MONETARY POLICY AND STOCK PRICES

by

DAVID BECKWORTH

(Under the Direction of Dr. George Selgin)

ABSTRACT

A number of economies at the end of the 20th century were characterized by boom-bust
cycles in their stock markets. In most cases, the dramatic growth in stock prices during
the boom phase was accompanied by relatively stable growth in output prices. The
achievement of stable output prices as a goal for monetary policy is, however, generally
regarded as consistent, if not conducive, to equity price stability. How then can there be
relatively stable output prices and unstable stock prices? I examine the relationship
between monetary policy, output prices, and stock prices by using a simple dynamic
general equilibrium model. I find that in periods of increasing aggregate productivity,
stabilizing output prices may actually promote stock market boom-bust cycles.
Empirically, I check these results and find that during the postwar period monetary policy
did systematically accommodate permanent changes in the growth rate of productivity
and that this accommodation was associated with some volatility in the real stock price.
These results provide consistent but not conclusive evidence for the theoretical findings.

INDEX WORDS: Stock Market, Monetary Policy, Boom-Bust Cycles, Asset Prices,
                 Price Level

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DAVID BECKWORTH

B.B.A., Southern Adventist University, 1994

M.B.A, Georgia State University, 1997

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DAVID BECKWORTH

Major Professor: George Selgin

Committee: William D. Lastrapes
                     Santanu Chatterjee
                     Fred Bateman

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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DEDICATION

I would like to dedicate this dissertation to my family members who faithfully supported me throughout my graduate program. I particularly want to recognize my wife Alicia whose companionship made this experience more meaningful. Also, I thank God for blessing me with the opportunity to attend the University of Georgia and earn a Ph.D. in economics. "Every good and perfect gift is from above…" James 1:17.

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CHAPTER 1

INTRODUCTION

Policymakers often claim that by pursuing price stability they will reduce the risk of boom and bust. But history suggests that, although price stability does deliver big benefits, it does not guarantee economic and financial stability. Indeed, there is reason to believe that financial bubbles may be more likely to develop during periods of low CPI inflation.

- *The Economist*, September 23, 1999.

How does systematic monetary policy influence stock prices? Developments in stock markets at the end of the 20th century provide an interesting context in which to examine this question. A number of countries experienced dramatic growth in real stock prices but relatively stable growth in output prices (Borio, Kennedy, and Prowse, 1994). Figures 1.1 and 1.2 show the two most notable experiences, Japan in the 1980s and the United States in the 1990s, where major boom-bust cycles in the stock market were accompanied by relatively stable output prices.

Output price stability, however, is generally regarded as consistent with, if not conducive to, financial stability. Bordo, Dueker, Wheelock (2000), for example, in their historical study of the relationship between price level stability and financial stability, conclude "that a monetary regime that produces aggregate price stability will, as a by-product, tend to promote stability of the financial system" (p.27). The fact that relatively stable output prices coincided with unsustainable surges in real stock prices

Figure 1.1 - Japan
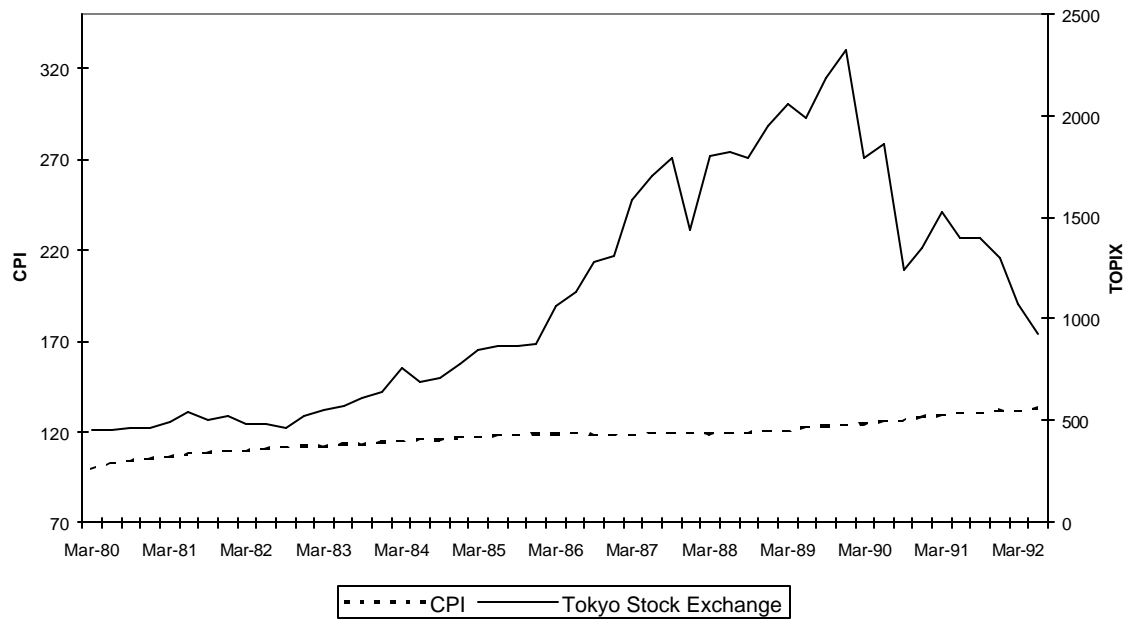
Figure 1.2 - United States

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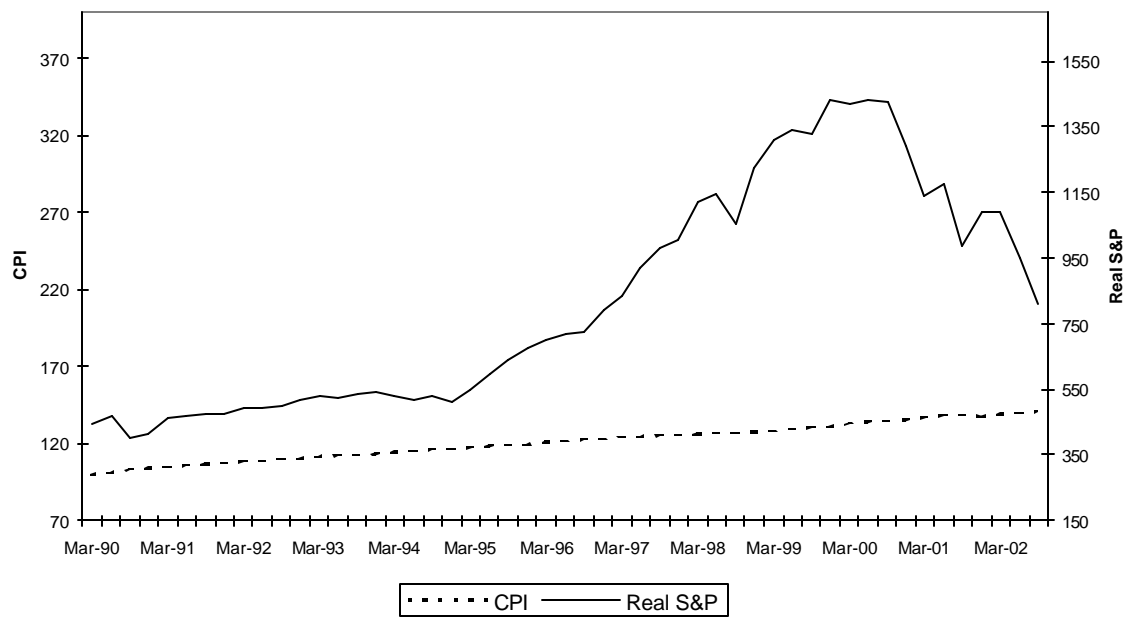
suggests, however, that monetary policy in systematically targeting price stability may not always be consistent with financial stability.

