

ASSET-PRICE BUBBLES AND MONETARY POLICY

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Abstract

In this paper we develop a theoretical framework that helps to analyse the role of monetary policy in responding to asset-price bubbles. A large and rapid fall in the nominal price of assets that form the basis of collateral for loans from financial intermediaries can have adverse effects on financial system stability. This asymmetric effect of asset price changes, by reducing the extent of intermediated finance, can reduce output below potential and keep inflation below the central bank's target for extended periods. We demonstrate that there may be circumstances where monetary policy should be tightened in response to an emerging asset-price bubble, in order to burst the bubble before it becomes too large, even though this means that expected inflation is below target in the short run. Such a policy is optimal because it can help to avoid extreme longer-term effects of a larger asset-price bubble and its eventual collapse. In principle, the adverse effects of asset-price bubbles on financial system stability can be moderated through appropriate financial system regulation and supervision. Nevertheless, provided that the effects of asset-price bubbles on the economy are not entirely eliminated, a role for monetary policy may remain.

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1. Introduction

What role do asset prices have in a monetary-policy framework that involves targeting medium-term inflation of prices of goods and services? This question has attracted considerable interest in recent times, in part due to the coexistence in some countries of low inflation of prices of goods and services and rapid increases in asset prices, most notably stock prices. In this paper, we argue that the main reason that a monetary authority with an inflation target might respond to movements in asset prices is that these movements can create future difficulties in the financial system, which in turn can affect future output and inflation. Furthermore, we argue that the effect of asset price changes on output and inflation is asymmetric, with declines in asset prices having stronger effects on output and inflation than do increases in asset prices. The asymmetry arises from the adverse effects that a collapse in asset prices can have on the process of financial intermediation.

Of particular importance are the prices of assets used as collateral for loans, for increases in these prices can generate the backing for additional loans and, in turn, a boom in credit growth. If the price increases turn out to be unsustainable, and a correction in prices occurs, much of this collateral can disappear, causing large losses for financial institutions and other firms. The outcome can be a pronounced and protracted slowdown in economic activity, and inflation below target.

In principle, the adverse effects of asset-price bubbles on the stability of the financial system can be moderated through appropriate financial system regulation and supervision. Nevertheless, provided that the effects of asset-price bubbles on the economy are not entirely eliminated, a role for monetary policy may remain. In particular, if the central bank can affect the probability of an asset-price bubble bursting by changing interest rates, it may be optimal to use monetary policy to influence the path of the bubble, even if it means that expected inflation deviates from the central bank's target in the short term. By seeking to change the path of the

bubble, monetary policy may be able to simultaneously contribute to maintaining financial system stability and to reducing the variance of inflation.

The reasoning behind this result is relatively straightforward. Suppose that the real asset price is above, and moving further away, from some fundamental level – that is, that there is an asset-price bubble. As the asset price rises it is likely to put some upward pressure on goods and services price inflation by increasing aggregate demand and expectations of inflation. When the bubble eventually bursts, these inflationary pressures will abate, but we argue that there will be an additional contractionary effect on inflation arising from the adverse effect that falling asset prices have on collateral values, financial system stability and the provision of intermediated finance.

There are two broad scenarios to consider. The asset-price bubble could burst in the near future or it could burst in the more distant future. If it bursts in the near future, there is likely to be a mild contraction in output, and inflation is likely to be below target. If on the other hand, the bubble survives and grows, there will be continuing expansionary effects on output and inflation. But eventually the bubble must burst, and when it does so, the collapse will be much larger with the potential to adversely affect the stability of the financial system. When this occurs we could expect a prolonged period of output below potential and inflation (substantially) below target.

Now suppose that the central bank, can increase the likelihood of a bubble bursting by raising interest rates. In this case it may make sense for the central bank to do so early on in the life of the bubble, even though this will increase the likelihood of inflation being below target in the near term. This is desirable, however, because it also decreases the chance of the bubble continuing, and hence, of much more extreme outcomes for inflation and output in the longer term. Of course the path of interest rates will depend on many factors, including the probability of the bubble bursting of its own accord, the expected growth rate of a surviving bubble, the magnitude of the bubble's direct effect on inflation, as well as the magnitude of the asymmetric effect of the bubble's collapse on inflation through reductions in intermediated finance. The objective of our paper is to develop a formal framework to help analyse the interplay of these different factors.

The structure of the paper is as follows. Section 2 outlines various arguments why monetary authorities might be concerned about asset prices. These arguments are

discussed in the context of our modelling strategy. Section 3 uses a simple model to analyse the links between monetary policy and asset-price bubbles. Section 4 presents a discussion of how financial regulation and the inflation environment might affect the parameters of the model and thus affect the appropriate monetary policy response to an asset-price bubble. Finally, Section 5 concludes by drawing some broad lessons for monetary policy.

2. Asset Prices and Monetary Policy

In an inflation-targeting regime, how should monetary policy respond to movements in asset prices? There is no clear consensus as to the appropriate answer. Some argue that the price index targeted by the central bank should include the prices of assets as well as the prices of goods and services. Others argue that asset prices are relevant to monetary policy only in so far as they affect forecasts of future goods and services price inflation. Finally, others see changes in asset prices as having implications for the stability of the financial sector, and thus perhaps indirectly for monetary policy.

2.1 The Inclusion of Asset Prices in an Overall Price Index

Goodhart (1993) has argued that, in principle, the central bank should target a price index that not only includes the prices of goods and services, but also the prices of *future* goods and services. Since these prices cannot be measured directly, Goodhart claims that a reasonable alternative is to include the prices of a broad range of assets in the price index targeted by the central bank. He suggests that this is appropriate since asset prices capture the value of claims on a basket of future goods and services. The argument rests on earlier work by Alchian and Klein (1973) who argued that a general measure of inflation should capture changes in the money cost of a constant utility basket of current and future goods and services.

In addition to the formidable practical problem associated with obtaining accurate and broadly based indices of asset prices, Goodhart's proposal has two conceptual difficulties.

