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Monetary Policy and Asset Price Bubbles: Calibrating the Monetary Policy Trade-offs

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Abstract

The issue of monetary policy and asset prices has been receiving much attention not only because it is an interesting topic for macroeconomists but also because central banks have faced daunting challenges from large swings in various types of asset prices. To some extent, the achievement of a low, stable inflation environment has not simultaneously brought about a more stable asset price environment. The record over the past decade, in fact, has raised the prospect of asset price booms and busts as a permanent feature of the monetary policy landscape. This paper lays out a general framework to explore some of the key monetary policy tradeoffs presented by asset prices, with particular emphasis on the role of asset price bubbles.

The paper first discusses what economists mean by asset price bubbles before offering a stylised macroeconomic model in which a monetary authority can influence the behaviour, in only an indirect way, of the path of asset prices. The baseline model suggests that central banks should systematically response to asset price developments generally and asset price bubbles specifically. Indeed, there are good reasons for the central bank to focus only on asset price bubbles, rather than the fundamental component of asset prices, when calibrating its monetary policy response. This general result does not depend on the volatility of asset prices per se or necessarily on the ability to distinguish fundamental movements in asset prices from asset price bubbles. The paper then introduces a form of uncertainty - intrinsic paradigm uncertainty about the existence of bubbles - to show how policymakers might want to weigh the options to respond or not to respond in such an environment. The paper then goes beyond the confines of the model to offer insights about issues such as moral hazard, nonlinearities, multivariate bubbles and communication strategies.

Keywords: monetary policy, asset price bubble

JEL classification: E5, G1

Table of contents

Introduction[1]

The issue of monetary policy and asset prices has been receiving much attention not only because it is an interesting topic for macroeconomists but also because central banks have faced daunting challenges from large swings in various types of asset prices. To some extent, the achievement of a low, stable inflation environment has not simultaneously brought about a more stable asset price environment. The record over the past decade, in fact, has raised the prospect of asset price booms and busts as a permanent feature of the monetary policy landscape. And the forces associated with these booms and busts appear to be exerting themselves in the current period. For example, ebullient real estate prices in various markets - the United Kingdom, Australia and Korea to name just a few - have created a disquieting sense of déjà vu.

Should we react or not? This is a question that has been asked over and over again by central banks, especially when asset prices have moved in a seemingly anomalous fashion. On the one hand, reacting may moderate the upward path of unsustainable asset prices and possibly prevent a disorderly unwinding. On the other hand, reacting may forestall a beneficial burst of economic activity and raise questions about a central bank's competencies. The trade-off is particularly difficult to calibrate because of various types of uncertainty associated with the analysis of the problem. Is it a bubble or is it not? How should asset prices generally and asset price bubbles specifically be modelled? What are the likely consequences of booms and busts?

This paper lays out a general framework to explore some of the key monetary policy trade-offs presented by asset prices, with particular emphasis on the role of asset price bubbles.[2] The first section of the paper develops a working definition of a macroeconomically relevant asset price bubble built upon previous theoretical and empirical research. With this, a benchmark monetary policy model with a role for asset prices is presented and the optimal policy response characterised. The subsequent sections address a range of modelling issues that enrich the analysis. The final section deals with some practical communication issues arising from the public discussion of asset price bubbles. The paper concludes that the case for thinking about asset price bubbles - rather than just asset price movements - is strong and in many ways sheds considerable light on the challenges facing monetary policymakers. Over the longer run, more research into asset prices, especially bubbles, could have high payoffs.

Bubble trouble: the case for focusing on bubbles

There are few topics in macroeconomics as contentious as that of asset price bubbles. Indeed, the debate has become more heated in recent years in the light of the large run-up in asset prices and their subsequent fall in the United States and elsewhere.[3] The discussion in this paper takes an intentionally provocative stance on asset price bubbles. To explore the potential intersection of asset price bubbles and monetary policy, it is useful to assume initially that asset price bubbles exist and are a significant feature of modern economies. Moreover, we need an operational definition of a bubble that is relevant to monetary policy. This section develops one by drawing on various aspects of existing theoretical and empirical research into asset price bubbles, and offers a working "definition" of

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[2]   This paper draws heavily on Filardo (2000, 2001, 2003c).

[3]   Another issue of interest is the root cause of asset price bubbles. See, for example, Allen and Gale (1999) for a good discussion of various models that might give rise to bubbles. In addition, the exact timing of the initiation of a bubble and the precipitating events leading to the bursting of a bubble are left to future investigation.

a *macroeconomic asset price bubble* that will be used in the rest of the paper to explore the implications for monetary policymakers.

The study of asset price bubbles has a rich yet, at times, controversial history.[4] It might be said that there still is considerable doubt about the relevance, if not the existence, of asset price bubbles. This topic is so controversial that some policymakers and researchers find it more useful to avoid the label of "bubble" and prefer to view wide swings in asset prices as booms and busts, financial imbalances or, in a policy setting, simply risks. At some level, the naming convention may represent inconsequential semantics. But on another level, if economists look at the wide swings and see irrationality, euphoria, herding and other non-fundamental forces at work, something might be overlooked by skirting the possibility of asset price bubbles.

So, what do economists exactly mean by "bubbles"? There is no simple answer. From a research point of view, the exact definition varies from one model to another. Rather than adopt one particular model, this paper uses a reduced-form approach that incorporates salient features of bubbles shared by many important models in the literature.

Rational bubble models are a good starting point to identify the key features of asset prices that economists associate with bubbles. In a forward-looking general equilibrium model based on rational behaviour and infinite horizons, rational bubbles arise because of the nature of expectations. These bubbles simply reflect the fact that expectations of rising prices can be self-fulfilling equilibrium outcomes. The key condition governing rational bubbles is that rational bubbles must conform to this expectational restriction:

$$E_t b_{t+1} = k b_t \text{, with } k > 1 \tag{1}$$

From this equation, we can see that rational bubbles have the following properties. They generally grow without any connection to fundamentals. Indeed, one of the motivations for holding a speculative asset experiencing a price bubble is the expectation that it will continue to rise. In the case where an iid error term also determines the evolution of the bubble, the bubble would also be driven stochastically by an extraneous factor unrelated to economic fundamentals.

Blanchard and Watson (1982) proposed a somewhat more appealing model of a bubble by building in stochastic asset price collapses:

$$b_{t+1} = \begin{cases} (1+r) b_t \dfrac{1}{p} + v_{t+1}, \text{ with probability } p \text{ of not bursting} \\ v_{t+1} \qquad\qquad \text{, with probability } 1-p \text{ of bursting} \end{cases} \tag{2}$$

These bubbles seem more realistic because they can start, collapse and start up again over and over. In particular, the bubble either grows with probability p or collapses with probability $1-p$. It is a rational bubble in the sense that equation (2) is consistent with equation (1), ie because $E_t(v_{t+1}) = 0$ by construction.

It is important to note that the evolution of rational bubbles need not always be completely detached from economic fundamentals. Froot and Obstfeld (1991), for example, introduced the notion of an intrinsic asset price bubble. The bubble generates highly persistent overvaluations and undervaluations due to excessive reactions to fundamentals.[5] These authors argue that linking, albeit incompletely, asset price bubbles to fundamentals provides a more realistic specification of a bubble. In addition, as will be argued later in the paper, the fact that a bubble is related to fundamentals provides a channel by which a monetary authority can influence, but not perfectly control, the evolution of an asset price bubble. This possibility enriches the set of trade-offs facing a policymaker.

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[4] See, for example, Garber (2000) and Kindleberger (2000).

[5] These rational bubbles differ fundamentally from the types studied by Santos and Woodford (1997).

While a theoretical curiosity, rational bubbles suffer from well-known theoretical and real-world inconsistencies. A rational bubble consistent with equation 1, for example, is assumed to grow in an explosive fashion. In reality, this is impossible because at some finite point in time the asset price would exceed all available earthly resources. By backward induction, if the bubble cannot grow forever, then theory says that the bubble could not start in the first place. And, even though the asset price bubble in equation 2 appears to avoid this problem because it may collapse in finite time, it too has a problem. Grossman and Diba (1988) point out that once the Blanchard and Watson bubble bursts, it cannot start growing again in a world of hyper-rational investors.[6] Therefore, we should not take the rational bubble models too literally as regards to what happens in the real world, but rather think of them as an approximation.[7]

Naturally, the types of bubbles relevant for monetary policy are ultimately empirical phenomena. The key issue is whether anything that resembles these theoretical bubbles can be found in the data. The results from econometric tests have generally been mixed. Some tests find evidence of rational bubbles while others reject them - the results depend generally on the underlying model of the bubble and the data.[8] Part of the reason for the mixed picture is that there are several well known difficulties in testing for bubbles. First, empirical tests are based on the joint hypothesis of the existence of bubbles and on a particular model of bubbles. Rejection of the null hypothesis can arise from either the absence of a bubble or a faulty model specification. Second, in a rational expectations model of asset prices, it may be impossible to know if mispricing errors represent bubble behaviour or if the econometrician has access to less information than is available to investors.[9]

One class of bubble models puts less weight on the theoretical purity of the model and more on the pragmatic relevance to policy makers. Meltzer (2003), for example, has emphasized the need to consider non-rational bubbles in thinking about the monetary policy environment. These bubbles exhibit some of the salient features of the rational bubbles without the restrictive assumptions of hyperrationality. Non-rational bubbles are characterized as a rapid upward movement in asset prices, based on exaggerated beliefs about some fundamentals such as greatly enhanced productivity. Ultimately, however, such bubbles collapse. This approach is closely related to the ideas Kindleberger (2000) had in mind when thinking about classic asset price bubbles.

For Kindleberger, asset price bubbles were permanent features of the economic environment that arose because of the nature of human behaviour. He bases his understanding of bubbles on Minsky's model of financial imbalances rather than on the constraints imposed by the assumption of perfectly rational, far-sighted investors. In Minsky's model, a speculative bubble arises from an exogenous factor - possibly a new invention, a political outcome, a financial liberalisation, etc - that presents new profit opportunities. If the future looks sufficiently bright for a large enough group of consumers and investors, the boom becomes self-sustaining and possibly self-reinforcing. Real-side developments may then interact with the financial intermediation sector, which, through an elastic credit creation process, stokes the flames of optimism. As supply constraints become increasingly binding, the boom can peter out or enter the "euphoria" stage, where speculation motives kick in with a vengeance. As long as asset prices continue to climb, the system can sustain an upward spiral of prices. Increasing

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[6] Grossman and Diba (1988) point out that the impossibility of negative bubbles precludes the restarting of rational bubbles of the Blanchard and Watson (1982) type.