Some policy makers have recognized this possibility. Edward Gramlich, a Federal Reserve Board Governor, notes that "[w]hile our goal of price stability can foster a favorable environment for business investment, we make no pretense to being able control how that plays out in the stock market" (2001). Masaru Hayami, the Bank of Japan Governor, also acknowledges the inconsistency by explaining during the 1980s, that to "prevent the emergence of a [stock market] bubble by monetary policy alone, we would have had to raise interest rates to levels which could not be justified because of the relatively stable prices at the time" (2000).

Underlying the apparent inconsistency between price stability and financial stability during this time was a surge in productivity that contributed to the growth in real stock prices, while keeping output prices relatively stable (Thygesen, 2002). Alan Greenspan has argued that the increased productivity growth permitted economic activity to "expand at a robust clip while helping to foster price stability," but at the same time engendered financial imbalances in the stock market that "could create problems for our economy when the inevitable adjustment occurs (1999).[1] Yutaka Yamaguchi, the Bank of Japan Deputy Governor, has similarly observed that the unique "macroeconomic environment in the second half of the 1980s" where "CPI inflation stayed close to zero for three years…while real growth accelerated" and real stock prices surged can be

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[1] The specific process through which the increased productivity growth could distort stock price is by creating "irrational exuberance" according to Alan Greenspan: "There can be little doubt that if the nation's productivity growth has stepped up, the level of profits and their future potential would be elevated. That prospect has supported higher stock prices. The danger is that in these circumstances, an unwarranted, perhaps euphoric, extension of recent developments can drive equity prices to levels that are unsupportable…Such straying above fundamentals could create problems for our economy when the inevitable adjustment occurs" (1999).

Figure 1.3 - Annual Percent Deviation in Productivity from Trend

Japan

| 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |

United States

Legend: ─── U.S   ─ ▪ ─ ▪ ─ Japan
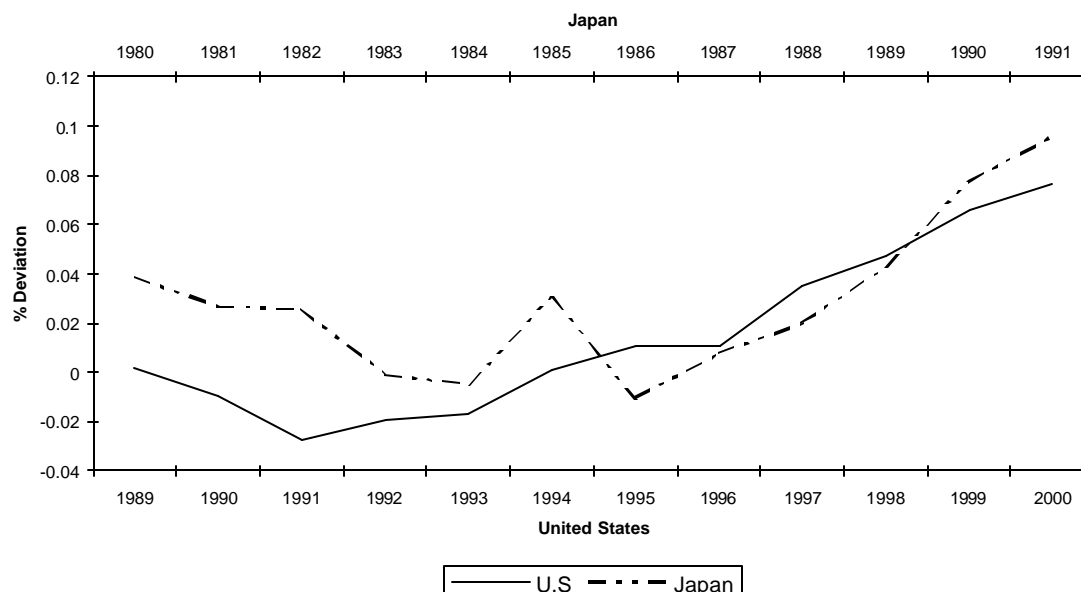
explained in part by "faster improvement in total factor productivity" (1999). Figure 1.3, which shows for each country the percentage deviation of the level of productivity from a fitted trend,[2] reveals that productivity accelerated in the latter half of each decade - the very time the real stock prices began their unsustainable surge.

Borio and Lowe (2002), reviewing this "confluence of events," argue that the "common positive association between favourable supply-side developments, which put downward pressure on prices, on the one hand, and asset price booms, easier access to external finance, and optimistic assessments of risk on the other" requires careful consideration of the role productivity plays in such cycles. Productivity movements, therefore, may be a key factor in explaining why price stability may not always be consistent with financial stability. Given this possibility, how should monetary policy be

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[2] The trends are based on productivity values from 1960 through the decade in question and are fitted using the least squares method. The productivity series for Japan is the manufacturing output per hours index series from the BLS, while the productivity series for the United States is manufacturing multifactor productivity series from the BLS.

conducted? Are certain forms of systematic monetary policy better able than others to handle productivity changes and avoid or limit stock market boom-bust cycles?

I examine this question by considering the effect systematic monetary policies, in the form of simple monetary policy rules, may have on stock prices in periods of accelerating productivity growth. Monetary policy rules have been defined as plans that specify "as clearly as possible the circumstances under which a central bank should change the instruments of monetary policy" (Taylor, 2000, p. 3). So far relatively little research has been done examining the influence alternative monetary policy rules may have on stock prices.[3] This is surprising given the voluminous work done on monetary policy rules,[4] the recent empirical work showing how monetary shocks can affect stock prices,[5] and the recent boom-bust performance of stock markets.   In his survey article on monetary policy and the stock market, Peter Sellin (2001) notes this absence and suggests that "It would be interesting to see what different types of monetary policy rules would imply for the behavior of equity prices…"(p. 533).

My dissertation follows Sellin's suggestion by examining the relationship between systematic monetary policy and stock prices. First, I review relevant research that examines the relationship between monetary policy, price stability, and stock price stability. Second, I develop a simple general equilibrium model that allows for both sticky wages and productivity innovations, and use it to simulate the stock market, real output, and the price level under different monetary policy rules. Third, I determine if the

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[3] Bernanke and Gertler (1999) and Cecchetti, Lipsky, and Wadhwani (2000,2002) are exceptions. These studies, however, only consider whether monetary policy should respond to destabilizing change in asset prices, not whether monetary policy conduct creates the destabilizing changes in the first place. Also, these studies only use Taylor-like rules in their analysis. I will use several alternative monetary policy rules and compare their performance.

[4] See John Taylor's monetary policy rules web page at http://www.stanford.edu/~johntayl/PolRulLink.htm.

[5] Examples include Dhakal, Kandall, and Sharma (1993) , Patelis (1997) Thorbeke (1997), Lastrapes (1998), and Ewing (2001).

theoretical model is consistent with the empirical record by estimating a VAR and performing innovation accounting and attempt a counterfactual simulation. Finally, I draw on my findings to determine how monetary policy might be systematically conducted so as to minimize stock market volatility in periods of accelerating productivity growth.

CHAPTER 2

PREVIOUS RESEARCH

A common idea equates price level stability with macroeconomic stability. What about

stock prices? Does a price-level-stabilizing monetary policy also promote stock price

stability?