The first is a result of the way inflation targets are actually implemented. Central banks with inflation targets do not target the *current* rate of inflation but rather the

future expected rate of inflation, or more precisely, the future expected *path* of inflation. Goodhart's and Alchian and Klein's concern was that by focusing on the current rate of inflation, central banks would ignore future inflationary pressures which were reflected in current asset prices, but not current goods prices. By including asset prices in the targeted index, this might be overcome. In practice, however, the fact that inflation targets are forward looking means that central banks are already directly concerned with future inflationary pressures.

The second difficulty is that asset prices change for a variety of reasons that are not associated with future inflationary pressures. In some cases, rising asset prices might mean reduced inflationary pressures, while in other cases the reverse might be true. Understanding the source of asset price movements and the implications for future inflation is important in determining the appropriate monetary policy response (Smets 1997). If asset prices are included in the targeted price index, then the ability of monetary policy to respond differently according to the nature of asset price change is severely restricted.

In Australia's case, the most obvious example of this point is the exchange rate. As the terms of trade rise, the exchange rate tends to appreciate (Gruen and Dwyer 1995; Smets 1997; and Tarditi 1996). This appreciation helps reduce any inflationary impact that would otherwise be associated with the increase in the terms of trade; thus the case for an easing of monetary policy in response to an appreciation of the currency is less than clear. In contrast, if the exchange rate appreciation is not based on underlying fundamentals, there is a stronger case for a change in monetary policy, especially if the appreciation is likely to reduce expected inflation.

Another example is the stock market. If a rise in equity prices has little fundamental justification, expected inflation is likely to rise, particularly if aggregate demand responds to the perceptions of higher wealth. In this case there is an argument for tighter monetary policy. In contrast, suppose the rise in equity prices reflects an improved outlook for corporate profits as a result of faster underlying productivity growth. In this case, the central bank's forecast of future inflation might actually fall. Tightening monetary policy in response to this change in asset prices would clearly be inappropriate.

To summarise, including asset prices in an index of prices which the central bank targets is not necessary in order for the central bank to focus on future inflation. Nor is this sensible since the appropriate monetary policy response to a change in asset prices will depend on the source of that change. We address each of these points in our model presented in Section 3. Firstly, we make it explicit that the central bank's objective is to target expected future inflation. Secondly, we restrict ourselves to a discussion of the behaviour of asset prices away from some fundamental level – that is, we look at asset-price bubbles.

2.2 The Effect of Asset Prices on Future Inflation

Some authors argue that in certain cases, central banks should respond to changes in asset prices, but in a more flexible fashion than would be the case if asset prices were included in the targeted price index. The guideline they propose is for the central bank to calculate the effect of the change in asset prices on expected inflation and then adjust the interest rate to bring expected inflation back to target.

An increase in asset prices can increase expected future goods and services price inflation. This can occur through a number of channels. The most frequently discussed is the wealth effect of higher asset prices; by increasing perceptions of wealth, higher asset prices can lead to increased consumption. Consumption might also be stimulated through an improvement in consumer sentiment resulting from higher asset prices. If the resulting increase in aggregate demand outstrips the increase in supply, inflation pressures are likely to rise. This process can be compounded if rapidly increasing asset prices generate higher *expected* goods and services price inflation on the part of the private sector, which then feeds through into higher actual inflation. Finally, in certain cases an increase in asset prices can signal to the central bank that the private sector is expecting higher general inflation. In turn, this information might affect the central bank's expectation of future inflation.

We include the standard effect of asset price changes on inflation in our model in Section 3. This can be interpreted as capturing these direct wealth effects and/or the signalling relationship that links higher asset prices to expected increases in future aggregate demand and hence, future inflationary pressures.

2.3 Asset Prices and Financial Stability

While increases in asset prices tend to have small direct effects on goods and services prices, they can have much larger indirect effects through their impact on the financial system. If increases in asset prices are not based on fundamentals, a correction in prices is inevitable. When the correction occurs it can be very costly if during the period of increasing prices, financial institutions have extended credit for the purchase of assets, or accepted assets as collateral for loans. In such cases, falling asset prices can lead to large losses amongst financial institutions and can impair the stability of the financial system. This may result in a protracted period of growth below potential, and low, or even negative, goods and services price inflation.

The connection between asset prices and the stability of the financial system introduces an important asymmetry into the effect of asset prices on inflation. The discussion above suggested that while rising asset prices might contribute to higher goods and services price inflation, the effect is in general, relatively small. In contrast, the unwinding of asset-price bubbles can cause problems for the financial system, and have a significant deflationary effect.

In Australia, the collateral for most loans is real estate; this means that changes in the price of real estate not only have potential effects on aggregate demand, but can also affect the health of the financial system. If nominal property prices fall, and financial institutions have made loans with relatively high loan-to-valuation ratios, the underlying collateral may be insufficient to match the face value of the loan. This can impose substantial losses on the financial system and have adverse effects on the future availability and cost of intermediated finance.

In a similar vein, changes in property prices can affect the balance sheets of corporations. A fall in property prices reduces the net value of firms and, due to imperfections in credit markets, makes it more difficult to attract intermediated finance for a given investment project (Bernanke and Gertler 1990; Gertler 1992; Kiyotaki and Moore 1995; and Lowe and Rohling 1993). As a result, a financial accelerator acts to amplify any downturn in economic activity (Fisher 1933).

In Australia, relatively little lending by financial intermediaries has been secured against equities. Hence, booms and busts in equity prices need not have the same

direct implications for the balance sheets of financial institutions that changes in property prices have had. Nevertheless, movements in equity prices can still affect the stability of the financial system. As the experience of the United States in 1987 shows, a major fall in equity prices can create problems in the payments system, with potentially large adverse consequences. Further, if a share market crash leads to a severe contraction in aggregate demand, borrowers may find themselves unable to repay their loans. As share ownership becomes more widespread, the aggregate demand effects of changes in equity prices may become more pronounced.¹ Continued financial innovation may also see the growth of lending secured against equities, adding to the exposure of financial institutions to changes in equity prices. Such a change in the pattern of financial intermediation would increase the relevance of stock prices for monetary policy.