[7] While the deep implications of rationality in an infinite horizon setting can rule out most bubbles as logical impossibilities, other theoretical settings may be more fertile for bubbles to grow. Tirole (1985) offers an alternative framework of a finite-lived overlapping generations model, which under certain conditions can generate bubbles that grow, burst and restart. As a theoretical possibility, negative bubbles were also generally thought to be inadmissible. Weil (1990), however, argues that negative bubbles can be thought of as persistent undervaluations of asset prices where an increase in interest rates in equilibrium may cause asset prices to fall below the "non-bubbly" fundamentals. In models in which confidence matters, overly pessimistic attitudes can lead to persistent undervaluations. Finally, these models have been criticized for their assumptions that they put arbitrary limits on short selling or rely on irrational arbitrageurs. Abreu and Brunnermeier (2003), however, recently show that bubbles can exist in markets with rational arbitrageurs as long as they cannot coordinate their selling strategies.

[8] The testing for asset price bubbles has a long history. Blanchard and Watson (1982), West (1987), Froot and Obstfeld (1991), Chirinko and Schaller (1996, 2001), Wu (1997) and Bhar and Malliaris (2001) find evidence supporting the existence of speculative bubbles.

[9] See Cogley (1999) for a recent restatement of the argument that the evidence of a speculative bubble can simply reflect rational investors responding to unobserved (to the econometrician) fundamentals.

leverage provides another possible channel through which to boost momentum as successes breed envy.[10] At some point the fragile edifice upon which the boom is built can no longer support the weight and implodes, taking asset prices with it.

While asset price booms and busts hardly follow this exact script, Kindleberger provides considerable prima facie evidence in support of the notion that the broad contours are plausible and consistent with a wide range of cross-country experiences. Since the initial publication of his book, such asset price booms and busts have continued to exhibit behaviour consistent with his view. Graphs 1-3 offer snapshots of the wide swings of equity, residential real estate and commercial real estate prices across a broad set of countries at different stages of economic development. The frequency and pervasiveness of such booms and busts have clearly remained. Recent BIS research has lent further support to the view that asset booms and busts are important phenomena - not one-off events but a more pervasive and regular part of the economic environment. See, for example, Borio and Lowe (2002a, 2003), Borio et al (2003) and Borio and White (2003) for more details of this view. Indeed, the high level of asset prices, especially real estate values, has recently raised red flags for policy makers. Compounding this concern is the fact that despite the rise in asset values, many countries have been experiencing high or rising household debt as a share of assets, indicating that households are becoming more leveraged (Graph 4). From a longer historical perspective, Bordo et al (2001) find that financial crises - a somewhat broader notion than asset price booms and busts - over the past 120 years have become more frequent but not obviously more severe.

What conclusions can be drawn from this review of the literature on asset price bubbles? First, an asset price bubble might best be summed up by its general shape. An asset price tends to grow persistently out of line with fundamentals, often in a frothy way, and tends to end unexpectedly with a sharp correction. In addition to this asymmetry, an asset price tends to alternate between persistent undervaluations and overvaluations.

Second, for a study of monetary policy trade-offs, the focus should be on a bubble's size, hence the label *macroeconomic* asset price bubbles. Magnitudes matter and a relevant asset price bubble should be large enough to affect macroeconomic variables relevant to monetary policy decisions.

As is often the case with somewhat qualitative definitions, it is sometimes easier to explain what a bubble is not rather than what it is. In particular, we are not interested in deviations from fundamentals that could best be described as a standard error terms in asset pricing equations. Likewise, when considering a macroeconomic asset price bubble, we are not interested in small short-lived bubbles in financial markets that might be due to fads, herding, bandwagon effects, positive feedback, information cascades, etc. If such phenomena are limited to a small sector of the economy, they are unlikely to have a large impact on the economy as a whole. Arguably, the dotcom bubble may have been big for the Nasdaq, but its macroeconomic significance was modest. Macroeconomic asset price bubbles would also rule out asset price anomalies that arise from issues of microfinance.[11] Foibles in the microstructure of the market may lead to paradoxes and anomalies in particular corporate stocks or derivatives contracts, but the consequences for output and inflation are probably inconsequential.[12]

To some, this relatively ad hoc definition of a macroeconomic asset price may seem inadequate. The drawback of this definition is also compounded by connotation problems with the term "bubble"; the public has used the term "bubble" to connote so many different aspects of asset price movements that it may be too imprecise to be meaningful. But to others, the qualitative definition might be insightful enough to frame important policy issues. In a sense, this view might be best characterised as the US Supreme Court Justice Stewart view of macroeconomic asset price bubbles.[13] It might be said of the definition of macroeconomic asset price bubbles, "I could never succeed in defining them, but I know

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[10] The recent run-up in consumer debts associated with rapid durables purchases in various countries is an example of the type of leverage that can deepen concerns about bubbles.

[11] See, for example, De Long et al (1990), Shiller (2000) and Shleifer (2000). Lo and MacKinlay (1999) provide a good survey of financial market anomalies.

[12] Cochrane (2003) argues that certain thin markets for stocks help to explain the tech boom on the Nasdaq. If convenience yield motives were sufficiently great, one could imagine market-specific anomalies spilling over to the real economy. No one, however, has yet established such a link.

[13] Justice Stewart (1964) is famous for having written: "It has been said of that definition [of obscenity], 'I could never succeed in [defining it] intelligibly, but I know it when I see it".

them when I see them." To this we might add, "And when they see them, policymakers should be concerned."

Is such an imprecise definition so unreasonable? I would like to draw parallels between what I am advocating here and the approach that arguably has worked rather well in the empirical business cycle literature: Burns and Mitchell's definition of business cycle phases.[14] This definition of the cycle has survived the test of time. While imprecise, it still resonates as a useful benchmark with which to observe and judge important economic phenomena. It is in this spirit that I use the term macroeconomic asset price bubble.

Macroeconomic asset price bubbles and the macroeconomy

Rather than summarise the voluminous literature on the correlations between various asset prices and macroeconomic variables, I will raise a critical issue about the causal versus predictive role of asset prices. This distinction highlights the need to differentiate between macroeconomic asset price bubbles and general asset price movements, especially when examining the challenges facing monetary authorities. Put bluntly, in a causal sense, macroeconomic asset price bubbles matter and the fundamental component of asset prices does not.

Consider first the fundamental component of asset prices. Economics, and in particular finance theory, is based on prices reflecting economic fundamentals. The fundamental component of asset prices, for example, is defined as the present value of the discounted flow of returns. For equities, asset prices are supposed to reflect the discounted value of future dividends. For real estate, the price would reflect the discounted flow of (implicit) housing services and pecuniary "dividends" in terms of capital gains or market rent. Other asset prices have analogous definitions relevant to their particular market. Except for an exogenous random noise term, the fundamental component of asset prices simply reflects fundamentals in standard asset pricing models.

Put differently, the fundamental component of asset prices does not "cause" output or its components; the converse is generally true. In terms of macroeconomic modelling, a well-specified output or inflation equation would have no intrinsic role for asset prices. As a consequence, the estimates from such regressions should be zero-valued in a well-specified equation, and unstable otherwise. This proposition is not at all inconsistent with ample evidence from reduced-form estimates of output and inflation equations.[15] From this viewpoint, the fundamental component of asset price movements is

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[14]   As a testament to the definition's longevity, the NBER business cycle dating committee still uses concepts of expansions and recessions consistent with the research of Burns and Mitchell. They defined the business cycle in the following way:

> Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitude approximating their own.

[15]   Stock and Watson (2001) perform an extensive search of the predictability of asset prices on output and inflation. They conclude that asset prices do provide predictive content, but that predictive content varies widely over time. This lack of robustness is consistent with the view that reduced-form inflation and output equations are not particularly well specified. Other studies find more consistent predictability between housing prices and inflation and output, but far less predictability with equity prices. See also, for example, Filardo (2000), Cecchetti et al (2000) and Goodhart and Hofmann (2000). For predictors of inflation in Korea, see Bank of Korea (2002) and Kim and Moon (2001). Hofmann (2003) finds cross-country evidence that property price innovations tend to drive credit growth rather than excessive credit driving property prices. Such a finding is supportive of the financial accelerator of Bernanke and Gertler (1999) but could also be interpreted as evidence that price bubbles drive credit booms. Evidence from Borio and Lowe (2002a, 2003), Borio et al (2003) and Borio and White (2003) indicates an important correlation between credit booms and busts with asset price booms and busts. See IMF (2000, 2003) for more on these relationships. Eichengreen and Mitchener (2003) argue that the Great Depression could be viewed as a credit boom gone bad. To these authors, confidence may have played a critical role in this process. When credit and equity prices boomed together during the interwar period, the subsequent unwinding was often quite disruptive. In contrast, the disruptions were less pronounced when only credit and investment boomed together, leading the authors to conclude that credit booms may be particularly disruptive when credit is driven by overly optimistic expectations. Kim (2000) presents evidence that the housing sector in Korea was not the cause of the economic crisis.

doing nothing more in these macroeconomic equations than picking up the effects of missing variables, which in many cases may represent expectations of future fundamentals.[16]

In contrast, the non-fundamental components of asset prices - again assuming they exist - play an intrinsic role in determining output and inflation. Asset price bubbles have the ability to distort economic decisions, and hence outcomes, in a way independent of other aspects of the macroeconomy. Asset price bubbles have the potential to affect consumption via a wealth effect, business fixed investment via a cost of capital effect, net exports through various channels, and government spending through a political economy tax channel. Of even greater concern is the correlation between asset price collapses and economic crises, often linked to real-financial interlinkages (see, for example, Helbling and Bayoumi (2003), IMF (2003) and Bordo (2003)). The theoretical interlinkages go beyond the cost of capital issues (Bernanke and Gertler (1999), Kiyotaki and Moore (1997)) to such channels as the sand that is thrown in the gears of the real economy due to financial fragility (excessive debt, leverage, etc). The impact of asset price collapses can also have important implications for inflation. The collapse of an asset price bubble, holding fixed the path of outside money, is likely to generate greater inflation; but the crash might also precipitate an endogenous decline in outside money that could, in turn, lead to a sharp disinflation. In the context of a low-inflation environment, this disinflation could easily morph into deflation. Given all these ways in which macroeconomic asset price bubbles can affect the economy, it is no mystery why a well-specified macroeconomic model of the economy would include macroeconomic asset price bubbles, while at the same time it would not include a significant causal role for the fundamental component of asset prices.