One of the first economists to examine this question was Irving Fisher, who held

that output price stabilization does serve to stabilize stock prices. Fisher begins his

analysis by arguing that stock prices are very sensitive to changes in the money supply.

Drawing on the quantity theory of money, which treats changes in output prices as a

means for keeping the supply of nominal money equal to demand for it, he observes that

some prices such as "wages, salaries, … [and] the price of bonded securities" are rigid

and "cannot change in proportion to monetary fluctuations" (1922, p.190). Relatively

flexible prices therefore tend to adjust more than proportionally in the short run following

a burst of money creation not matched by any increase in real money demand. Stock

prices are especially likely to overshoot:

Th[e] supersensitiveness to the influence of the volume of currency… applies in a special
way to stocks … since the money price of bonds is relatively inflexible, that of stocks
will fluctuate more than the price of the physical wealth as a whole. The reason is that
these securities not only feel the general movements which all adjustable elements feel,
but must also conform to a special adjustment to make up for the nonadjustability of
bonds associated with them (1922, pp.190-191).

Fisher concluded on the basis of this argument that a monetary policy aimed at general

price stability will not only promote macroeconomic stability but also serve to minimize

fluctuations in stock prices. Fisher also insisted that the behavior of the stock market during the 1920s was consistent with his reasoning. Although he acknowledged that the "expected earnings of corporations … bulk larger [in the late 1920s] than they did a few years ago," (1930, p.182) he claimed that this was true only because the "stable dollar" had given rise to more "prosperous conditions, bigger earnings, better prospects" (ibid).

While Fisher believed output price stability and equity price stability to be fully compatible goals, a few of his contemporaries took exception to his view. They claimed that price stability was consistent with equity price stability only under conditions of zero growth in productivity. Otherwise, they argued, equity price stability was best achieved by allowing the price level to move inversely with changes in productivity. Central to their way of thinking was their understanding that changes in productivity imply changes in per unit costs of production and, given competitive pressures, changes in the relationship between input and output prices. Allowing changes in the price level, an average of output prices, to reflect the underlying changes in per unit costs serves to stabilize actual and expected profits, despite the stickiness of certain money prices, thereby stabilizing stock prices.[6] It follows that, in an environment of positive productivity growth, a <u>decline</u> in output prices may be required to keep stock prices in line with fundamentals. Attempts to stabilize output prices under circumstances of rising productivity will, on the other hand, require upward adjustments in nominal input prices.

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[6] Stated differently, if productivity gains result in lower unit production costs, firms confronted with an unchanged market demand schedule will lower their sale price to beat the competition yet maintain their profit margins. Consequently, the aggregate price level, an average of all the sale prices, will also decline without harming firm viability.

Figure 2.1 - 1922-1931
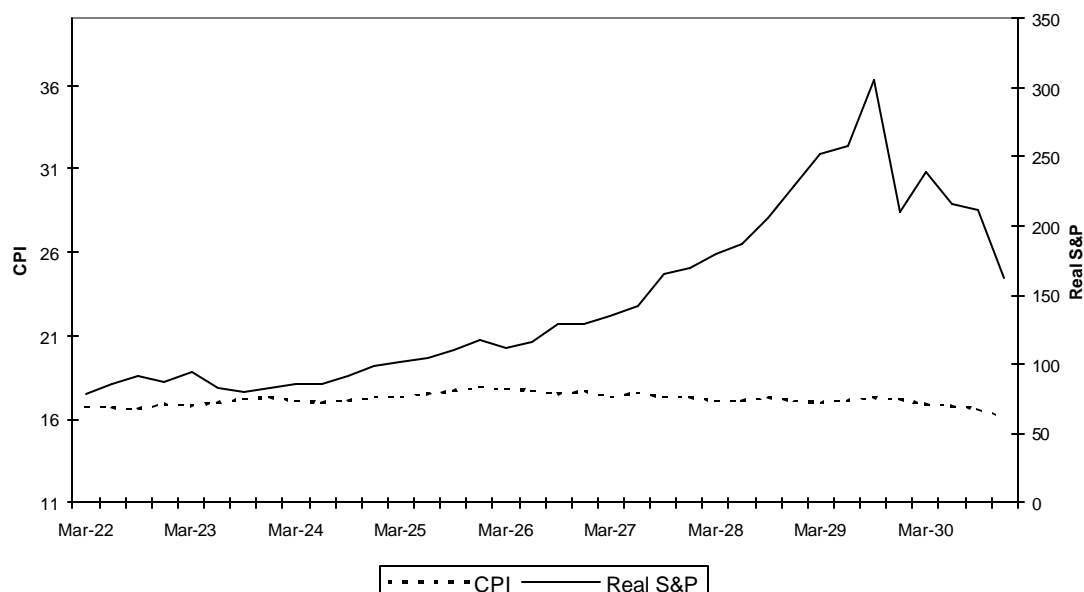
Consequently, if input prices are sticky, such attempts might destabilize stock prices by causing a temporary "profit" inflation (e.g. Robbins, 1934, p. 42).[7]

Applying such reasoning, C.A. Phillips, T.F. McManus, and R.W. Nelson (1937, p.176), among others,[8] concluded that the 1920s stock market boom "had [its] origin in the price stabilization policy, or managed currency experiment, of the Federal Reserve Board during the years leading up to the depression." Figure 2.1 reveals the 1920s are indeed years of relatively stable output prices combined with surging real stock prices. Kendrick (1961), among others, shows that the 1920s was also a period where productivity accelerated. The evidence from the 1920s, therefore, is at least consistent

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[7] "Profit" inflation occurs in the presence of price stability if the money supply is growing fast enough to increase aggregate demand, offset the downward pressure on the price level from the productivity gains, and create a relative inflation where prices, although stable, are higher than they would otherwise be. Consequently, Robbins argued a "stationary price-level shows an absence of inflation only when production is stationary," but in "a period of increasing productivity the stability of prices…far from being a proof of the absence of inflation, is a proof of its presence" (ibid).

[8] Hayek (1935, p.133), for example, explains that "[t]here can be no doubt that this sort of 'paper profit' has played an enormous role…during all major booms – even if no rise in the absolute level of the prices of consumers' goods has taken place. And even more important than the pseudo-profits computed by entrepreneurs under such conditions are the gains on capital appreciation made on the stock exchange."

with the idea that by accommodating productivity growth in order to stabilize the price level, monetary authorities may contribute to stock market booms.

Research concerning the bearing of monetary policy on stock prices was largely abandoned after the Great Depression and was not taken up again until after the stock market booms of Japan and the United States in the 1980s and 1990s. By this time the debates concerning the 1920s had been largely forgotten, while a goal of general price level stability had become of the reigning orthodoxy. Researchers renewed the inquiry by considering whether systematic monetary policy should deliberately target asset as well as output prices. Goodhart (1999) and Cecchetti, Genberg, Lipsky, and Wadhwani (2000, 2002) insist monetary authorities should target asset prices. [9] Cecchetti et al. (2000, p. xix), for example, argue that a "central bank concerned with stabilizing inflation about a specific target level is likely to achieve superior performance by [systematically] adjusting its policy instruments… also to asset prices." Others (e.g. Kindleberger, 1995; Cogley, 1999; Bullard and Schalling, 2002) reply that monetary authorities lack the information needed to regulate stock prices appropriately and are therefore likely to destabilize real output by attempting to reign in stock prices.[10] Alan Greenspan similarly states that it is "far from obvious that bubbles, even if identified early, could be preempted short of the central bank inducing a substantial contraction in economic activity." Greenspan believes that the monetary authority should instead let "bubbles" pop on their own and then "mitigate the fallout when it occurs" so as to "ease the transition to the next expansion" (2002).

