No. 02-6, Bank of Japan, 2002.

———, and Masashi Saito, "Shisan Kakaku to Kin'yu Seisaku (Asset Prices and Monetary Policy)," *Kin'yu Kenkyu* (Monetary and Economic Studies), 27 (2), 2008, pp. 1–64 (in Japanese).

Gilchrist, Simon, and John V. Leahy, "Monetary Policy and Asset Prices," *Journal of Monetary Economics,* 49, 2002, pp. 75–97.

———, and Masashi Saito, "Expectations, Asset Prices, and Monetary Policy: The Role of Learning," in John Y. Campbell, ed. *Asset Prices and Monetary Policy,* Chicago: University of Chicago Press, 2008.

Iacoviello, Matteo, "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycles," *American Economic Review,* 95 (3), 2005, pp. 739–764.

Kiyotaki, Nobuhiro, and John H. Moore, "Credit Cycles," *Journal of Political Economy,* 105, 1997, pp. 211–248.

Kohn, Donald L., “Monetary Policy and Asset Prices,” Remarks, Board of Governors of the Federal Reserve System, March 16, 2006.

Okina, Kunio, and Shigenori Shiratsuka, “Asset Price Bubbles, Price Stability, and Monetary Policy: Japan’s Experience,” *Monetary and Economic Studies,* 20 (3), Institute for Monetary and Economic Studies, Bank of Japan, 2002, pp. 35–76.

Queijo von Heideken, Virginia, “How Important Are Financial Frictions in the U.S. and the Euro Area?” Sveriges Riksbank Working Paper No. 223, 2008.

Ravenna, Frederico, and Carl E. Walsh, “The Welfare Consequences of Monetary Policy and the Role of the Labor Market: A Tax Interpretation,” mimeo, 2008.

Woodford, Michael, *Interest and Prices: Foundation of a Theory of Monetary Policy,* Princeton: Princeton University Press, 2003.