To be clear, I am not suggesting that macroeconomic models that include asset prices as explanatory variables are incorrect or wrong. In terms of prediction, asset prices may be much better proxies for expectations about future fundamentals than other alternatives. Predictability, of course, does not imply causation.[17] Nor does a causal relationship for asset price bubbles guarantee a major role for asset price bubbles in macroeconomic models. Empirical evidence on this issue has been fairly limited but intriguing. Blanchard, Rhee and Summers (1993) find little role for market valuations in investment growth, given fundamentals. This is consistent with Chirinko and Schaller (1996), who find statistical evidence of asset price bubbles but observe little evidence of an effect of such bubbles on US investment demand.[18] This seems to suggest that economic agents may have some ability to see through asset price booms and busts when making decisions about real versus financial variables. Theory has little to say about this. Indeed, the resilience of consumption spending in the wake of the 1987 and 2000 U.S. asset price collapses is consistent with this view.[19] In Japan, however, Chirinko and Schaller (2001) find evidence of a bubble that did have significant implications for investment outcomes. More research is needed.

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[16] In the same vein, Alchian and Klein (1973) theorised that a well designed cost of living index would not just include the cost of a typical consumer's bundle at a particular point in time but would represent the present discount cost of lifetime consumption. The difficulty in constructing such an index is that state-contingent prices for future goods and services have to be measured or suitable proxies must be found. To simplify the calculation, the authors suggest using asset prices as proxies for the prices. See Goodhart and Hofman (2000), Filardo (2000, 2003a), Shibuya (1992), Shiratsuka (1999) and Bryan et al (2003) for further details on the model's strengths and limitations in the conduct of monetary policy. Its biggest drawback is the violation of some important cross-equation restrictions. More importantly for this paper, the role of asset prices in this approach is simply to reflect hard to measure future fundamentals. Asset prices in this model are not causal factors, just proximate factors. Moreover, this role of asset price fundamentals also relies on some potentially restrictive assumptions that may be at odds with those in the corporate finance literature. Such assumptions preclude the complications arising from imperfect information and the absence of collateral effects. These channels raise the possibility that the fundamental component of asset prices may be a useful proxy for these distortions. The macroeconomic significance of these factors, however, is still an unresolved research issue.

[17] See, for example, Zellner (1979).

[18] Their study, of course, leaves out the late 1990s when, arguably, the link from an asset price bubble to investment behaviour was much stronger. See also, for example, Galeotti and Schiantarelli (1994) and Morck et al (1990) for related studies.

[19] It is also possible that the "displacement" shock (in the Minsky sense) that initiates bubble-type behaviour may also be correlated across the real variables and asset price bubbles (eg optimism or pessimism).

Monetary policy model

Output, inflation and asset prices. This section uses a simple monetary policy model to highlight the salient trade-offs between asset price bubbles and monetary policy. Some of the assumptions will then be relaxed in subsequent sections in order to enrich the policy discussion; it is important to note that neither the basic thrust nor insights will be invalidated.

Output and inflation are modelled as functions of past interest rates, output, inflation and asset prices and are consistent with standard IS and Phillips curve specifications.[20] Linearity is assumed for convenience.

Output

$$y_t = \theta_{yr} r_{t-1} + \theta_{yy}(L) y_{t-1} + \theta_{y\pi}(L)\pi_{t-1} + \theta_{yf}(L)f_{t-1} + \theta_{yb}(L)b_{t-1} + \theta_{yz}(L)z_{t-1} + \varepsilon_t \tag{3}$$

Inflation

$$\pi_t = \theta_{\pi y}(L) y_{t-1} + \theta_{\pi\pi}(L)\pi_{t-1} + \theta_{\pi f}(L)f_{t-1} + \theta_{\pi b}(L)b_{t-1} + \theta_{\pi z}(L)z_{t-1} + \eta_t \tag{4}$$

where y is output, π is inflation, r is the interest rate, f is the fundamental component of asset prices, b is the non-fundamental (or bubble) component of asset prices and z is a set of deterministic variables. The error terms (ε_t, η_t) are assumed to be iid normally distributed random variables with constant variances. The $\theta_{ii}(L)$ functions are standard lag operator polynomials

By definition, asset price growth, *AP*, is the sum of the fundamental and bubble components.

Asset prices

$$AP_t = f_t + b_t \tag{5}$$

For simplicity, the growth rate of the fundamental component of asset prices is assumed to be a reduced-form linear function of the fundamentals in the economy.[21] In general, asset prices would be thought of as having a forward-looking specification. Here, though, the fundamental component of asset prices is largely a sideshow. One can think of the equation as the projection of asset price returns against variables in the available information set, with ν being an iid normally distributed random variable with a fixed variance.

Fundamental component

$$f_t = \theta_{fy}(L) y_{t-1} + \theta_{f\pi}(L)\pi_{t-1} + \theta_{ff}(L)f_{t-1} + \theta_{fb}(L)b_{t-1} + \theta_{fz}(L)z_{t-1} + \nu_t \tag{6}$$

Finally, the economy is subject to asset price bubbles that exhibit features broadly consistent with a macroeconomic asset price bubble. At this level of generality, the deep causal factors behind asset price bubbles (à la Minsky or Kindleberger) are unimportant. To add in these features would strengthen the lessons learned from this exercise. It is nonetheless assumed that the growth rate of

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[20]   Rudebusch and Svensson (1999) explored the non-asset price version of this model.

[21]   The fundamental component specification is consistent with a log-linearised version of a consumption-based capital asset price model.

the asset price bubble can be specified as a random variable that is independent of the other variables in the economy. In particular, the growth rate of the bubble is

Bubble component

$$b_t = \zeta_t \tag{7}$$

Various assumptions about the nature of the error term, ζ_t, have different implications for monetary policy. For the initial set of results, it is simply important that $E\zeta$ not be influenced by the policy rule of the monetary authority. This assumption is relaxed later when the issue of pricking asset price bubbles is addressed.

The bubble is assumed to exhibit three possible states of behaviour: a no bubble state, a positive bubble state and a negative bubble state:

$$I_t = \begin{cases} 1, & +bubble \\ 0, & no\ bubble \\ -1, & -bubble \end{cases}$$

where the asset price bubble is modelled as a Markov process.[22] The Markov process is calibrated so that long upward movements in the bubble will be followed by a sudden unexpected collapse. The start and collapse are not deterministic but purely stochastic. The negative bubble state means that asset prices can remain undervalued for long periods of time. As specified, the bubble is duration-independent, which means that the expected duration of the bubble is independent of its length. This assumption can be relaxed without loss of generality. One possible path for the asset price bubble (in levels) is illustrated in Graph 5.

Monetary policy. In this economy, the monetary authority sets the interest rate so as to minimise the losses associated with the variance of output, inflation and the volatility of interest rate changes. In particular, the central bank's decision problem is the conventional one:

$$Minimise\ L = \text{var}(y) + \mu_\pi \text{var}(\pi) + \mu_r \text{var}(r - r_{-1}) \tag{8}$$

subject to the implicit constraints of the economy described in equations (3) to (7) and the policy reaction function of the monetary authority, which is a linear function of the four key state variables, (y, π, f, b).[23]

Given this loss function, the monetary authority's problem becomes one of choosing the optimal policy instrument, ie parameters $\{a_y, a_\pi, a_f, a_b\}$, that minimises its value. In the case where the error terms above are standard normal random variables, the optimal policy is a linear function of the state of the system (Chow (1975)).

Optimal monetary policy

$$r_t = a_y^* y + a_\pi^* \pi + a_f^* f + a_b^* b \tag{9}$$

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[22]   See Appendix for further details about the stochastic specification of the bubble.

[23]   For notational convenience, I ignore the dependence on the deterministic component, *z*, of the system. Along the same lines, I restrict the state space to the contemporaneous values of these variables. Empirically the differences are minor.

General results I: responding to asset prices. First, and most significantly, optimal monetary policy is generally a function of the non-trivial state space. This is a technical way of saying that central banks should systematically respond to asset price bubbles!

Moreover, as a corollary to this unambiguous result, it is also clear that central banks should be reluctant to respond to the fundamental component of asset prices. As argued above, if the fundamental component of asset prices simply reflects underlying fundamentals (with no significant macroeconomic asset mispricing error, ν_t), then it would not show up as a non-trivial state variable in the system of equations (3) to (7).[24] These results apply generally and are robust to reparameterisations of the system of equations. It is worth noting that these results are in stark contrast to the conventional wisdom.[25]

Second, the noisiness of the asset prices does not overturn the optimality of responding to asset price bubbles. The volatility of asset prices is often seen as a reason for policymakers to avoid responding to asset price movements. In the monetary policy model above, such a reason is not warranted because of the well known certainty equivalence proposition from linear stochastic control problems.[26] Assume that a monetary authority could not distinguish the fundamental and bubble components of the asset price. Consequently, the monetary authority has the choice of not responding to asset prices or responding to overall asset price movements. If the monetary authority can only observe overall asset price movements, *AP*, rather than the two components, it is still optimal for the monetary authority to respond to asset prices. Filardo (2001) simulates such a model with the informational constraint and finds that it is optimal for the monetary authority to respond to asset prices.

Third, the volatility of asset prices does matter for the aggressiveness of the monetary policy response. The volatility enters the calculations because of concern about the variance of changes in interest rates, not because of the variance of output or inflation. Interest rate smoothing in the preference function, while still somewhat controversial, implies that variables in the reaction function that are volatile will directly add to the volatility of interest rates. Therefore, assuming that monetary authorities prefer smooth interest rates above and beyond the implicit concern for the variance of output and inflation makes responding to asset prices less attractive.

In sum, this monetary policy model in equations (3) to (7) presents fairly clear policy trade-offs. If the assumptions are correct, monetary authorities should generally *respond* to asset price bubbles. Simulation results confirm this and generally indicate that monetary authorities should tighten (relative to a simple Taylor-type rule) when asset price bubbles are inflating and should ease when positive asset price bubbles collapse. It is, of course, obvious in this case that monetary policy is symmetric in response to asset prices. But a monetary authority might appear to be asymmetric in the sense that monetary authorities appear to respond aggressively to busts of asset prices. The apparent asymmetry arises from asymmetric asset price bubble behaviour rather than from asymmetric policy rules.[27]

General results II: pricking asset price bubbles. The model above provides insights into the question of whether the monetary authority should *respond* to asset price bubbles but not about whether it should *prick* asset price bubbles. By assumption, the monetary authority has no influence on the evolution of the asset price bubble. While this may seem reasonable for small changes in a monetary authority's policy rate, large changes could have big effects on the economy and expectations. This section considers such a possibility.