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[9] Earlier work arguing for considering asset values include Santoni and Moehring (1994), and Alchian and Klein (1973).
[10] Bernanke and Gertler (1999) also take a relatively negative stand in arguing that asset prices should be considered only if they signal changes in expected inflation.

Importantly, this recent literature concerning asset-price targeting asks only whether central banks ought or ought not to *respond* to observed changes in stock prices; implicitly this literature holds central bankers to be more or less capable of stabilizing stock prices, without addressing possibility that their policies may in fact be responsible for unsustainable stock price movements.

A few modern researchers have, however, concerned themselves with the possibility that monetary policy may itself be a cause of unintended stock price movements when productivity growth is accelerating. Selgin (1999, p. 1), drawing on earlier arguments, argues that slowly adjusting factor prices such as wages can mean swollen profit margins and stock prices if a monetary authority attempts to stabilize prices while productivity is on the rise:

> The relative rigidity of input prices, and of the price of labor especially, compared to output prices is … reason for doubting the widespread belief that a stable price level best avoids booms and busts. Suppose, for example, that productivity grows more rapidly than usual. In that case, a zero-inflation policy requires a money growth rate sufficient to sustain a rate of factor-price inflation equal to the rate of productivity growth. If, however, factor prices are rigid, more rapid monetary expansion may at first succeed in swelling corporate earnings, without inducing any equivalent rise in factor prices. Firms' profits will then be artificially enhanced. Speculators who fail to appreciate the temporary nature of those swollen profits will bid up stock prices, generating a boom.

A 1998 Federal Reserve Bank of Cleveland *Annual Report* (p. 11) similarly argues that the money growth associated with relatively stable prices and increasing productivity can "turn productivity gains into a speculative bull run", possibly contributing to the then present bull market. Bernard and Bisignano (2001, p. 31) also believe that price stabilization policies may create macroeconomic distortions, and that understanding this may "provide some insights [into] the boom-crash in economic activity and asset prices in Japan during the second half of the 1980s … and to a lesser

extent … the experience of the United States during the latter half of 1990s." Borio and Lowe (2002) implicitly make the same claim by noting that the "co-existence of an unsustainable boom in credit and asset markets on one hand, and a low declining inflation on the other" can be explained in part by "an improvement in the supply side of the economy" where such developments can put both "upward pressure on asset prices not only because of their positive effect on profitability, but also because of the general sense of optimism about the future" and "downward pressure on the prices of goods and services, particularly by reducing labor unit costs" (p. 21). These studies, like the earlier 20th century productivity literature, suggest that rapid productivity improvements accommodated by monetary easing to stabilize the price level may in fact contribute to and partly explain stock market booms. Consequently, during periods of rising productivity deflation may be necessary to minimize boom-bust cycles in the stock market

Two differing views thus emerge from the literature. The first view assumes that systematic monetary policy that aims for some form of price stability is generally conducive to stock price stability regardless of productivity improvements. This view suggests that monetary authorities should resist compromising price stability in order to attempt to resist rapid stock price increases. The second view argues that maintaining price level stability during times of increasing productivity growth requires monetary easing that may itself contribute to unsustainable surges in stock prices. According to this view, allowing the price level to reflect changes in productivity can and should minimize stock market volatility.

Monetary policy rules reflecting these two perspectives - one that offsets changes in the price level arising from positive changes in aggregate productivity and one that does not - will therefore be considered in this paper. The first rule aims at simple output price level stabilization by targeting a growth rate for the money supply equal to the real output growth rate. Monetary policy under this rule accommodates real output growth driven by positive productivity changes and consequently prevents the price level from changing. The second rule, which, following Selgin (1995b, 1997) I refer to as a "productivity norm" rule, allows the money supply to grow at the growth rate of the factor input.[11] Given a constant capital stock, a productivity norm stabilizes the nominal wage, but permits the output price level to alter in response to anticipated as well as unanticipated productivity changes. Positive productivity movements will then be reflected in proportional negative movements in the price level and vice versa. The real stock return consequences of these alternative rules are explored in the sections that follow.

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[11] Selgin (1997) actually discusses two forms of the productivity norm rule. The first version allows the money supply to grow at the total factor input growth rate. The second version sets the money supply growth rate equal to labor input growth rate. Selgin argues that the former is probably preferable.

CHAPTER 3

MONETARY POLICY AND STOCK PRICES IN A GENERAL EQUILIBRIUM
MODEL

I begin my theoretical analysis with a standard stochastic neoclassical growth model of the kind often used in business cycle analysis,[12] which I modify to allow for nominal rigidities, monetary policy rules, productivity innovations, and a market for equity.[13] These elements provide a framework by which to examine how systematic monetary policy may influence stock prices. The examination is accomplished by comparing the theoretical impulse response functions of the model for different monetary policy rule specifications.

3.1 The Economic Environment

The economy consists of production firms and identical infinitely-lived households. The production firms purchase labor from the households and payout their profits to them as dividends. Household wealth consists of real money balances, one-period riskless bonds denominated in real output, and equity shares. Preferences for the households are defined over consumption, real money balances, and leisure. Finally, a monetary authority manages the nominal money supply according to a monetary rule.

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[12] For example, see King, Plosser, and Rebelo (1988) Hairault and Portier (1993), King and Watson (1995), Ireland (1997), Bernanke, Gertler, and Gilchrist (1999), and Kim (2000).
[13] I build in stocks following the work of Obstfeld and Rogoff (1996) and Lantz and Sarte (2001).

Nominal rigidities arise because nominal wages are set one period in advance.[14] The preset nominal wages give rise to monetary non-neutralities when the economy is perturbed from its steady state. In particular, nominal wages do not rise in concert with the increased nominal demand for labor generated by an unexpected increase in the money supply. Consequently, real wages lag behind monetary innovations, and output temporarily increases.

3.2   Production Firms

A large number of identical firms produce Y_t units of output according to the following constant-returns-to-scale Cobb-Douglass technology, where capital has a constant value normalized to one, N_t is the labor force, and L_t denotes labor input, which is purchased from households at W_t :

(3.1) $$Y_t = A_t \left(N_t L_t^{1-a} \right) \quad 0 < a \leq 1.$$

A_t, the productivity component, and N_t grow in the steady state according to g_A and g_N, respectively, where $g_X = \left(\dfrac{X_{t+1} - X_t}{X_t} \right)$ and is determined exogenously.

Productivity deviates from its steady state level according to productivity shocks that follow a first-order autoregressive process represented by

(3.2) $$\hat{A}_t = r_A \hat{A}_{t-1} + e_{A_t}$$

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[14] I assume but do not model transaction costs that rule out contemporaneous adjustments to wages in response to perturbations to the economy. Thus, wages are preset. My sticky wage assumption follows a number of recent studies that show nominal wage contracts can generate output responses in a dynamic general equilibrium model that are consistent with the empirical record (e.g. Benassy, 1995; Cho and Cooley, 1995; Kim, 2000). Some empirical studies also indicate the sticky wage assumption is justified (e.g. Spencer).

where r_A is set equal to one, e_{A_t} is an i.i.d. normal random variable with zero mean, and letters with a hat represent percent deviations from the steady state path of variable levels.[15] Dividing equation (3.1) through by N_t and denoting the quotient in lower case letters gives rise to the per capita production function

$$(3.3) \qquad y_t = a_t l_t^{1-a},$$

which implies

$$(3.4) \qquad \hat{a}_t = r_A \hat{a}_{t-1} + e_{A_t}.$$

Productivity therefore includes a deterministic component as well as a white noise component.