In the model presented below we include the indirect, and asymmetric effect of falling asset prices on goods and services price inflation. This indirect effect captures the (circular) links between falling collateral values, financial instability, contractions in intermediated finance and falling aggregate demand. For the moment we focus on the role of monetary policy and ignore the influence of prudential policy. However, we later discuss the important issue of prudential supervision and describe how it can be incorporated into our basic model.

3. Monetary Policy and Bubbles: A Simple Model

3.1 The Model

In this section we develop a simple model which captures some of the ideas discussed above. The primary question of interest is how monetary policy should respond to an increase in asset prices that is not justified by fundamentals. The

¹ The 1997 *Australian Sharemarket Survey* finds that 34 per cent of the Australian adult population have direct or indirect share holdings. This percentage would be considerably higher if account was taken of employer-funded pension schemes.

model has four key elements which we argue are reasonable representations of reality. These elements are:

1. an asymmetric effect of asset price increases and decreases on goods and services price inflation;
2. a central bank with an inflation target, which cares about the variability of inflation as well as its expected level;
3. the probability of an asset-price bubble bursting is influenced by the level of interest rates; and
4. an assumption that once an asset-price bubble has burst it does not return (at least within any reasonable policy horizon).

The structure of the model is intentionally very simple, with the focus on these four elements. The economy runs for only three periods and we assume that a bubble emerges in the first period. Throughout we assume that the central bank knows that the increase in asset prices is not justified by fundamentals. This is a strong assumption, and one that in practice would generally not be met. Nevertheless, central banks, like other institutions and individuals, can and do make judgments about whether or not certain asset price changes are detached from fundamentals. While a less restrictive form of our model would incorporate the fact that the central bank does not know for sure that a bubble exists, relaxing this assumption would not change the basic insights of the model.

We begin with the following model of inflation:

$$\mathbf{p}_t = \mathbf{a} A_t + \mathbf{b} D_t \Delta A_t - R_{t-1} \quad \mathbf{a} \geq 0, \mathbf{b} \geq 0 \quad (1)$$

where \mathbf{p}_t is the deviation of inflation from the central bank's target, A_t is the deviation of the asset price from its fundamental value, R_t is the deviation of the policy interest rate from its neutral level and D_t is a dummy variable which takes a

value of 1 if the asset price has fallen, and 0 otherwise.² While the target variable is taken to be inflation, the following analysis would apply equally if the target was the deviation of output from its potential level; indeed we are implicitly assuming that the effect of asset prices on inflation works primarily through their impact on economic activity.

We assume that rising asset prices put upward pressure on goods and services prices; the larger is α , the larger is this direct effect. However, we also assume that when the bubble bursts and the asset price returns to its fundamental value, not only are the stimulatory effects of the higher asset price withdrawn, but there are additional contractionary effects. As discussed above, these effects arise from the adverse effects of falling asset prices on financial system stability; the larger is α , the larger is this asymmetric effect. The experience of the past decade suggests that α is likely to be larger if the bubble is in property prices, rather than in equity prices.

Note that in this model, monetary policy operates with a lag. If current inflation is above target, the central bank cannot immediately return it to target. This means that the central bank must forecast future events when setting the current interest rate.

When an asset-price bubble does emerge, we assume that there is some probability p that the price will return to its fundamental value next period. This probability is assumed to be a function of the deviation of the interest rate from its neutral level. Higher interest rates increase the debt servicing on purchases of the asset and make a downturn in the business cycle more likely; these changes increase the probability that the bubble will collapse.³

² Equation (1) relates the inflation rate of goods and services to the *level* of asset prices, rather than the *inflation* rate of asset prices (which would be more natural). However, given the fact that we are only concerned with three discrete time periods we ignore any distinction between shifts in the price level and inflation.

³ In addition, a decision by the central bank to increase the interest rate could be accompanied by remarks regarding the high level of asset prices and the unsustainability of current trends; such remarks might also make the continuation of the bubble less likely.

We model the relationship between today's interest rate and the probability of the bubble collapsing in the next period as follows:

$$p_{t+1} = f + j R_t \quad j \geq 0 \quad (2)$$

The larger is j , the larger is the effect of the interest rate on the probability of the bubble collapsing. If the bubble does burst, we assume that it does not return. While this assumption is important in deriving the results, it is not important that it holds exactly; what is important is that the probability of the bubble re-emerging is relatively small.

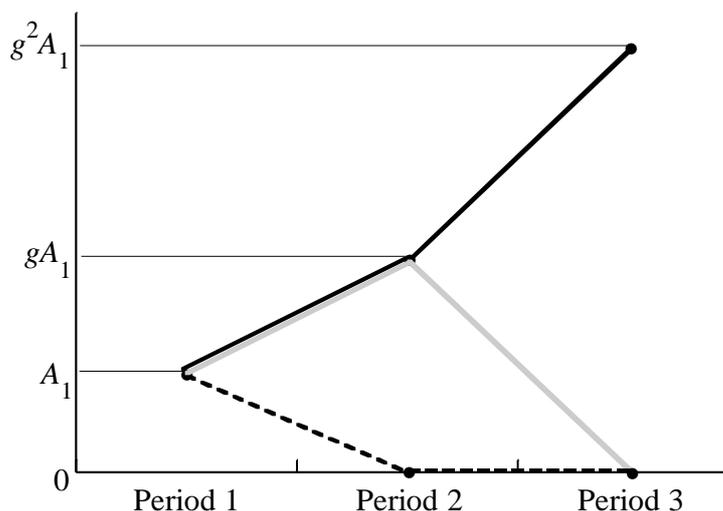
If the bubble does not burst it is assumed to grow at rate g^* so that:⁴

$$A_{t+1} = g A_t \quad (3)$$

where $g = 1 + g^*$.

The possible time paths of the bubble are shown in Figure 1.