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[24] Presumably longer lag specifications on output growth and inflation would be sufficient to eliminate the role of asset prices in this system of equations. If, for example, output and inflation were jointly stationary, then this would be true because a Wold decomposition would exist in lags of the two variables. The asset price variables, however, might wind up being correlated with output and inflation in any finite lag approximation.

[25] Timing conventions play a key role in the model; for example, if asset prices affect output and inflation only with a lag, the benefits of responding would be greatly diminished. Part of the reason is that the model assumes output is observed without error and without an observational lag. Reality of course is at odds with this assumption. In general, the weaker is the link from asset prices to output and inflation (ie the poorer are output and inflation at being sufficient statistics of the state of the economy), the greater would be the role for a central bank to respond to asset prices and bubbles. Of course, the converse would be true too.

[26] The pioneering articles on certainty equivalence go back to Simon (1956) and Theil (1957).

[27] In this sense, the monetary policy implications for symmetry are consistent with Greenspan (1999).

If the economy were experiencing growth of an asset price bubble, there is little doubt that a monetary authority could jack up interest rates sufficiently to throw the economy into a recession and quash any market euphoria. To capture this possibility, the asset price bubble can be reformulated as a function of output, inflation and interest rates. Following Filardo (2003c), the bubble is assumed to have the following form:[28]

$$b_t = \zeta_t(y_{t-1}, \pi_{t-1}, r_{t-1}) \tag{10}$$

In this case, the monetary authority can take actions that affect the likelihood and size of asset price bubbles.[29] This opens up the possibility that it might be optimal to prick asset bubbles. Such actions can be interpreted as a defence against asset price bubbles in the sense that the monetary authority may want to prick the bubble in order to limit the disruptive effects of the collapse. By reacting, the monetary authority can reduce the expected duration of the asset price bubble. This would also reduce the expected size of the bubble, since the bubble in this model is assumed to grow at a constant rate. Simulation results generally confirm that the optimal policy is one of "leaning against" asset price bubbles. For example, it is optimal for a monetary authority to raise interest rates as an asset price bubble inflates in order to reduce its expected size, which in turn moderates the expected variability of output and inflation.[30]

Once one starts to consider defensive actions against asset price bubbles, it is natural to think about manipulating asset price bubbles opportunistically to achieve even better economic outcomes than otherwise. Before proceeding with these arguments, it is useful to point out the speculative nature of this inquiry. What comes to mind here is a warning similar to those that accompany death-defying acts on television. The analogous warning in our case is that "this is a model and should not be attempted by those at home" (ie be very careful before attempting this in practice, there may be extreme risks).

The possibility of *using* asset price bubbles opportunistically to achieve a monetary authority's stabilisation goals is intriguing. During expansions, for example, the monetary authority not only may want to fight asset price bubbles but also may prefer to pursue a policy that helps to induce a negative asset price bubble. Why? To move the economy back to its potential at a faster pace. In the typical case of an overheated economy, the monetary authority prefers, all else the same, to pursue a tight monetary policy in order to restrain aggregate demand and return the economy to its potential. Working the opportunistic bubble channel offers an additional way to moderate growth and thereby affect inflation. To better understand this, consider the following scenarios. First, assume the output gap is positive and there is a positive asset price bubble. In this case, the monetary authority has an incentive to prick the bubble in order to restore output to potential faster than otherwise and to enhance its control of inflation. Second, assume instead that there is no bubble. In the absence of a bubble, the monetary authority would have an incentive - at least in this model - to try to induce a negative asset price bubble. The negative asset price bubble would provide extra downward momentum to output. Of course, there might be a risk of overshooting that would have to be factored in. Finally, assume the expansion coincides with a negative bubble. In this case, the monetary authority may still want to tighten more than otherwise in order to increase the persistence of the negative bubble. Turning to recession scenarios, the monetary authority would have incentives, using the same logic, to promote positive asset price bubbles. In sum, these thought experiments suggest that if the monetary authority can influence asset price bubbles, then it will generally want to take advantage of a more proactive stance of monetary policy than otherwise.

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[28] The correlation of the bubble component with the state variables violates a key assumption used by Simon (1956) and Theil (1957) to establish the certainty equivalence property in the otherwise linear quadratic setup. The paper by Filardo (2003c) can therefore be thought of as an approximate solution that may provide guidance on the issues at hand.

[29] In some sense, this bubble process possesses some of the features of the intrinsic bubbles of Froot and Obstfeld (1991), Diba and Grossman (1988) and Ikeda and Shibata (1992). The bubbles are persistent and linked to fundamentals. The difference here is that the bubbles are not simply deterministic functions of the level of fundamentals.

[30] Such a view that monetary policy can directly address asset prices may be problematic in practice. Okina et al (2001) dismissed the desirability of reacting to asset price bubbles in Japan on the grounds that it may be too difficult to calibrate the economy's reaction with sufficient precision to warrant taking action. This is an important type of uncertainty discussed in a later section.

Issues arising in a disaggregated macroeconomic model. If we were to consider a disaggregated model of the macroeconomy, other opportunistic tradeoffs might present themselves. For example, an asset price bubble might have differential effects on consumption and investment. As Dupor (2001) argues, asset price bubbles can act like a tax (or subsidy) on one component of aggregate demand relative to another. In an economy with investment and consumption, it might be advantageous at times to use the "tax" to try to balance growth as best as possible. Balancing here means using monetary policy to "lean against" asset price bubbles in order to curb the excess accumulation of either consumption or investment, and thereby reduce the likely adverse effects arising from overhangs of capital and consumer durables. Blanchard (2000) offers similar arguments but in the context of why inflation targeting may not be the optimal monetary policy in the presence of asset price bubbles.[31]

From a pragmatic monetary policy point of view, this discussion of defensive and opportunistic strategies towards asset price bubbles may be considered theoretical musings. If facing a bubble, the monetary authority may be stuck simply trying to do the best it can to grapple with the difficult trade-offs. But it is a completely different matter for a monetary authority to be creating situations that are not under its full control, especially when the root causes of bubbles as well as why they evolve the way they do and why they burst are not well known. One might draw an analogy with driving a car which is experiencing brake failure. The driver in such an unfortunate situation will try whatever is possible to bring the car under control and be justified in doing so. But having some skill at doing so might not seem to be a good reason for the driver to seek risky situations where he can test those skills.

Beyond the basic setup of the model

The remainder of the paper considers important policy trade-offs that go beyond the basic setup of the model. It deals with the issues of moral hazard, refinements to the model specification, uncertainty and central bank communication.

Moral hazard considerations. The simple informational assumptions of the model obscure the possible moral hazard problems that may arise from systematic monetary policy responses to asset price bubbles. The moral hazard problems are not limited to the more familiar asymmetric response strategies but also from symmetric response strategies.[32]

The attractiveness of asymmetric response strategies stems from the difficulty in identifying asset price bubbles as they inflate. Given this difficulty, some policymakers have questioned whether they can feasibly do anything more than just respond to asset prices when bubbles collapse. The benefits of responding to the sharp decline in asset prices are clear. Lower rates would be expected to cushion the blow to aggregate demand as well as to help insulate the financial sector from balance sheet vulnerabilities. The possible problem in this case is not the prescription, per se, but the effects that such a policy could have on incentives during the asset price boom. In such a situation, investors (in financial as well as physical assets) are likely to take too much risk during the good times because investors may perceive the monetary authority as providing free downside risk insurance in the case of bad times - in the language of options, the monetary authority is offering an unpriced put. Moreover, such insurance may fuel euphoric expectations and unrealistic risk assessments, which in some circumstances could lead to a significant and perverse effect of feeding the bubble. To fully understand the implications of this moral hazard issue, it would have to be factored into the macroeconomic model (equations (3) to (8)). Consideration of such complications goes beyond the scope of this paper but generally involves the following trade-off. On the one hand, there are the macroeconomic costs associated with the implicit put. On the other hand, there are the implied macroeconomic costs of non-action by the monetary authority, especially if it means sacrificing some central bank credibility or independence.

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[31] For a more sanguine view of inflation targeting in the presence of asset price booms and busts, see Bean (2003). This view reflects the more general finding of Borio and Lowe (2002a) that, in the presence of booms and busts, policymakers may need to consider the implications well beyond the conventional policy horizons to appropriately calibrate the policy risks.

[32] This is a different type of moral hazard from that in Allen and Gale (1999).

A different moral hazard problem may arise from a symmetric policy to respond to asset price bubbles. This problem has its foundation in Minsky's theory of endogenous cycles.[33] Minsky argued that business cycles and asset price cycles were permanent features of the inherently fragile environment of a capitalist economy. Moreover, he had a particularly gloomy outlook in that he theorised that attempts by policymakers to smooth cycles could ultimately be self-defeating. A monetary policy, for example, that smoothes out the cycles might only allow deep-seated imbalances to grow and grow and grow. This summary from Zarnowitz (1992) captures the spirit of the argument: "Minsky argues that long periods of prosperity interrupted only by mild recessions or slowdowns breed overconfidence, excessive short-term financing by banks of long-term business projects, investment booms interacting with stock market booms, and growing indebtedness and illiquidity. [...] If a crisis is averted and stimulative monetary policies continue, a mild recession may ensue but another inflationary and eventually destabilizing investment boom will soon follow." It is not clear how this type of concern could be dealt with by monetary policy other than by allowing booms and busts to transpire unimpeded. Better fiscal and prudential policies might offer more attractive possibilities of dealing with bubbles.

To fully appreciate the quantitative extent of these moral hazard problems, more research into the nature of bubbles and the countercyclical effectiveness of monetary policy is called for. But the two sources of moral hazard offer a serious policy dilemma for policymakers. It is not clear what the monetary authority is to do with an interest rate instrument alone. The monetary authority can treat the bubble as a source of inefficiency and try to remedy it. In doing so, however, it could fuel the source of the problem, especially if the source of the problem was unrealistic risk assessments.

Multivariate bubbles. So far, the paper has restricted itself to univariate bubbles. This is not a modelling necessity nor is it necessarily the best way to characterise the challenges facing monetary policymakers. In fact, Graph 6 (reprinted from BIS (2003)) shows that housing price booms typically lag the peak in stock market booms.[34] One might hazard to speculate that this timing may in part reflect the effect of policy actions. Countercyclical monetary policies have generally led to low interest rates after a collapse of equity prices, which would have the knock-on effects of boosting activity in interest-sensitive sectors more than would otherwise be the case. It might be said that bubbles beget bubbles via a policy channel. Exploring how policy responses to one type of asset price can generate echo booms and busts is important, especially so now in the light of housing market conditions in various G10 and emerging market economies.