Abstracting from investment and capital depreciation (and thereby adhering to my simplifying assumption of K =1), I assume that the production firms pay dividends, d_t, equal to each period's real profits,

$$(3.5) \qquad d_t = a_t l_t^{1-a} - \frac{w_t l_t}{p_t}_t.$$

Households own the firms through shares and seek to maximize their returns. Consequently, each firm's problem is to choose labor input to maximize current and discounted future profits for its shareholders. This problem can be represented as

$$(3.6) \qquad \max \quad E_t \sum_{j=0}^{\infty} \left[\left(\frac{1}{1+r_{t+j-1}} \right)^s \left(a_{t+j} l_{t+j}^{1-a} - w_{t+j} l_{t+j} / p_{t+j} \right) \right].$$

The first order condition associated with the each firm's problem is

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[15] This implies that productivity term evolves according to $A_t = (1 + g_A) A_{t-1} + (1 + \hat{A}_t - \hat{A}_{t-1}) A_{t-1}$.

(3.7)
$$(1-\mathbf{a})a_t l_t^{-\mathbf{a}} = \frac{w_t}{p_t}.$$

Therefore, each firm maximizes current and discounted future profits by choosing labor input such that the marginal product of labor equals the real wage rate in equilibrium.

3.3   Households

The infinitely-lived households maximize their expected discounted flow of period t utility defined over consumption, real money balances, and leisure for periods $t = 0, 1, 2, 3, \ldots$ according to

(3.8)
$$E_t \sum_{j=0}^{\infty} \mathbf{b}^j U\left[c_{t+j}, m_{t+j}/p_{t+j}, 1 - l_{t+j}\right],$$

where c_t represents consumption in period t, m_t/p_t represent real money holdings acquired at time t and carried into $t+1$, $1-l_t$ represents leisure, and $\mathbf{b}$ is the discount factor that is assumed to constant but can change.[16] I assume real balances generate utility by facilitating transactions in period t, without attempting to incorporate actual transactions frictions into the model. The utility function is assumed to be strictly concave, continuously differentiable, and increasing in all arguments. The single-period utility function takes the additively separable form,

(3.9)
$$U\left[c_t, m_t/p_t, 1 - l_t\right] = \ln c_t + \mathbf{g}_t \ln \frac{m_t}{p_t} + \mathbf{h} \ln(1 - l_t),$$

where $\mathbf{g}_t$ is a money demand innovation (the inverse of the velocity innovation, v_t), that follows $\ln \mathbf{g}_t = \mathbf{r}_g \ln \mathbf{g}_{t-1} + (1 - \mathbf{r}_g) \ln \mathbf{g} + \mathbf{e}_{g_t}$ and $\mathbf{h} > 0$.

---

[16] A change in the discount factor can be considered an interest rate shock.

Each household supplies l_t units of labor at nominal wage rate w_t. Wages are set one period ahead. Consistent with rational expectations, the pre-set wage rate clears the market (that is, it remains at equilibrium as state variables evolve at constant rates of change) in the steady state, giving rise to real rigidities only given an unforeseen perturbation to the economy. In this exercise, the perturbation will be a productivity innovation that may or may not be accommodated to by the monetary authority. Given preset wages, the greater the monetary accommodation, the greater the relative decline in real wages and the greater the increased nominal demand for labor. Consequently, real output temporarily increases.

As noted, production firms are owned by the households through equity shares, x_t, with shareholders receiving t period real profits, d_t, as dividends. The real market value of household equity is $s_t x_t$, where s_t represents the real price of outstanding equity shares. Each household also owns one-period riskless real bonds, b_t, where each of these is purchased at a discount of $(1+r_t)^{-1}$ units output in period t, and redeemed in the following period, $t+1$, for b_t output. Finally, the monetary authority transfers its seigniorage profits back to the households. Consequently, each household solves

(3.10)
$$\max E_t \sum_{j=0}^{\infty} \boldsymbol{b}^j U\left(\ln c_{t+j} + \boldsymbol{g}_t \ln \frac{m_{t+j}}{p_t} + \boldsymbol{h} \ln\left(1 - l_{t+j}\right) \right)$$

subject to the budget constraint

(3.11)
$$c_t = \left[\frac{w_t l_t}{p_t} + \frac{m_{t-1}}{p_t} + b_{t-1} + d_t x_{t-1} + \left(s_t x_{t-1} - s_{t-1} x_{t-1}\right) + t_s \right]$$

$$- \left[\frac{m_t}{p_t} + b_t \left(1 + r_t\right)^{-1} + \left(s_t x_t - s_{t-1} x_{t-1}\right) \right].$$

The first bracket on the right hand side of equation (3.11) contains sources of consumption: real wages, real money balances carried into period t, real bonds, real dividends, capital gains on equity shares, and seigniorage transfers. The second contains expenditures reducing consumption opportunities: carry over real money balances, bond purchases, and net increases in real equity holdings. The first-order conditions for a solution to the household problem are

$$(3.12) \qquad c_t(j)^{-1} = \mathbf{1}_t,$$

$$(3.13) \qquad \left(m_t(j)/\mathbf{g}_t p_t\right)^{-1} = \mathbf{1}_t - \mathbf{b}E_t\left(\mathbf{1}_{t+1}\, p_t/p_{t+1}\right),$$

$$(3.14) \qquad (1 + r_t) = E_t\left(\frac{\mathbf{1}_t}{\mathbf{b}\mathbf{1}_{t+1}}\right),$$

$$(3.15) \qquad 1 = \mathbf{b}E_t\left(\frac{\mathbf{1}_{t+1}}{\mathbf{1}_t}\left\langle\frac{d_{t+1}(j) + s_{t+1}(j)}{s_t(j)}\right\rangle\right),$$

$$(3.16) \qquad \mathbf{h}\frac{1}{1 - l_t(j)} = \frac{w_t(j)}{p_t}\mathbf{1}_t,$$

and equation (3.11), where $\mathbf{1}_t$ is the multiplier on the budget constraint. Equations (3.12) and (3.13) together show the marginal rate of substitution of consumption for real money balances.[17] The demand for real money balances is given by

$$(3.17) \qquad \frac{m_t(i)}{p_t} = \mathbf{g}_t c_t(i)\left(\frac{R_t^n - 1}{R_t^n}\right)^{-1},$$

---

[17] $\dfrac{U_{\frac{M}{P}}}{U_C} = \dfrac{\left(m_t/p_t\right)^{-1}}{c_t^{-1}} = 1 - E_t\left(\dfrac{p_t/p_{t+1}}{1 + r_t}\right) = \dfrac{R_t^n}{1 + R_t^n}$

where R_t^n is the gross nominal interest rate, i.e., $R_t^n = E_t(1+r_t)(1+E_t\boldsymbol{p}_{t+1})$.[18] Equation (3.14) indicates that, at the risk-free rate, a riskless one period bond must be equal to the stochastic discount factor in equilibrium, while equation (3.15) is a Lucas asset pricing equation for equity shares. Equation (3.16), finally, is the household labor supply equation.