Figure 1: Potential Paths of the Asset-price Bubble



⁴ Our model is not consistent with rational expectations. In a world of rational expectations, monetary policy induced interest rate changes will not only affect the probability of collapse, but also the current size of the bubble and the growth rate of a surviving bubble. We discuss the relevance of rational expectations in more detail below.

Having observed that a bubble has emerged in period 1, the task for the central bank is to minimise the sum of the expected squared deviations of inflation from the target. Since the central bank cannot affect the current rate of inflation, this amounts to minimising:

$$E_1(\mathbf{p}_2^2) + E_1(\mathbf{p}_3^2) \quad (4)$$

where E denotes the expected value and subscripts refer to time periods.⁵ This objective function assumes that the central bank is not only concerned about the expected value of inflation but also the variability of inflation. This objective function appears to be a reasonable representation of inflation targets in practice. Central banks care about the entire future path of inflation, and they care about the variability of inflation around the midpoint of their target.

We solve the above problem recursively, solving first for the two possible interest rates in period 2; one for the case in which the bubble bursts in period 2, and one for the case in which the bubble continues. Using these solutions we then solve for the optimal interest rate in period 1. This assumes that when setting the interest rate in period 1, the central bank knows that it will be able to change the rate in period 2, depending on whether the bubble has burst or not.

The solutions are analytically quite complicated since non-linearities are introduced by making the probabilities of various outcomes a function of the interest rate.⁶ Thus, rather than present the algebraic solution we discuss the solutions for a few different parameter sets. A summary of the results is presented in Table 1.

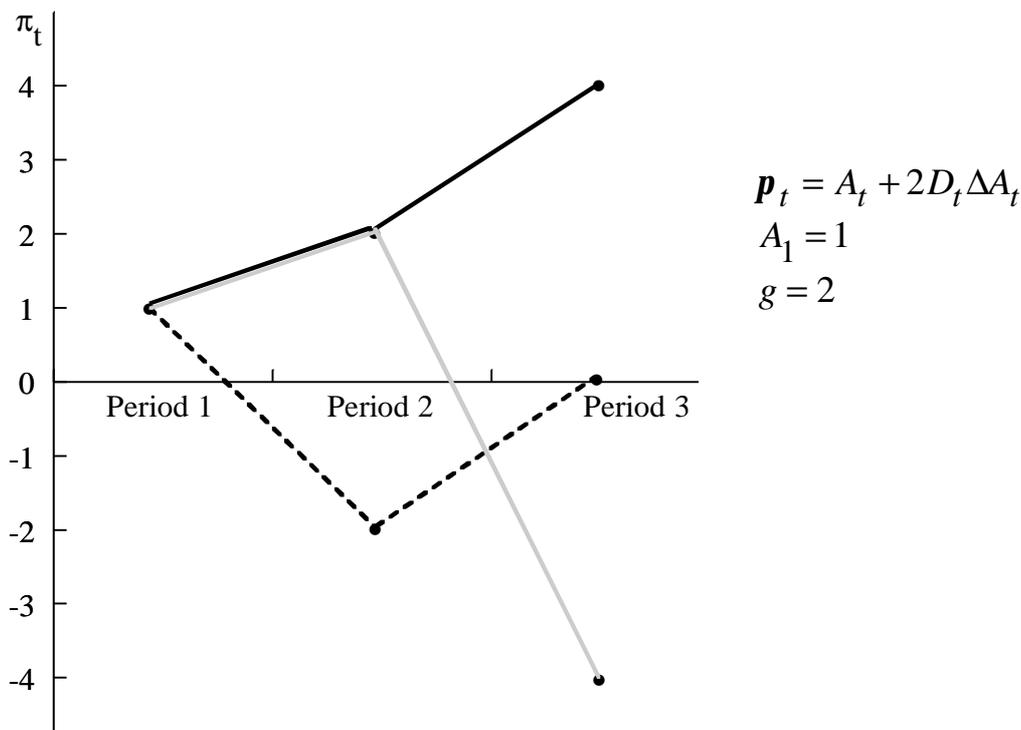
In the following examples we set $\mathbf{a} = 1$ and the size of the bubble in the first period, A_1 , equal to 1. Initially, we set $\mathbf{b} = 2$; this value implies that the asymmetric effect of asset price changes on inflation is quite pronounced. We also set $g = 2$ (if the bubble survives, it doubles in size each period). Using these parameters, we illustrate the three possible paths for inflation in Figure 2 assuming that the interest rate is equal to its neutral rate for all periods. If the bubble bursts going from the first to the second period, then inflation is below target in period 2 but then returns

⁵ In period 2, the objective becomes to minimise $E_2(\mathbf{p}_3^2)$.

⁶ The analytical solutions were derived with Mathematica Version 3.0.

to target in period 3. However, if the bubble does not burst going into period 2, inflation is above target in period 2, but more importantly, inflation will necessarily be either substantially above or substantially below target in period 3.

Figure 2: Potential Paths of Inflation with Neutral Interest Rates



In the next few examples we combine the above parameter settings with the exogenous probability of the bubble bursting next period, f , set at 0.5. That is, if the interest rate is at its neutral level, the probability of the bubble bursting is 0.5.

Now suppose that changing the interest rate has *no* effect on the probability of the bubble bursting ($j = 0$); this is case 1a in Table 1. In this example the optimal policy is to leave the interest rate unchanged (at the neutral rate); if the bubble continues next period, inflation will equal +2, if it collapses inflation will equal -2. Given that these two events have the same probability of occurring, the expected loss from the bubble bursting is equal to the expected loss from the bubble continuing. Expected inflation is equal to the target in periods 2 and 3. The expectation at period 1 of the sum of squared deviations of inflation from target is 4 and 8 for periods 2 and 3 respectively. This ‘variance’ cannot be reduced by changing the interest rate.