Non-linearity. This paper has chosen to analyse the impact of macroeconomic asset price bubbles using linear monetary policy reaction functions.[35] Even though linear reaction functions reveal much about the policy tradeoffs, the structure of the underlying macroeconomic model suggests that research into non-linear reaction functions may offer even further opportunities to improve our understanding. In particular, the non-linearity of the macroeconomic model, created by the non-linear asset price bubble, opens up potential gains from considering asymmetric policy responses, ie ones where the monetary authority reacts differently before and after the collapse of a bubble.[36] Additionally, other potential non-linearities could also be important such as those arising from the linkages between the real side of the economy and the financial side via financial sector balance

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[33] See, for example, Filardo (2003b).

[34] IMF (2003) also highlights such cross-correlations of asset price booms and busts.

[35] The linear nature of the underlying model raises the possibility that asset prices may help to capture left-out intrinsic non-linearities. If so, they would only proxy rather than cause the underlying fundamentals in the economy. In practice, trying to distinguish the two possibilities would be rather difficult.

[36] Kent and Lowe (1997), for example, offer a model where monetary policy actions can affect the evolution of a bubble. The analysis is based on a one-shot bubble that never reemerges after it collapses. As the bubble inflates, inflation rises through an accelerator type process. When it collapses, a strong disinflation occurs. The monetary authority therefore has an incentive to fight the bubble on the way up and deal with the aftermath with an easy policy. In the post-bubble stage, the monetary easing does not raise the possibility that another bubble may arise or the possibility of a negative bubble. The model implications are more fully developed in Gruen et al (2003). They argue that the desirability of pursuing a "leaning against the wind" policy varies with the size of the bubble. In contrast, Smets and Wouters (2003) examine the welfare implications of monetary policy reactions based on whether output is positive or negative. Bordo and Jeanne (2002) explore Taylor-type rules that are a non-linear function of macroeconomic fundamentals and private sector expectations.

sheets.[37] Investigating such policy reaction functions is not without its difficulties. Non-linear estimation is somewhat harder and theory provides little guidance about how to narrow the search through the infinity of non-linear policy options.

Alternative modelling approaches. The model outlined in this paper is, technically, a linear stochastic control model of monetary policy. It offers pros and cons. On the one hand, it is easy to solve. The simulation-based solution methods in Filardo (2003c) can easily handle the complications arising from endogenous bubbles.[38] On the other hand, the model is backward-looking, not forward-looking. Implicitly, all forward-looking aspects of the problem are assumed to be captured in the time-invariant autoregressive components of the specification. Hence, the results may be particularly vulnerable to criticisms of the Lucas critique. Moreover, the model is not based on explicit microfoundations as in the case of Bernanke and Gertler (1999) who offer a dynamic stochastic general equilibrium (DSGE approach). But, at this point in time, the DSGE approach may not be the best way to understand the policy trade-offs associated with asset price bubbles.

The major drawback of the DSGE approach stems from the computational approximations that are used to solve for optimal monetary policy. The DSGE model is typically solved after linearising the key equations, thereby limiting the accuracy of the model to small perturbations around the steady state. In other words, the findings of the model only apply to small asset price bubbles. But small asset price bubbles are not the type of phenomena that we typically have in mind when thinking about the key policy challenges arising from asset price bubbles. Macroeconomic asset price bubbles are large swings in asset prices; small bubbles can probably best be thought of as random noise.

Looking forward, both research approaches deserve further investigation in order to ultimately reconcile the facts and microfoundations. In the short run, the linear stochastic control models of the type used in this paper can yield insights into the various trade-offs arising from large bubbles. Many policy-relevant lessons can also be learned by considering a wide range of bubble processes and various non-linear interactions among financial frictions, bubbles and monetary policy. The DSGE models can also offer insights into the role of forward-looking expectations as well as the deeper microfoundations of how bubbles distort investor, worker and consumer behaviour. In the end, however, both of these approaches will have to be reconciled with the findings of behavioural finance.

Uncertainty, asset prices and monetary policy

Uncertainties play a critical role in the debate about asset prices and the conduct of monetary policy. The nature of the uncertainties is multifaceted. There is data uncertainty, parameter uncertainty and, most importantly, model/paradigm uncertainty. This section briefly reviews these different types of uncertainty and how they impinge on the monetary policy trade-offs.

Data uncertainty. Data uncertainty is probably the most misunderstood aspect of the issue of asset prices and monetary policy. The conventional wisdom seems to be that the inability to measure asset price bubbles precisely should preclude a monetary authority from responding to asset price fluctuations. As a general statement about the monetary policy trade-offs, it is simply incorrect.

Again, let us examine what the model above tells us. Initially we assumed that a monetary authority could distinguish between fundamental and nonfundamental components of asset prices. In that case, the optimal monetary policy rule was a function of both components of asset prices - because each component is a nontrivial state variable. Consider instead the opposite informational assumption. Assume that the monetary authority cannot distinguish between the fundamental and bubble components. As shown in Filardo (2001), the optimal rule is of the form of

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[37] It is also important to note that Borio and Lowe's (2003) argument that the cost of a bubble depends on whether there is excessive leverage. In their view, this leverage is the key source of nonlinearity and the reason why focusing on an asset price bubble per se, rather than "financial imbalances", may not be sufficient.

[38] See Filardo (2003c) for a description of the simulation methods to solve the model.

$$r_t = \tilde{a}_y^* y + \tilde{a}_\pi^* \pi + \tilde{a}_{AP}^* AP \qquad\qquad (11)$$

where the $\tilde{a}_{AP}$ is generally positive. Simulations show that the marginal benefit of reacting to overall asset price movements is significant when compared to not responding to asset prices at all.[39]

The simulation results also highlight key implications for practical policymaking. First, the noisiness of overall asset price movements may be less of a concern than generally thought. Technically, the simulation results suggest that the noise associated with asset price fluctuations may be of second-order importance for monetary policy decisions.[40] Practically, this result means that monetary authorities should use asset prices, even if they are volatile and even if asset price bubbles are hard to estimate. Second, there might be additional welfare gains from narrowing the uncertainty surrounding the estimates of bubbles, for example by using econometric methods to infer their size.[41]

While using imprecise estimates of asset price bubbles may sound radical, such a procedure is not conceptually much different from what is done regularly in the policy process. Policymakers have to grapple routinely with such concepts as potential output, NAIRU and equilibrium real interest rates. If the monetary policy record over the past decade is any guide, it seems that monetary authorities deal with such data uncertainties rather well. In this sense, I am somewhat sympathetic to the argument of Cecchetti et al (2000) that producing and using estimates of asset price bubbles in the policy process might not be so different from what is done now with respect to other aspects of monetary policy.

The simulation results also cast a favourable light on the recent literature that has stressed the role of financial imbalances in monetary policymaking.[42] If seen as proxies, albeit noisy ones, for asset price bubbles, financial imbalances could also prove to be very useful in policymaking. For example, if an asset price increases with a corresponding boom in credit, investment, productivity, debt burdens, leverage or a host of other possible variables that often signal an unsustainable boom, then policymakers may want to interpret such asset price movements as largely reflecting bubble-like behaviour. In this case, a monetary authority might prefer to use a reaction function like equation (9) rather than equation (11). The research by Borio and Lowe (2002a, 2002b, 2003) and others suggests that such correlations may be exploitable and the theory above provides a solid justification for pursuing such a strategy.[43]

Parameter uncertainty. As with any macroeconomic model, parameter uncertainty is an important concern and can affect the monetary policy trade-offs (Brainard (1967)). But there is nothing particularly new in this model beyond the standard issues, except one source of uncertainty that I will interpret as a much deeper issue of paradigm uncertainty.[44]

Paradigm uncertainty. Two types of paradigm uncertainty are important. The first is whether asset price bubbles truly belong in a well specified model of the macroeconomy.[45] If not, the policy model in

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[39] Graph 2 in Filardo (2001) illustrates this point. The policy frontiers for the unconstrained rule and the constrained rule lie nearly on top of each other. Optimal rules that preclude responses to asset prices produce significantly worse outcomes.

[40] In the language of linear stochastic control models, the linear-quadratic structure of the model exhibits a certainty equivalence property.

[41] Methods such as Bhar and Malliaris (2001), Ikeda and Shibata (1992) and Wu (1997) could be employed here. A recent example of such an effort is Sze and Yu (2003).

[42] It should be noted that the model in this paper tells us that the optimal monetary policy is to "lean against the wind" as asset prices grow. The insurance motive suggested by Borio and White (2003) does not naturally arise in the model. Part of the reason is the specification of the loss function. If the loss function resembled a minimax criterion, the notion of insurance against small probability events, such as a bursting bubble, would become relevant.

[43] Borio and Lowe (2003) question the usefulness of a focus on asset price bubbles when examining asset price booms and busts. From a practical point of view, using variables such as credit can help avoid the controversies associated with the term "bubbles" and hence may be a more productive way to address these issues. I see considerable merit in this view. Nonetheless, in this paper, I am assuming - possibly unrealistically - that the asset price bubble issue can be examined clinically and dispassionately.

[44] Walsh (2003) offers a general statement on these issues. See also Chow (1976) for the specifics on non-linear econometric systems with unknown parameters.

[45] See Garber (2000) for a sceptic's view of bubbles.

this paper would assign no intrinsic role for asset prices as a state variable, and hence the optimal policy parameter in the reaction function would be zero. If, in contrast, asset prices are non-trivial state variables, then the monetary authority should respond. The crucial issue is the uncertainty about whether asset prices belong in a macroeconomic model.

Filardo (2001) offers a simple approach to incorporate this model/paradigm uncertainty into the decisions of a central bank. Formally, this is a Bayesian decision-theoretic framework, which factors in prior probabilities of the appropriate model as well as the associated losses (ie payoffs) from various policy actions.[46] In a nutshell, the monetary authority minimises the expected loss of its choices. To simplify the choice set, assume that asset prices either matter (ie they are part of the non-trivial state space) or they do not. Not mattering assumes that $\theta_{y,f}(L) = \theta_{y,b}(L) = \theta_{\pi,f}(L) = \theta_{\pi,b}(L) = 0$.[47] And the monetary authority can choose either to respond to asset prices or not. The payoffs and probabilities are summarised in Table 1. Given the probabilities for these possible outcomes, the expected loss of responding to asset prices is[48]

$$E(L_{respond}) = P_{matter} L_{matter,matter} + P_{not\ matter} L_{matter,not\ matter}$$

Correspondingly, the expected loss of not responding is

$$E(L_{not\ respond}) = P_{matter} L_{not\ matter,matter} + P_{not\ matter} L_{not\ matter,not\ matter}$$

The decision to respond or not depends on the expected loss of responding versus not responding: If $E(L_{respond}) < E(L_{not\ respond})$, then respond to asset prices; otherwise do not respond.