3.4 Market Value of Equity Shares

The market value of equity shares can be derived from the household's first order conditions. Equation (3.14) and (3.15) can be rearranged to show the discounted present value of an equity share:

$$(3.18) \qquad s_t(i) = \left[\frac{E_t\left(d_{t+1}(j)+s_{t+1}(j)\right)}{1+r_t}\right] + Cov_t\left[\boldsymbol{b}\frac{c_t(j)}{c_{t+1}(j)}\left(d_{t+1}(j)+s_{t+1}(j)\right)\right],$$

where the first term shows the expected payout given the risk-free rate, while the second shows the riskiness of the payout. Real stock prices, therefore, are influenced by the real interest rate, expected dividends or profits, and a risk premium.

3.5 Monetary Policy

The money stock evolves according to the generalized monetary policy rule

$$(3.19) \qquad\qquad m_t = m_{t-1} + \boldsymbol{m} - v_t + \boldsymbol{q}_t,$$

where $\boldsymbol{m} = \boldsymbol{j}_A g_A + \boldsymbol{j}_A(\hat{a}_t - \hat{a}_{t-1}) + \boldsymbol{j}_N g_N$, v_t is a velocity shock, and $\boldsymbol{q}_t$ is a money supply shock. A price stabilization rule sets $\boldsymbol{j}_A = \boldsymbol{j}_N = 1$, while a "productivity norm" sets $\boldsymbol{j}_N = 1$ and $\boldsymbol{j}_A = 0$. The price stabilization rule thus allows the money supply to grow at

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[18] Note that $(1 + E_t\boldsymbol{p}_{t+1}) = E_t p_{t+1}/p_t$.

the economy's rate of real output growth. This implies that the price level will be

unchanging in the steady state. The productivity norm rule allows the money supply to

grow at the growth rate of the labor force. This implies that nominal wages will be

stabilized while the price level will decline at the rate of productivity growth in the steady

state. [19] Since e_{A_t} is a white noise process, the $(\hat{a}_t - \hat{a}_{t-1})$ term is only different from zero

when e_{A_t} is shocked. Consequently, this term only matters outside the steady state. The

velocity term, v_t, drops out when the money supply equation is set equal to the money

demand equation since under both rules velocity is accommodated or $g_t = -v_t$. Both the

money demand shock and the money supply shock follow an AR(1) process and are

defined in section 3.6. [20]

3.6   Potential Perturbations

The model outlined above allows for five potential disturbances to the system as shown

in table 3.1. The first perturbation can arise from a productivity shock. This shock will

permanently affect all endogenous variables owing to its influence on output and also

because $r_A = 1$.   A second perturbation can occur if households change their

intertemporal discounting. This disturbance would be seen in a change to b, the

discount factor, which is essentially a shock to the real interest rate. This shock

permanently affects all the endogenous variables, but has no influence over productivity,

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[19] This rule holds in per capita form when the labor force is set equal to 1, which occurs with the representative agent framework used in section 3.6.

[20] The budget constraint of the monetary authority can be stated as follows: $\dfrac{m_t - m_{t-1}}{p_t} = t_s$, where t_s is the seigniorage transfer.

Table 3.1 - Potential Perturbations to the Model

Potential Perturbations	Consequences
Productivity	Permanently affects all endogenous variables
Real Interest Rate	Permanently affects all endogenous variables, but does not influence productivity
Money Demand	Permanently affects endogenous variables except for the real interest rate. Does not influence productivity.
Stock Price	Permanently affects only real stock price
Money Supply Shock	Permanently affects only money supply

which is exogenously driven. The third perturbation can arise from a money demand shock. This shock can permanently influence all endogenous variables except for the real interest rate. The fourth perturbation can arise from a change to the risk premium term in the stock equation. This shock, however, only permanently influences the real stock price. The final perturbation can arise from a money supply shock. This shock can temporarily influence the other endogenous variables, but can only permanently influence the nominal money supply.

Although there are five potential shocks, I only consider in this chapter the implications of the productivity shock given the objectives of this paper. This discussion of the potential perturbations, however, will guide my identification strategy in the empirical chapter that follows.

3.7 Model Solution

The equilibrium conditions given above can be used to find a solution of the dynamic interaction between variables out of the steady state where nominal rigidities are encountered.

The solution is derived in several steps. First, the identical nature of all households and production firms allows us to focus on a representative household and a representative production firm. In a representative agent framework the net supply of bonds, b_t, is zero, and the net supply of stocks each period, x_t, is unity. Given this representative agent framework and an aggregate resource constraint

(3.20)
$$y_t = c_t, [21]$$

there exists a system of equations for the variables y_t, c_t, w_t, l_t, r_t, i_t, m_t, p_t, s_t, a_t, and $\boldsymbol{g}_t$.

Second, given the steady state values of the system of equations, a log-linearized model defined in terms of percent deviations from steady state can be derived. The log-linearized model is presented below, with lower case variables with hats representing percent deviations from the steady state level. These equations define how variables dynamically interact given a perturbation from the steady state. [22] The equations are:

Aggregate Demand

(3.21)
$$\hat{y}_t = \hat{c}_t$$

(3.22)
$$\hat{r}_t^G = E_t \hat{c}_{t+1} - \hat{c}_t$$

(3.23)
$$\hat{m}_t - \hat{p}_t = \boldsymbol{g}_t + \hat{c}_t - \boldsymbol{1}_1 \hat{i}_t$$

(3.24)
$$\hat{l}_t = \hat{y}_t - \hat{w}_t + \hat{p}_t$$

Aggregate Supply

(3.25)
$$\hat{y}_t = \hat{a}_t + (1 - \boldsymbol{a})\hat{l}_t$$

(3.26)
$$\hat{w}_t = \left(l^{ss} \big/ 1 - l^{ss} \right) \hat{l}_t + \hat{p}_t + \hat{c}_t$$

---

[21] An alternative aggregate resource constraint is $y_t = d_t + \dfrac{w_t l_t}{p_t}$.

[22] The parameters are defined in the appendix.

23

Innovation Processes

(3.27)
$$\hat{a}_t = \boldsymbol{r}_A \hat{a}_{t-1} + \boldsymbol{e}_{A_t}$$

(3.28)
$$\boldsymbol{g}_t = \boldsymbol{r}_g \boldsymbol{g}_{t-1} + \boldsymbol{e}_{g_t}$$

(3.29)
$$\boldsymbol{q}_t = \boldsymbol{r}_q \boldsymbol{q}_{t-1} + \boldsymbol{e}_{q_t}$$

Stock Price, Dividends, Nominal Interest Rate, Monetary Policy Rule

(3.30)
$$\hat{s}_t = E_t \big((1-\boldsymbol{b}) \hat{d}_{t+1} + \boldsymbol{b} \, \hat{s}_{t+1} \big) - \hat{r}_t$$

(3.31)
$$\hat{d}_t = \hat{y}_t$$

(3.32)
$$\hat{i}_t = \hat{r}_t^G + E_t \hat{\boldsymbol{p}}_{t+1}$$

(3.33)
$$\hat{m}_t = \hat{m}_{t-1} + \boldsymbol{j}_A \boldsymbol{e}_{A_t} - \boldsymbol{e}_{g_t} + \boldsymbol{e}_{q_t}$$

Equations (3.21) - (3.24) show the aggregate resource constraint, the real interest rate, money demand, and labor demand.[23] Equations (3.25) and (3.26) refer to real output and labor supply. Equation (3.27) shows the productivity shock, while equations (3.28) and (3.29) show the money demand and money supply shocks. The real stock price, dividends, the nominal interest rate, and the monetary policy rule are shown in equations (3.30) - (3.33). Note that if one substitutes equations (3.22), (3.23), and (3.31) into equation (3.30), the real stock price simply becomes a function of real output. Equation (3.33) shows how the money supply responds outside the steady state to perturbations, which in this exercise is focused on productivity innovations. The price stabilization ruled fully accommodates the productivity innovation by setting $\boldsymbol{j}_a = 1$, while the productivity norm does not accommodate it at all, setting $\boldsymbol{j}_a = 0$.