Table 1: Model Results

Parameter/ variable	Definition	Case 1			Case 2	
		1a	1b	1c	2a	2b
g	Growth rate of bubble	2.0	2.0	3.0	2.0	2.0
?	Exogenous probability of collapse	0.5	0.5	0.5	0.2	0.2
?	Effect of interest rates on the probability of collapse	0.0	0.2	0.2	0.0	0.2
?	Cost of bubble collapse	2.0	2.0	2.0	2.0	2.0
R_1	Interest rate in period 1	0.0	0.6	2.1	1.2	1.0
p_1	Probability of collapse in period 1	0.5	0.6	0.9	0.2	0.4
$E_1(\mathbf{p}_2)$	Expected inflation in period 2	0.0	-1.1	-3.7	0.0	-0.6

Note: The inflationary effect of the bubble (?) and the initial size of the bubble (A_1) are always set equal to 1.

In this example, monetary policy cannot affect the probability of the bubble bursting and so possible events beyond the standard transmission lag (one period) have no bearing on the current setting of policy. Of course, possible events next period are important; if we increase the growth rate of the bubble, reduce the probability of the bubble collapsing, or reduce the costs associated with a bubble collapse, interest rates should be increased, rather than held constant.

Now instead, suppose that the central bank can affect the probability of the bubble bursting (say $\mathbf{j} = 0.2$). In this case (1b in Table 1) the optimal policy is to raise the interest rate by 0.6 above the neutral rate.⁷ The higher interest rate increases the probability of the bubble collapsing from 0.5 to 0.6. The effect of this policy is to cause expected inflation to be below target in the second period (expected inflation will be at the target in the third period). Even though expected inflation is below target, the expected squared deviations of inflation from target is actually lower for periods 2 and 3 combined (that is, $E_1(\mathbf{p}_2^2) + E_1(\mathbf{p}_3^2) = 5 + 6$).

Where does our result come from? Monetary policy has two effects in this model: one standard and one non-standard. First, if the central bank takes the probability of the bubble collapsing as fixed, it faces the usual problem of making decisions under

⁷ The units are not important here, as they could be rescaled by introducing a parameter on the interest rate in Equation (1).

uncertainty. The bank solves this problem by determining the possible levels of inflation in the second period and then, taking the relevant probabilities as given, solves for the interest rate that minimises the expected variance of inflation around the target. The expected rate of inflation is equal to the bank's target.

The second, and non-standard, effect of monetary policy is on the probability of the bubble collapsing. If the central bank can affect this probability, it needs to take into account not only possible outcomes in period 2, but also possible outcomes in period 3. While the standard transmission lag is only one period, monetary policy can affect the probability of events occurring in subsequent periods. If policy can burst the bubble in period 2, the probability of the bubble bursting in period 3 is reduced to zero (because the bubble does not re-emerge). In this example, it makes sense for the central bank to raise the interest rate to increase the probability of the bubble bursting in period 2 and thereby reduce the probability of an even more extreme outcome in period 3.

As the growth rate of the bubble increases, the optimal interest rate increases at an increasing rate. A higher growth rate of the bubble increases the variance of possible outcomes in each of the following periods, with the effect being substantially larger for the third period. As a result, the pay-off to bursting the bubble in period 2 rises. For example, if g equals 3 rather than 2 (so that the bubble triples in size each period, rather than doubles), the optimal interest rate in the first period is 2.1 above the neutral level and the probability of the bubble collapsing increases to 0.9 (case 1c in Table 1). In a sense, the large increase in the interest rate amounts to a strategic attack on the bubble. Policy is tightened to such an extent that the bubble will almost certainly break. The policy-maker knows that this will be quite contractionary; not only will growth be retarded by the lagged effect of the high interest rate, but it will also be adversely affected by the flow-on effects of the fall in asset prices. Yet failing to increase the interest rate results in a much higher probability of a larger crash at some later point.

In case 1a above, optimal policy involves maintaining the interest rate at its neutral rate when the probability of the bubble bursting is exogenous, but increasing the interest rate when the probability is endogenous. We now consider case 2a, in which the optimal policy is to increase the interest rate when the probability of the bubble bursting is exogenous. To do this we reduce θ (the exogenous probability of collapse) from 0.5 to 0.2, while keeping all other parameters unchanged. With a

reduced probability of the bubble bursting next period, it is more likely that the inflation will be above target in the second period and so the optimal interest rate in period 1 is higher than it was in the earlier case (1.2 compared to 0). If we now make the probability of collapse endogenous ($j = 0.2$), the optimal policy again sees the interest rate above the neutral level (to 1.0; case 2b), but the interest rate is smaller than that required when the probability of collapse is not influenced by monetary policy.

In this example, the higher interest rate needed to counteract the expansionary effect of the asset-price bubble also increases the probability of the bubble collapsing; this amplifies the expected effect of the tightening of policy. The central bank should therefore increase the interest rate by a smaller amount than would otherwise be the case. This result comes partly from the way we have modelled the probability of the bubble collapsing (Equation 2). If this probability is a function not of the deviation of the interest rate from the neutral level, but of the difference between the interest rate and the rate needed to offset the standard expected demand effects of the bubble (1.2 in the above example), then monetary policy would always be tightened by more than the standard analysis would suggest.

While the results described so far are partly driven by the value of parameters that we have chosen, the basic insight of the model is general and holds true for a wide range of parameter values. The fundamental point is that the central bank may need to raise interest rates to attempt to burst an asset-price bubble with the result that expected inflation is below target in the short run. This conclusion is driven by three basic elements of the model. Namely, that the probability of the bubble bursting is an increasing function of the interest rate; that if a bubble bursts it does not return (in the near term) and that the central bank has a desire to avoid very extreme deviations of inflation from target. This result will hold for some range of parameter values, so long as either one of β , the direct effect of the bubble, or γ , the indirect asymmetric effect of the bubble collapsing, are non-zero.