Table 1

Payoff matrix

		True macroeconomic structure	
		Asset prices matter	**Asset prices do not matter**
Monetary authority's view	Asset prices matter	$L_{matter,\ matter}$	$L_{matter,\ not\ matter}$
	Asset prices do not matter	$L_{not\ matter,\ matter}$	$L_{not\ matter,\ not\ matter}$

Probability structure

		Asset prices matter	**Asset prices do not matter**
Monetary authority's view	Asset prices matter	P_{matter}	$P_{not\ matter}$
	Asset prices do not matter	P_{matter}	$P_{not\ matter}$

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[46] This model can generally be extended to a more formal Bayesian analysis using posterior odds based on the combination of policies, models, estimation and data.

[47] Alternatively, the decision-theoretic model can be extended to consider the uncertainty involved in the parameters on the asset price variables (or all of them, for that matter) and search for robust monetary policies, ie policies that generate the lowest average loss for the distribution $f(\theta_{y,f}, \theta_{y,b}, \theta_{\pi,f}, \theta_{\pi,b})$.

[48] It might be reasonable to calculate these probabilities as Bayesian posterior probabilities based on the data and the prior beliefs of a monetary authority. See, for example, Zellner (1985).

Policy advisers could think of calculating these expected losses under the different assumptions and reporting the conclusions to policymakers. Alternatively, the expected losses for each value of the prior probabilities could be tabulated. Then, a policymaker armed with an assessment of his prior probability could make the appropriate choice of whether to respond or not. In addition, policymakers may want to take into account a much broader set of risks - especially those that have a low probability but represent particularly large adverse consequences.[49]

Another type of paradigm uncertainty arises from the assumption of optimality in a stochastic control framework. This paper advocates exploring the monetary policy trade-offs by looking at optimal monetary policies vis-à-vis a standard linear stochastic control model. This assumption of optimality, however, need not be the best or the most relevant criterion with which to advise policymakers. Simply, if policymakers do not act in a way consistent with such a model, then the advice based on the model may not be particularly useful.

The seminal research by Bernanke and Gertler (1999, 2001) explores the trade-offs within a class of non-optimising models of monetary policy. Rather than explore optimal monetary policies, the authors examine "reasonable" monetary policy reaction functions that are consistent with actual central bank behaviour. From this vantage point, the Bernanke and Gertler approach may offer useful practical advice to policymakers who are thinking about marginally augmenting their explicit or implicit policy reaction functions with asset prices.

Their approach produces a now well known conclusion that central banks might not want to respond to asset prices even if asset prices are non-trivial state variables. This would be true in two plausible situations (though inconsistent with the assumptions in the model summarised in equations (3) to (8)). First, a monetary authority which is following a suboptimal policy rule may be worse off by putting weight on asset prices. Moving from one suboptimal rule to another need not improve outcomes. In practice, establishing the optimality of a particular policy rule may be difficult, if not impossible, and may limit the attractiveness of the policy implications raised earlier in the paper. Second, even if the response coefficients on output and inflation are optimal, putting additional but somewhat arbitrary weight on asset prices (as in Bernanke and Gertler) could also lead to worse outcomes. The central lesson one learns from these cases is that a monetary authority cannot just start responding to asset prices without a risk of making matters worse.[50]

Addressing this type of uncertainty could conceptually be cast within a Bayesian posterior odds framework. Such a framework requires several types of information. First, one would generally need to know the prior beliefs that monetary policymakers have about the two alternative hypotheses of optimality, $P(H_0)$ and $P(H_1)$. Second, the posterior probability density functions of the two models would need to be calculated, $P(w \mid H_0)$ and $P(w \mid H_1)$. The variable, w, reflects all data available with which to assess the models. With these pieces of information, the posterior odds could be calculated and the best policy chosen. If the most appropriate model is the one in this paper, monetary policymakers would generally want to respond to asset price bubbles. If the Bernanke and Gertler model is a more appropriate characterisation of reality, monetary policymakers would generally not want to respond to asset prices.

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[49] Greenspan (2003), for example, notes the importance of factoring low-probability events into the decision-making process. Such considerations imply that a central bank might want to take out "insurance" against large downside risks. Along these lines, Mori et al (2001) suggest that part of post-bubble adjustments in Japan may have been due to the failure to anticipate fully and prepare adequately for the consequences of the asset price collapse.

[50] Cecchetti et al (2000), using Bernanke and Gertler's model, expand the search for possible monetary policy reaction functions and reversed Bernanke and Gertler's policy conclusion. Since they did not solve for the optimal policy either, further parameter searches would have yielded even better policy responses. The key issue, however, is not the discovery of better specifications since this is not the point of this paradigm; finding better specifications is true by construction. The challenge is finding more accurate representations of existing policies and investigating whether adding a marginal reaction to asset prices can make improvements.

Bubbles and monetary policy communication

The case for considering asset price bubbles in monetary policy does not stop at the doorstep of the central bank. In an era of central bank openness, a monetary authority must describe its policy motivations to the public. The use of the term "asset price bubbles" raises some thorny communication issues.

Central bank communication is complicated by the fact that there are various audiences for central bank information, each having different levels of sophistication and willingness to digest the messages. Some audiences prefer basic information and others prefer more detailed information. A monetary authority's preference for sending simple messages about the various aspects of the policy process further complicates matters. These messages might include information about its objectives, its policy framework, the information used in arriving at a decision and the decision itself. Moreover, these messages often include "code words or phrases" to economise on the volume of information that would otherwise have to be sent. These are phrases loaded with much more meaning than the literal words themselves.

The term "bubble" in many ways represents a word laden with various alternative interpretations. Some in the public may interpret "bubbles" as an opportunity for short selling. Some might interpret the term to mean a crash is imminent. Some may interpret it as a signal that drastic policy measures are in train. From a monetary authority's point of view, the use of the term brings the risk of misinterpretation. As a consequence, a monetary authority's utterances about bubbles could cause asset prices to react, often in unpredictable ways.

This possibility alone might make some argue that policymakers should avoid the use of the term "bubble" in their communication with the public. I have much sympathy for this view. The use of the term could make it quite difficult to communicate clearly. In a sense, the public discussion of asset price bubbles may generate more heat than light.

But avoiding the use of the term is not so simple. Consider a situation where the monetary authority feels confident that there is a bubble. Should it communicate its information, albeit properly nuanced? On the one hand, if the monetary authority were perceived to have no extra informational advantage over the markets, it is not clear why its comments would matter. Of course, if the monetary authority proved to be wrong in its assessment, the public might lose some confidence in its ability to read financial trends.

On the other hand, if the public believed the monetary authority had better information than the public, or if individual investors put more weight on the monetary authority's information than on their own private information, the communication issues could become much more difficult.[51] For example, if the monetary authority chose not to state a position on whether there is a bubble, the public might interpret this as tacitly endorsing the notion that there is no bubble. That action by itself could reinforce factors driving the bubble. From this vantage point, the intersection of theory and communication leads to difficult choices. The theory in this paper suggests that asset price bubbles lie at the heart of the monetary policy tradeoffs. But the preconceived connotations of the term "bubbles" may make it difficult to communicate effectively with the public. Some have suggested an alternative approach that might bridge this gap.[52] Monetary authorities might prefer to couch their description of the tradeoffs to the public in a less controversial fashion, say by focusing on the proximate causes of asset price bubbles such as credit growth or financial imbalances. These variables might eliminate the need to mention the term "asset price bubble" and hence avoid any associated misperceptions. The simulation results using the overall asset prices, AP_t, in equation (11), provide support for this notion as long as it can be shown that credit growth and measures of financial imbalances are sufficiently correlated with asset price booms and busts. Borio and White (2003) summarise cross-country evidence in support of this correlation. Nonetheless, this communication issue does not in any way diminish the central insights of this paper about the importance of focusing on asset price bubbles from an analytical perspective.

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[51] These types of strategic complementarities in monetary policy have been recently stressed by Amato and Shin (2003).

[52] See, for example, Borio and Lowe (2003) and Stevens (2003).

Conclusion

This paper has laid out the case for focusing on asset price bubbles as a means to truly understand the policy trade-offs facing monetary authorities. Asset price bubbles, not general swings in asset prices or other proximate causes of booms and busts, are at the heart of the analysis. Viewed from this angle, the extant research record into asset price bubbles and their implications for the macroeconomy has been rather disappointing. Future research is needed to strengthen our understanding of empirical macroeconomic asset price bubbles, their effect on macroeconomic variables, the effect of policy actions on the evolution of such bubbles and ways to characterize the irreducible uncertainty facing policymakers. Of these, the most fruitful avenue in the near term may be further exploration of the linkages between the real and financial sides of the economy.

Other important issues include those regarding the interaction of monetary, fiscal and prudential policies in dealing with asset price bubbles, both on the way up and on the way down. Monetary policy is not the only policy that can moderate asset price bubbles - and in many situations may not be the most effective or the most precise. Fiscal authorities, for example, can use tax policies to deal with the distortions that asset price bubbles create for consumption and investment decisions. And it may be important for fiscal authorities to fight the temptation to adopt procyclical spending patterns that may accompany transitory changes in revenues due to bubbles. Prudential authorities can also play a key role by being vigilant about future vulnerabilities in the financial sector if an asset price bubble were to burst. As history has shown, the collapse of credit in the aftermath of a deflated asset price bubble can create a vicious downward economic spiral. Such a possibility puts a premium on prompt corrective prudential actions to remove impediments to a financial system. While the role of each authority is important, the optimal sequencing of coordinated actions may be even more so.

Finally, the underlying premise of this paper has been that asset price bubbles could be addressed in a fairly clinical and dispassionate way. Admittedly, however, the term "bubble" does bring up delicate communication issues for a monetary authority. While there is considerable merit to the arguments in favour of using alternative terms such as financial imbalances, credit booms and busts, and risks, the point of this paper is that, from a scientific modelling perspective, asset price bubbles may be the best means to understand the policy trade-offs associated with wide swings in asset prices.