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[23] r^G is the gross real interest rate.

Finally, following Walsh (2001), I now show how nominal wages are preset and then solve to obtain reduced form equations that can be used to find the dynamic paths of my model's variables.[24] Equating the labor supply (3.26) and labor demand, (3.24) yields

$$(3.34) \qquad \hat{w}_t = \hat{p}_t + \hat{y}_t.$$

Since this equation shows the market clearing nominal wage with no rigidities, a one period ahead preset nominal wage is set equal to the expected values of next period's price level and real output:

$$(3.35) \qquad \hat{w}_t^c = E_{t-1}\hat{p}_t + E_{t-1}\hat{y}_t,$$

where $\hat{w}_t^c$ is the contract nominal wage at time t. Employment under this framework becomes labor demand driven so that equation (3.24) becomes

$$(3.36) \qquad \hat{l}_t = \hat{y}_t - \hat{w}_t^c + \hat{p}_t$$

$$= (\hat{y}_t - E_{t-1}\hat{y}_t) + (\hat{p}_t - E_{t-1}\hat{p}_t).$$

Plugging equation (3.36) back into the production function, taking expectations of this expression as of time t-1, and subtracting this new equation from its time t version yields

$$(3.37) \qquad \hat{y}_t = E_{t-1}\hat{y}_t + w(\hat{p}_t - E_{t-1}\hat{p}_t) + e_t,$$

where $v = (1-a)/a$ and $e_t = (\hat{a}_t - E_{t-1}\hat{a}_t)/a$. Expression (3.37) is the summary aggregate supply equation, which shows how productivity innovations and deviations in the actual level of prices from the expected level affect real output. A summary equation for aggregate demand can also be derived by combining equations (3.21) and (3.22),

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[24] Like Walsh (2001), I also assume that labor supply is relatively inelastic with respect to real wage in the long run. The amount of labor employed, however, can be temporarily off the labor supply curve. The inelastic labor assumption implies that $E_t\hat{y}_{t+1} = E_t\hat{a}_{t+1} = r_A\hat{a}_t$ since $E_t\hat{l}_{t+1} = 0$.

plugging the result into the Fisher equation, (3.32), and then plugging this expression into the money demand equation (3.23). The results is

$$(3.38) \qquad \hat{y}_t = \frac{\boldsymbol{l}^{-1}(\hat{m}_t - \hat{p}_t) + E_t\hat{\boldsymbol{p}}_{t+1} + \boldsymbol{r}_A\hat{a}_t - \boldsymbol{l}^{-1}\boldsymbol{g}_t}{1 + \boldsymbol{l}^{-1}}.$$

This aggregate demand equation shows that real output is negatively related to the price level for a given stock of nominal money and positively related to inflationary expectations and productivity innovations.

Equating the aggregate supply and aggregate demand equations through $\hat{y}_t$ and solving for $\hat{p}_t$ yields

$$(3.39) \quad \hat{p}_t = \frac{\boldsymbol{l}^{-1}\hat{m}_t + \boldsymbol{v}(1 + \boldsymbol{l}^{-1})E_{t-1}\hat{p}_t + E_t\hat{\boldsymbol{p}}_{t+1} + \boldsymbol{r}_A\hat{a}_t - (1 + \boldsymbol{l}^{-1})(\boldsymbol{r}_A\hat{a}_{t-1} + e_t) - \boldsymbol{l}^{-1}\boldsymbol{g}_t}{\boldsymbol{l}^{-1} + \boldsymbol{v}(1 + \boldsymbol{l}^{-1})},$$

which is the dynamic general equilibrium time path for the price level outside the steady state. Taking the expected value of this equation at time *t-1* and subtracting it from equation (3.39) gives

$$(3.40) \quad \hat{p}_t - E_{t-1}\hat{p}_t = \frac{\boldsymbol{l}^{-1}(m_t - E_{t-1}m_t) + E_t\hat{\boldsymbol{p}}_{t+1} - E_{t-1}\hat{\boldsymbol{p}}_t + \boldsymbol{r}_A\hat{a}_t - (1 + \boldsymbol{l}^{-1})e_t - \boldsymbol{l}^{-1}e_t}{\boldsymbol{l}^{-1} + \boldsymbol{v}(1 + \boldsymbol{l}^{-1})}.$$

It is now possible to solve for the dynamic general equilibrium time path for real output by plugging equation (3.40) into the aggregate supply equation while noting that $E_{t-1}\hat{y}_t = E_{t-1}\hat{a}_t = \boldsymbol{r}\hat{a}_{t-1}$. This results in the expression

$$(3.41) \qquad \hat{y}_t = \boldsymbol{r}_A\hat{a}_{t-1} + \left(\frac{\boldsymbol{l}^{-1}}{\boldsymbol{l}^{-1} + \boldsymbol{v}(1 + \boldsymbol{l}^{-1})}\right)e_t$$

$$+ \frac{\boldsymbol{v}\left\{\boldsymbol{l}^{-1}(\hat{m}_t - E_{t-1}\hat{m}_t) + E_t\hat{\boldsymbol{p}}_{t+1} - E_{t-1}\hat{\boldsymbol{p}}_{t+1} + \boldsymbol{r}_A e_t - \boldsymbol{l}^{-1}\boldsymbol{g}_t\right\}}{\boldsymbol{l}^{-1} + \boldsymbol{v}(1 + \boldsymbol{l}^{-1})}.$$

Thus, in general equilibrium real output is driven by unexpected changes in the nominal money stock, unexpected changes in inflationary expectations, and innovations to productivity.

Before I can use this expression to examine the dynamic path of real output, I must first simplify the price equation to show the price level as a function of the money supply and innovations only. I begin by replacing the inflation term with its individual components. Equation (3.39) becomes

$$(3.42) \quad \hat{p}_t = \frac{\boldsymbol{I}^{-1}\hat{m}_t + \boldsymbol{v}\left(1+\boldsymbol{I}^{-1}\right)E_{t-1}\hat{p}_t + E_t\hat{p}_{t+1} + \boldsymbol{r}_A\hat{a}_t - \left(1+\boldsymbol{I}^{-1}\right)\left(\boldsymbol{r}_A\hat{a}_{t-1} + e_t\right) - \boldsymbol{I}^{-1}\boldsymbol{g}_t}{1+\boldsymbol{I}^{-1} + \boldsymbol{v}\left(1+\boldsymbol{I}^{-1}\right)}.$$

Next, following the method of undetermined coefficients as outlined by Campbell (1994) and Uhlig (1997), I posit that the price level is a function of the money supply, productivity innovations, and their permanent effects.[25] After some algebra, this yields

$$(3.43) \qquad \hat{p}_t = \hat{m}_{t-1} - \boldsymbol{r}_A\hat{a}_{t-1} + \left(\frac{\boldsymbol{I}^{-1}\boldsymbol{j}_a + \boldsymbol{j}_a - \left(1+\boldsymbol{I}^{-1}\right)}{\left(1+\boldsymbol{v}\right)\left(1+\boldsymbol{I}^{-1}\right)}\right)e_t.$$

Given these reduced form equations for real output and the price level I can now examine the dynamic paths of the variables of interest.