3.2 A Simple Extension – Bigger Bubbles are More Likely to Burst

We have assumed that the probability of the bubble bursting in the next period is only a function of the current interest rate. This can be generalised to allow for other influences on this probability. Here we allow the size of the bubble to affect the probability of it bursting next period. We assume that the larger is the size of the

bubble the higher is the probability that the bubble will burst in the next period. This assumption can be justified on the grounds that as the bubble becomes larger and larger, more and more people identify the increase in asset prices as a bubble and become increasingly reluctant to purchase the asset; this makes it more likely that a correction will occur.

To capture this idea we replace Equation (2) with the following:

$$p_{t+1} = f + j R_t + l A_t \quad (2')$$

We again consider the solutions when the initial size of the bubble equals 1, the growth rate of the bubble is equal to 2, the exogenous probability of collapse equals 0.5 and the effect of interest rates on the probability of collapse equals 0.2 (this is case 1b above, with θ equal to zero). We begin by assuming that θ is equal to 0.15 (case 3a in Table 2). By allowing the probability to be influenced by the

Table 2: More Model Results

Parameter/ variable	Definition	1b	3a	3b
g	Growth rate of bubble	2.0	2.0	2.0
θ	Exogenous probability of collapse	0.5	0.5	0.5
θ	Effect of interest rates on the probability of collapse	0.2	0.2	0.2
θ	Effect of bubble size on the probability of collapse	0.0	0.15	0.3
θ	Cost of bubble collapse	2.0	2.0	2.0
R_1	Interest rate in period 1	0.6	0.3	-0.1
p_1	Probability of collapse in period 1	0.6	0.7	0.8
$E_1(p_2)$	Expected inflation in period 2	-1.1	-1.2	-1.1

Note: The inflationary effect of the bubble (θ) and the initial size of the bubble (A_1) are always set equal to 1.

level of the bubble, the optimal interest rate response is reduced. In this example, the optimal interest rate in period 1 is 0.3, rather than at 0.6. If we increase the impact of the bubble's size on the probability of the bubble bursting, interest rates may actually fall below the neutral rate (case 3b). The intuition is that if it is likely that the bubble will collapse under its own weight, the case for monetary policy to

be used in an attempt to burst the bubble is much weaker. If there is a high probability that the bubble will burst of its own accord, monetary policy needs to be more concerned with the contractionary effects of the expected collapse; in some circumstances this might require a reduction in interest rates before the collapse actually occurs!

3.3 Rational Expectations

In our model we do not allow the current size of the bubble to be influenced by the current interest rate, nor do we allow the growth rate of the bubble to be influenced by the level of the interest rate. In this regard, the behaviour of the asset-price bubble in our model is not entirely satisfactory. More generally, the behaviour of the bubble is not consistent with rational expectations. However, we argue that it is not possible to incorporate rational expectations into our model. Even so, we believe that our model provides a realistic description of how a central bank should respond to asset-price bubbles.

For a bubble to satisfy the requirements of rational expectations, the expected capital gain on the bubble component of the asset must be equal to some given outside rate of return (Blanchard and Fisher 1994). In the case of a *deterministic bubble*, the bubble expands at a fixed rate. In the case of a *stochastic rational bubble*, there is some probability that the bubble will collapse, so that the growth rate of a surviving bubble is higher than the growth rate of the deterministic bubble. This difference is necessary to encourage rational investors to hold the asset. In fact, the growth rate of a *surviving* bubble must increase when the probability of the bubble collapsing increases.

In our model, there is some probability that the bubble will collapse. However, the growth rate of a surviving bubble is independent of this probability.

Before explaining why it is difficult to incorporate rational expectations in our model, we present a familiar example of the relevance of rational expectations for monetary policy and asset prices. In the Dornbusch (1976) model of exchange rate overshooting there are two broad effects on the exchange rate of a surprise tightening of monetary policy that causes domestic interest rates to rise above the foreign interest rate. First, uncovered interest parity says that the expected exchange rate must be depreciating – that is, the growth rate of the exchange rate has fallen.

Second, when the tightening is announced, the level of the exchange rate will jump. In this model the size of the initial exchange rate appreciation is determined by the final equilibrium level of the exchange rate and the speed of adjustment along the path to the final equilibrium.

Compare this to the effect of an increase in the interest rate on an asset-price bubble. The return on the bubble component of the asset price is equal to the expected capital gain on the bubble, which we take as given. When the interest rate increases, so does the probability of the bubble bursting. Therefore, to keep the expected capital gain on the bubble constant, it must be the case that the growth rate of a surviving bubble increases. However, the value of the asset-price bubble should also have a discrete jump down when the interest rate increase is announced. Unlike the example of exchange rate overshooting, there is no way of tying down the size of the initial jump in the bubble when the interest rate changes. This is because the size of the bubble is indeterminate in the first place, given that the bubble by definition is a deviation from the fundamental value of the asset. Herein lies the problem of incorporating rational expectations into our model.

A naive approach would be to make the growth rate of a surviving bubble (g^*) an increasing function of the interest rate. By itself this could imply a circumstance where the central bank would actually want to lower interest rates in order to reduce the size of a surviving bubble! A more complete analysis would be likely to rule out this prescription by realising that there would be a discrete jump in the level of the bubble in the opposite direction of the interest rate change (for a large enough increase in interest rates the bubble may even collapse instantaneously).

If we are primarily concerned with property prices, the failure of rational expectations in our model is not a major issue. Changes in interest rates do not appear to lead to immediate and discrete jumps in the level of property prices, as might be the case for other assets which are continuously traded in relatively deep markets.⁸ We regard it as a realistic assumption that the central bank takes the current level of property prices as given and that a change in interest rates does not lead to an immediate jump in property prices, but does increase the probability of the bubble bursting.

⁸ Although, discrete jumps in property prices could be partially obscured by the fact that data on these prices are not collected on a continuous high-frequency basis.