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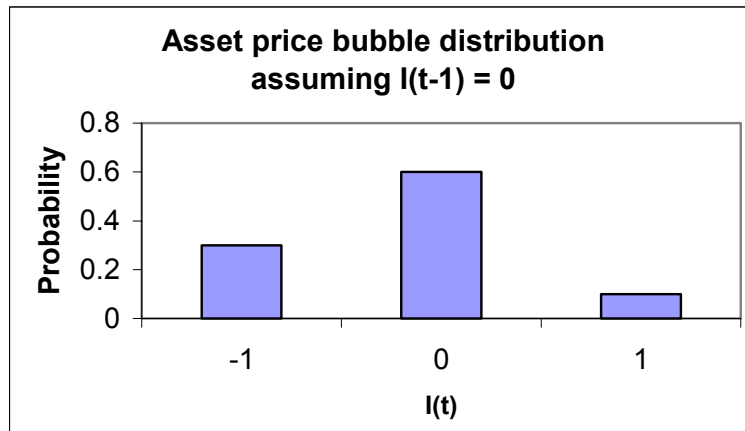——— (1985): "Bayesian econometrics", *Econometrica*, March.

Appendix

The bubble in this paper can be thought of as a first-order Markov model where the bubble is drawn from the following distribution:

$$\zeta_t = \begin{cases} \theta_p & \text{with probability } p_{1,1}, \text{ given } s_{t-1} = 1 \\ -\theta_p \tau_{t-1} & \text{with probability } 1 - p_{1,0}, \text{ given } s_{t-1} = 1 \\ \theta_p & \text{with probability } 1 - p_{0,1}, \text{ given } s_{t-1} = 0 \\ 0 & \text{with probability } 1 - p_{0,0}, \text{ given } s_{t-1} = 0 \\ \theta_n & \text{with probability } 1 - p_{0,-1}, \text{ given } s_{t-1} = 0 \\ \theta_n & \text{with probability } 1 - p_{-1,-1}, \text{ given } s_{t-1} = -1 \\ -\theta_n \tau_{t-1} & \text{with probability } 1 - p_{-1,0}, \text{ given } s_{t-1} = -1 \end{cases}$$
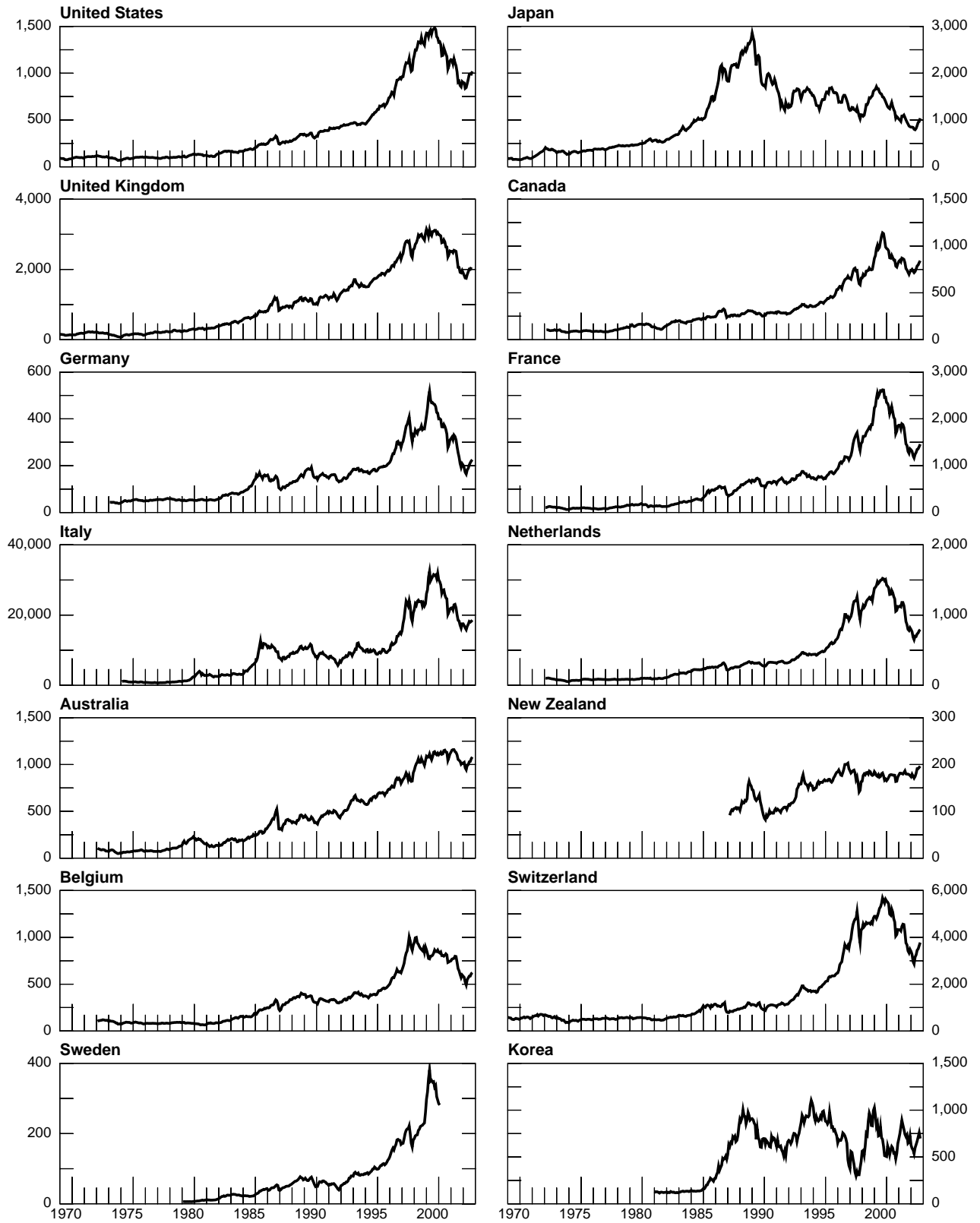
τ is the duration of the asset price bubble and $\theta_i, i \in \{p,n\}$ is the respective growth rate of negative and positive asset price bubbles. More generally, the transition probability matrix can be written as

$$P(I_t \mid I_{t-1}, X_{t-1}) = \begin{pmatrix} p_{-1,-1}(X_{t-1}) & p_{-1,0}(X_{t-1}) & p_{-1,-1}(X_{t-1}) \\ p_{0,-1}(X_{t-1}) & p_{0,0}(X_{t-1}) & p_{0,1}(X_{t-1}) \\ p_{1,1}(X_{t-1}) & p_{1,0}(X_{t-1}) & p_{1,1}(X_{t-1}) \end{pmatrix}$$

and is described in more detail, along with the optimisation routine to solve for the optimal monetary policy, in Filardo (2003c). In the case where the asset price bubble evolves independently of the state of the economy, the transition probabilities would not depend on X. The graph below offers an illustration of the stochastic nature of the bubble evolution (assuming $p_{0,0} = 0.6$ and $p_{0,1} = 0.1$).

Asset price bubble distribution assuming I(t-1) = 0

Graph 1

Equity prices

United States

1,500
1,000
500
0

Japan

3,000
2,000
1,000
0

United Kingdom

4,000

2,000

0

Canada

1,500

1,000

500

0

Germany

600

400

200

0

France

3,000

2,000

1,000

0

Italy

40,000

20,000

0

Netherlands

2,000

1,000

0

Australia

1,500

1,000

500

0

New Zealand

300

200

100

0

Belgium

1,500

1,000

500

0

Switzerland

6,000

4,000

2,000

0

Sweden

400

200

0

Korea

1,500

1,000

500

0

1970   1975   1980   1985   1990   1995   2000   1970   1975   1980   1985   1990   1995   2000

Source: National data.

25

Graph 2

Residential prices

United States

Japan

United Kingdom

Canada

Germany

France

Italy

Netherlands

Australia

New Zealand

Belgium

Switzerland

Sweden

Korea

1970   1975   1980   1985   1990   1995   2000

1970   1975   1980   1985   1990   1995   2000

Source: National data.

26

Graph 3

Commercial prices

United States

Japan

United Kingdom

Canada

Germany

France

Italy

Netherlands

Australia

New Zealand

Belgium

Switzerland

Sweden

Hong Kong SAR
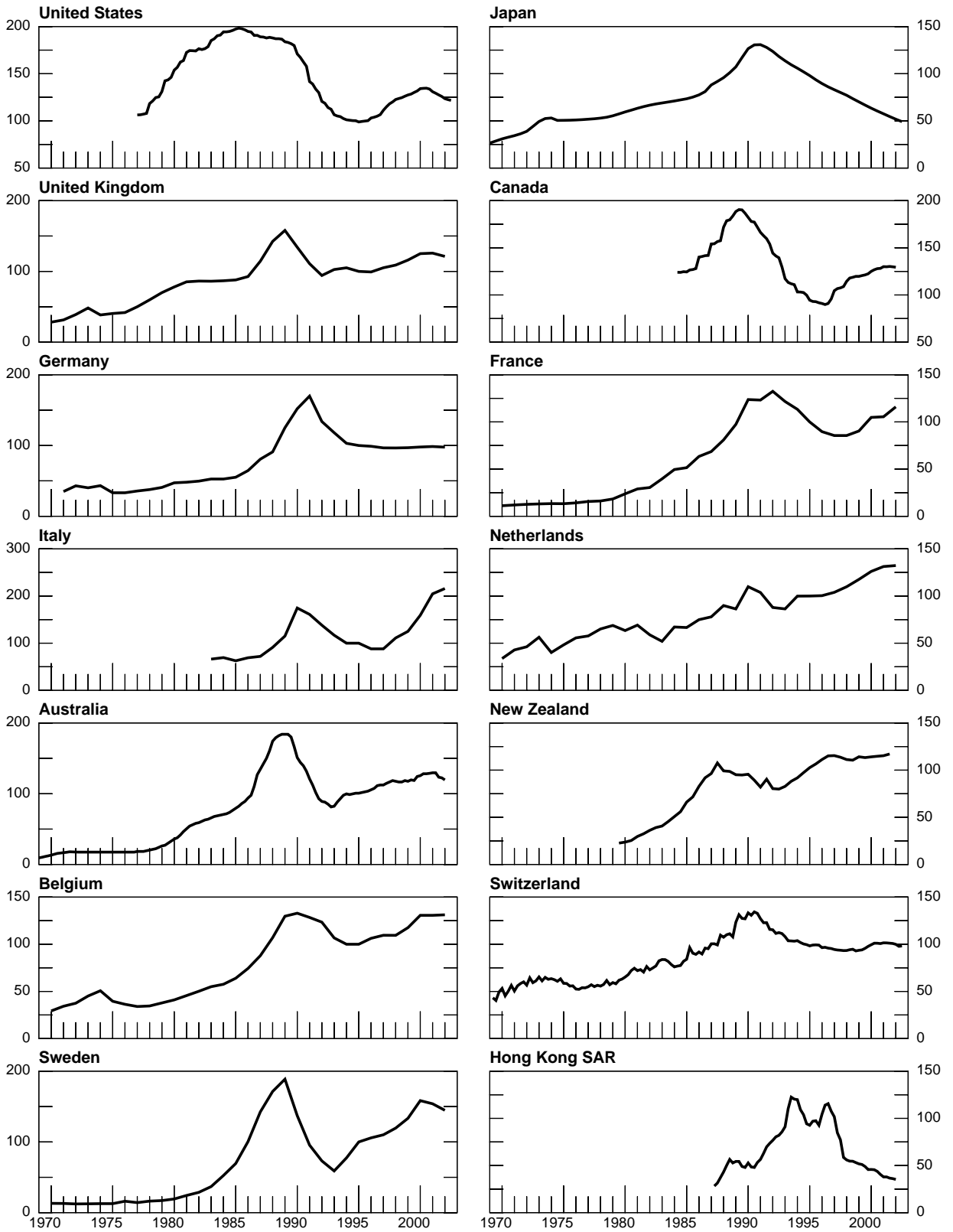
Source: National data.