3.4 A Summary

The above discussion highlights a number of general points:

- ? A central bank may wish to raise interest rates to increase the chance of an asset-price bubble bursting in the short run if declines in asset prices have significant effects on the stability of the financial system. While such a policy is likely to lead to a period of below trend growth and inflation below target in the short run, it reduces the probability of the much larger medium-term swings in output and inflation that would eventuate if the bubble was allowed to continue unchecked.
- ? The monetary authorities need to be concerned with possible outcomes beyond the period of the normal transmission lag. If the probability of a bubble collapsing is endogenous, the expected path of the economy beyond the control lag is affected by today's interest-rate decision.
- ? If interest rates need to be increased to offset the standard expansionary effect of a bubble, the size of the optimal interest-rate increase may be smaller if the probability of a bubble collapsing is endogenous rather than exogenous. By adding what amounts to an additional transmission channel, the size of the optimal response may decline. Also, the case for higher interest rates is weakened if there is a high probability that the bubble will collapse under its own weight.

4. Financial Regulation and the Inflation Environment

In the above model we assumed that the parameters linking asset price changes to inflation are fixed, and not influenced by other policy instruments or by the general macroeconomic environment. In this section we relax this assumption and discuss how financial regulation and the central bank's target rate of inflation might affect these parameters and thus affect the appropriate monetary policy response to an asset-price bubble.

4.1 The Role of Financial Regulation

So far we have assumed that the authorities have only one policy instrument. If other instruments – such as prudential regulation – are available, the need for monetary policy to respond to changes in asset prices is lessened. Sound bank regulation and supervision are likely to reduce the links between asset price growth and credit growth and reduce the financial system's exposure to a decline in asset prices. This should lessen the asymmetric inflation effects of asset price changes (measured by Δ).

Financial regulation might also be able to reduce Δ . By leading to tighter liquidity constraints on borrowers as the asset-price bubble grows, appropriate regulation and good credit assessment techniques reduce the scope for higher perceived wealth to be translated into higher consumption, and thus higher inflation.

The greater is the ability of regulatory policy to insulate the economy and the financial system from the effects of asset-price bubbles, the smaller will be the required monetary policy response to an asset-price bubble, and thus the closer expected inflation will be to target and economic growth to potential growth. In this way, sound bank regulation makes it easier for the central bank to achieve its inflation target. In the limit, if regulatory policy were able to reduce both Δ and Δ to zero, asset price changes need have no implications for monetary policy.

Note, however, that a role for monetary policy remains if regulatory policy is unable to eliminate the symmetric effect of asset price movement on inflation, even if it does eliminate the asymmetric effect (that is, $a > 0$ and $b = 0$). In this case, if the asset-price bubble is allowed to run unchecked, the expected variability of inflation and output are still unnecessarily high because of the direct effects of the bubble. Optimal monetary policy would still seek to bring forward the correction in prices and benefit from the fact that once the bubble collapses it will not reappear for some time.⁹ The important point, however, is that using regulatory policy to reduce the asymmetric effect of asset price changes on inflation, reduces the need for monetary policy to respond to asset-price bubbles and reduces the variability of inflation and output.

⁹ Using the same type of reasoning, the same is true if $a = 0$ and $b > 0$.

While sound bank regulation and supervision are likely to reduce the need for the monetary authorities to run tight policy to burst a bubble, the more difficult issue is what form that policy should take. In principle, cyclical changes in banking regulation might be appropriate; for example, increasing loan to valuation ratios or imposing higher capital ratios in the upswing of the cycle might slow a credit/asset-price boom and enhance the stability of the financial system. However, the very real danger with such an approach is that it is likely to induce a shift towards financial institutions that are more lightly regulated. In a sense this was the experience in Australia in the early 1970s (Kent and Lowe 1997).¹⁰ Tight regulation on banks simply saw the rapid growth of non-bank financial institutions (some of which were owned by banks) and the transfer of risk to these institutions. The lesson from this period is that imposing restrictive regulation on just one part of the financial system leads to a flow of resources to another part of the system. This reduces the effectiveness of the regulation and distorts the dynamic efficiency of the financial system. In fact, it was for these reasons that many central banks around the world embarked on a program of extensive deregulation of the financial system in the late 1970s and early 1980s.

While the case for using *changes* in prudential regulation to deal with asset price fluctuations is relatively weak, there is a much stronger consensus that well structured prudential policy, even if it does not respond dynamically to movements in asset markets, makes the financial system less prone to instability. Many of the principles of such a regulatory system are set out in the Basle Core Principles. While these measures do not rule out lending booms on the back of asset price rises, they help reduce the costs of asset price booms and busts. As such, they make the task of monetary policy easier and contribute to the stability of both output and inflation.

¹⁰ Large increases in property prices saw rapid growth of non-bank financial institutions as well as other vehicles for investing in property. When the property price crash eventuated, losses were concentrated in these institutions rather than in the banks, but there were still considerable contractionary effects on the economy.

4.2 Implications of Low Inflation

A second issue is whether the target rate of inflation affects the critical parameters of our model.

We have argued above that asset-price declines can have large effects on output and inflation. However, we have largely ignored the issue of whether the size of these effects depends upon the rate of inflation. While this was useful from a modelling point of view, the asymmetric effects of asset price changes may well depend upon the background rate of inflation. When inflation is low, a given correction in real asset prices must occur through falling nominal prices, rather than asset-price inflation failing to match goods and services price inflation. The Australian experience is instructive here. After the property-price boom of the early 1970s, real property prices declined significantly; while this involved some fall in nominal prices, the high background rate of goods and services price inflation accounted for much of the adjustment in real prices. In contrast, in the low-inflation 1990s, relatively more of the adjustment in real property prices has taken place through the nominal price of property falling (Kent and Lowe 1997).

Since in a low-inflation environment falls in nominal asset prices are more likely, financial institutions run a greater risk of not being able to collect the full collateral value on bad loans. In response, some reduction in average loan-to-valuation ratios may be appropriate. If this does not occur, bubbles in asset markets may be more costly in a low-inflation environment because they increase the risk of difficulties in the financial system. In terms of our model, this means that the size of the asymmetric effect, β , of a bubble collapsing may be higher in an environment of steady low inflation than in an environment of steady higher inflation (other things being equal). If this is the case, low inflation increases the importance of monetary policy responding relatively early in the life of the bubble.

While low inflation increases the probability of nominal asset price declines, it should also reduce the probability of an asset-price bubble emerging in the first place. In an environment in which inflation is high and variable, property acts as a hedge against inflation and there are also substantial tax advantages to property

investments. In a low-inflation environment these advantages are reduced, making speculative increases in property prices less likely.¹¹

While low and stable inflation should reduce the likelihood of an asset-price bubble occurring, it does not guarantee that bubbles will not occur; the Japanese experience in the late 1980s is an obvious example. If a bubble does occur in a low-inflation environment, and financial institutions do not adjust their lending practices, there are perhaps stronger implications for the future health of the financial system than would be the case if inflation was higher. As a result, low inflation may raise the returns to early action to increase the probability of the bubble collapsing.

5. Conclusion

In this paper we have developed a theoretical framework that helps to analyse the role of monetary policy in responding to asset-price bubbles. Our primary concern is with asset classes that form the basis of collateral for loans from financial intermediaries, and thus have implications for the financial system. A large and rapid fall in the nominal price of these assets can have adverse effects on financial system stability. In this way the collapse of the bubble can reduce the extent of intermediated finance, reduce output below potential for an extended period and, in the process, keep inflation below the central bank's target.

¹¹ There is also the question of the likelihood of a bubble emerging during a transition phase between high and low inflation environments. A lowering of the rate of inflation should lead to an increase in the value of real assets because average real interest rates are likely to be falling when moving from a period of disinflation into a period of sustained low inflation. However, determining the extent of this effect is difficult, and improving fundamentals can themselves be conducive to generating bubbles. In addition, a number of authors have argued that low inflation reduces the 'equity risk premium'. As a result, real equity prices should increase as low inflation becomes entrenched (Modigliani and Cohn 1979; Blanchard 1993). Furthermore, lower nominal interest rates associated with lower inflation can reduce liquidity constraints which can place further upward pressure on asset prices. In Australia, it is not uncommon for financial institutions to set an individual's maximum borrowing capacity for a home loan such that the loan would generate initial repayments equal to 30 per cent of the individual's income. As a result, lower interest rates mean larger loans and more individuals qualifying for a housing loan (Stevens 1997).

The central insight of our analysis is that when an asset-price bubble emerges, there may be circumstances where monetary policy should be tightened in order to bring on the collapse of the bubble before it becomes too large, even though this means that expected inflation is (temporarily) below target. The reason for doing so is that such a policy can help to avoid extreme longer-term effects of a larger asset-price bubble and its eventual collapse. This result is driven by three essential elements. First, tighter monetary policy increases the likelihood of the bubble bursting. Second, when the bubble bursts it does not reappear for some time. And third, that the monetary authority wants to avoid the possibility of extreme outcomes for inflation.

Satisfying the requirements for good financial regulation should significantly reduce the costs of collapses in asset-price bubbles, and also help to slow the progress of a bubble by putting pressure on the circular linkages between asset prices, collateral values, intermediated finance and output. This should reduce (although not eliminate) the need for monetary policy to respond to asset-price bubbles, allowing expected inflation to be closer to target, and output to be closer to potential output. Finally, in a low-inflation environment asset-price bubbles are less likely, although if they occur, they may be more costly. An implication of this is that asset-price developments need to be carefully studied by central banks even when goods and services price inflation is at, or close to, target.

References

Alchian, A. and B. Klein (1973), ‘On a Correct Measure of Inflation’, *Journal of Money, Credit and Banking*, 5(1), pp. 173–191.

Bernanke, B. and M. Gertler (1990), ‘Financial Fragility and Economic Performance’, *Quarterly Journal of Economics*, 105(1), pp. 87–114.

Blanchard, O. (1993), ‘Movements in the Equity Premium’, *Brookings Papers on Economic Activity*, 2, pp. 519–543.

Blanchard, O.J. and S. Fischer (1994), *Lectures on Macroeconomics*, The MIT Press, Cambridge, Massachusetts.

Dornbusch, R. (1976), ‘Expectations and Exchange Rate Dynamics’, *Journal of Political Economy*, 84(6), pp. 1161–1176.

Fisher, I. (1933), *Booms and Depressions*, George Allen and Unwin Ltd, London.

Gertler, M. (1992), ‘Financial Capacity and Output Fluctuations in an Economy with Multi-period Financial Relationships’, *Review of Economic Studies*, 59(3), pp. 455–472.

Goodhart, C. (1993), ‘Price Stability and Financial Fragility’, paper presented to the Conference on Financial Stability, H.C. Coombs Centre for Financial Studies, Sydney, 31 October and 1 November, 1993.

Gruen, D.W.R. and J.A. Dwyer (1995), ‘Are Terms of Trade Rises Inflationary?’, Reserve Bank of Australia Research Discussion Paper No. 9508.

Kent, C. and P. Lowe (1997), ‘Property-Price Cycles and Monetary Policy’, paper presented at the Central Bank Economists’ Meeting, Basle, 28 to 29 October.

Kiyotaki, N. and J. Moore (1995), ‘Credit Cycles’, National Bureau of Economic Research Working Paper No. 5083.

Lowe, P.W. and T. Rohling (1993), 'Agency Costs, Balance Sheets and the Business Cycle', Reserve Bank of Australia Research Discussion Paper No. 9311.

Modigliani, F. and R.A. Cohn (1979), 'Inflation, Rational Valuation and the Market', *Financial Analysts Journal*, March/April, pp. 3–23.

Smets, F. (1997), 'Financial Asset Prices and Monetary Policy: Theory and Evidence', in P. Lowe (ed.), *Monetary Policy and Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp. 212–237.

Stevens, G.R. (1997), 'Some Observations on Low Inflation and Household Finances', Reserve Bank of Australia *Bulletin*, October, pp. 38–47.

Tarditi, A. (1996), 'Modelling the Australian Exchange Rate, Long Bond Yields and Inflationary Expectations', Reserve Bank of Australia Research Discussion Paper No. 9608.