Graph 4

Debt to total assets ratio

United States

Japan

United Kingdom

Canada

Germany

France

Italy

Korea[1]
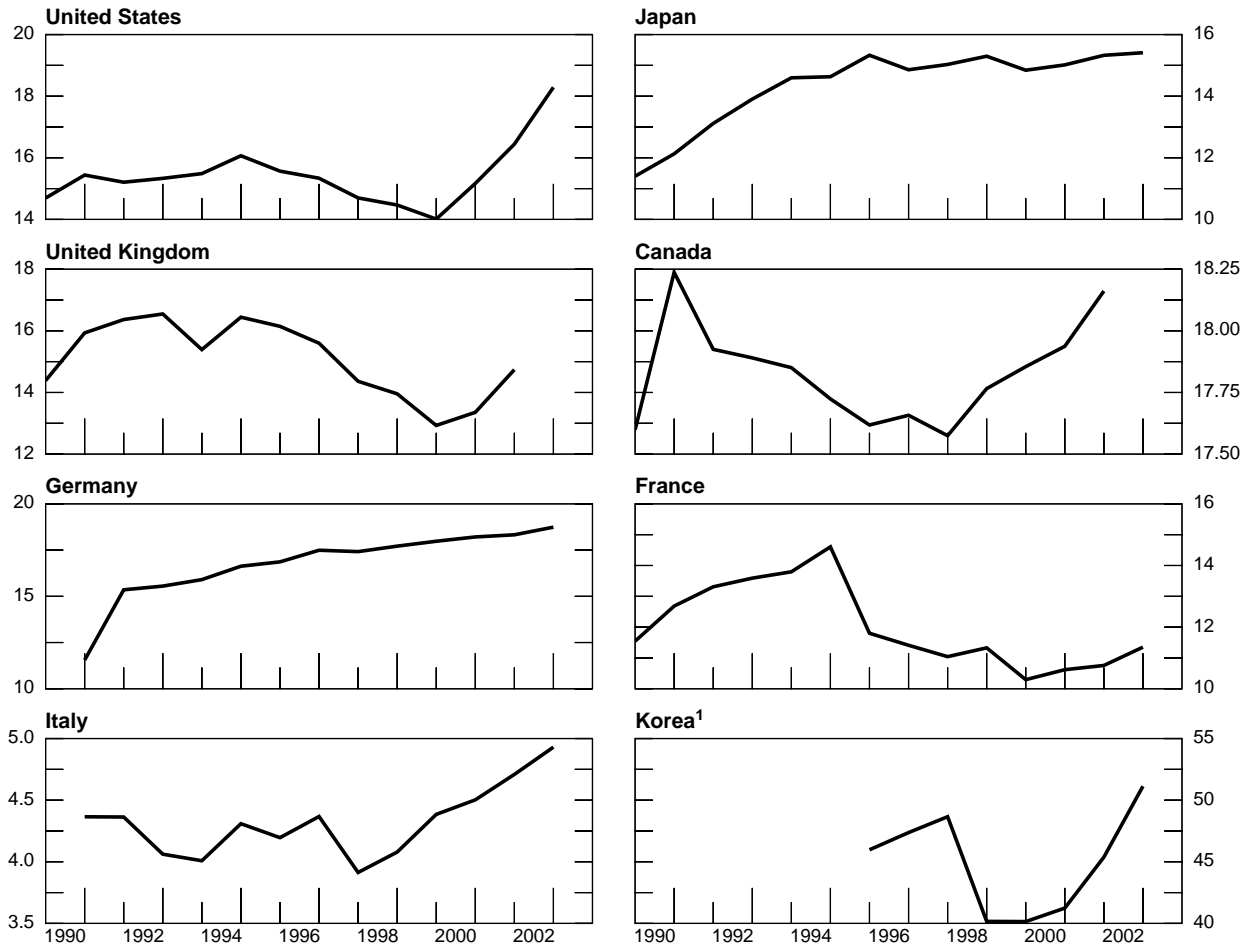
[1]   Total debt as proportion of financial assets.

Sources: OECD; national data.

28

Graph 5

Model simulation of an asset price bubble

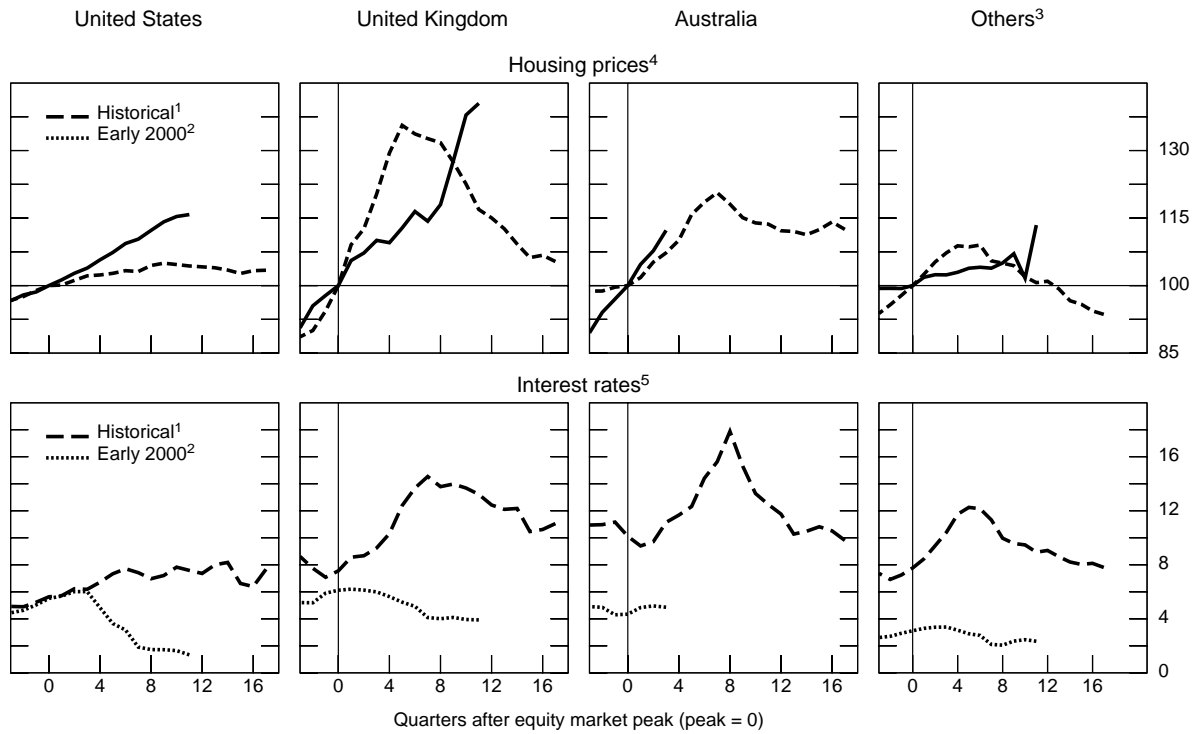Time periods
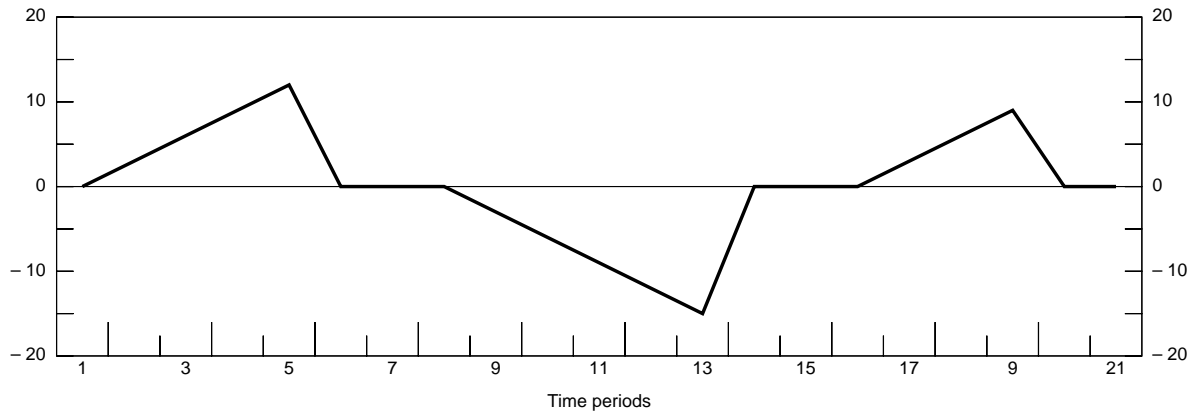
Source: BIS calculations.

Graph 6

Housing prices and interest rates around equity market peaks

| United States | United Kingdom | Australia | Others[3] |

Housing prices[4]

- - Historical[1]
.... Early 2000[2]

130

115

100

85

Interest rates[5]

- - Historical[1]
.... Early 2000[2]

16

12

8

4

0

0   4   8   12   16   0   4   8   12   16   0   4   8   12   16   0   4   8   12   16

Quarters after equity market peak (peak = 0)

[1] Historical averages of periods around peaks in the early 1970s, late 1970s - early 1980s and late 1980s.   [2] 2002 Q1 for Australia, 2000 Q1 for all other countries.   [3] Simple average of Canada, Japan and Sweden.   [4] Housing price = 100 at each equity market peak.
[5] Short-term nominal interest rate, in percentages.

Sources: Office of Federal Housing Enterprise Oversight; national data; BIS calculations.