3.8   Implications

I now consider some dynamic simulations based upon the solution of the model. Using the equations for money supply, (3.33), productivity innovations, (3.28), real output, (3.41), and the price level, (3.43), and calibrating the model to quarterly values, I can trace out the dynamic path of variables given a productivity innovation. The simulations consist of "shocking" or increasing productivity by one percent above its steady state level and observing the dynamic response or impulse response function of other

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[25] Since the money demand and money supply shocks are not considered in this paper, I drop them for convenience.

variables. Specifically, the response of real output, the price level, the nominal wage, and real stock prices are examined given the productivity innovation under different monetary policy rules.

Money has real effects in this model because nominal wages are preset one period ahead. When there is an unexpected increase in the nominal money supply and consequently an increase in nominal spending, as when a price stabilization rule increases the money supply to accommodate a productivity shock, the contract wage prevents nominal wages from adjusting to changes in labor demand. Real output and profit margins both increase while nominal wages lag. Real output, however, can only increase in equilibrium if aggregate demand increases, and this requires a fall in the real interest rate. How do the different monetary policy rules play into this mix? And how do the rules influence stock prices? The next few figures provide results from the simulations and offer some insights to these questions.

Figure 3.1 shows the response of real output to the 1% productivity innovation. This figure shows that the real output responses depend on the accommodation monetary policy provides in response to the productivity innovation. Under the price stabilization rule, where the productivity innovation is fully accommodated with a proportional increase in the money supply, real output jumps 1.65% above the old steady state level in period one and then returns to a new steady state level in period two. The productivity norm rule, however, which provides no monetary accommodation increases real output 1% above the old steady state level, exactly the value of the new steady state level. These responses imply that a monetary policy rule targeting price stabilization during a period of increasing productivity is likely to generate a real output boom-bust experience.

Figure 3.1 - Real Output Response to Productivity Innovation
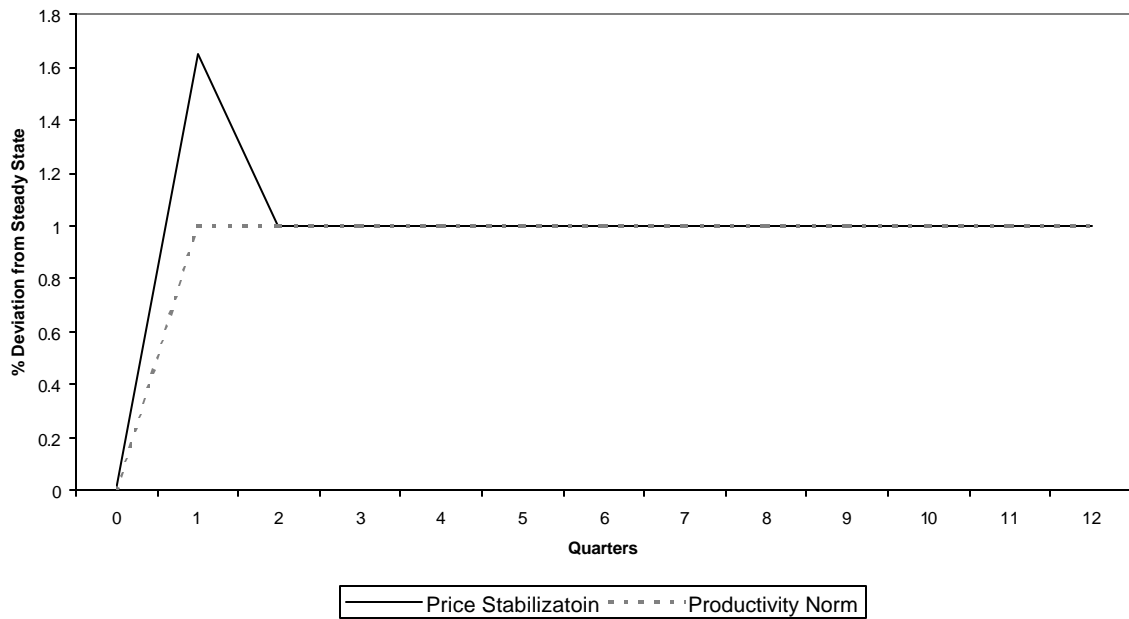
Given that wages are only set one period ahead, the boom-bust cycle only takes two quarters.[26] These illustrations suggest, therefore, that a monetary policy that targets price level stabilization, may not be consistent with minimizing real output volatility in periods of increasing productivity.

Figure 3.2 shows the responses of the price level to the productivity innovation. This figure shows that a 1% productivity innovation is strong enough to force a decline in the level of prices under both monetary policy rules but at different degrees and with only a permanent decline under the productivity norm rule. The price level falls .65% in period one under the price stabilization rule and then returns to its original steady state level in period two. This is consistent with the objective of the price stabilization rule.

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[26] Other research, however, involving models with multiperiod wage contracts that overlap, shows that the boom-bust experience can persist for longer periods (Taylor, 1979, 1980).

Figure 3.2 - Price Level Response to Productivity Innovation
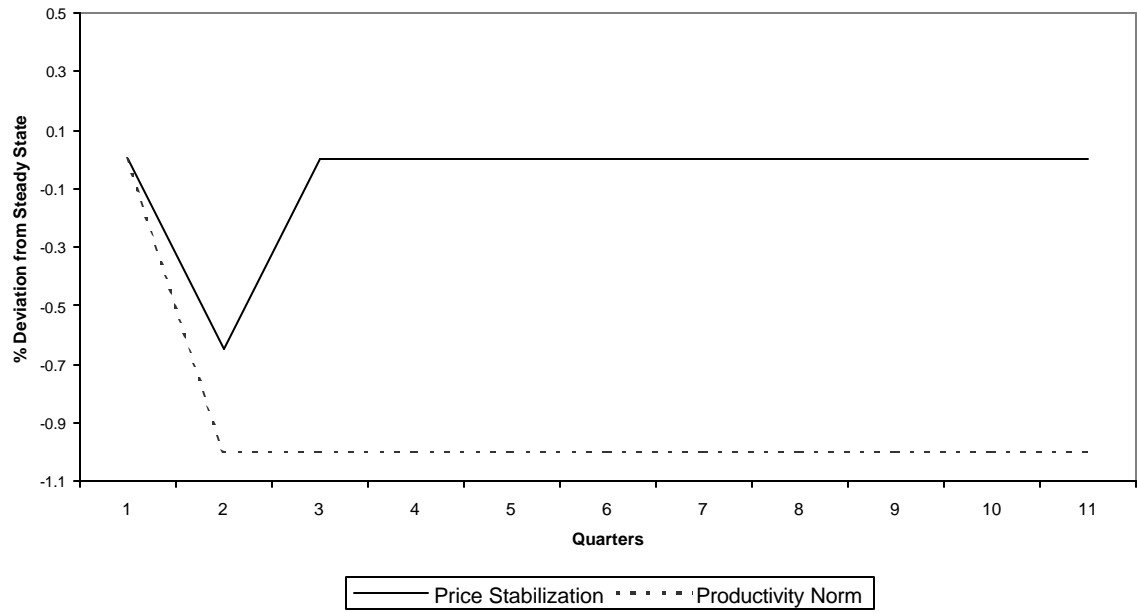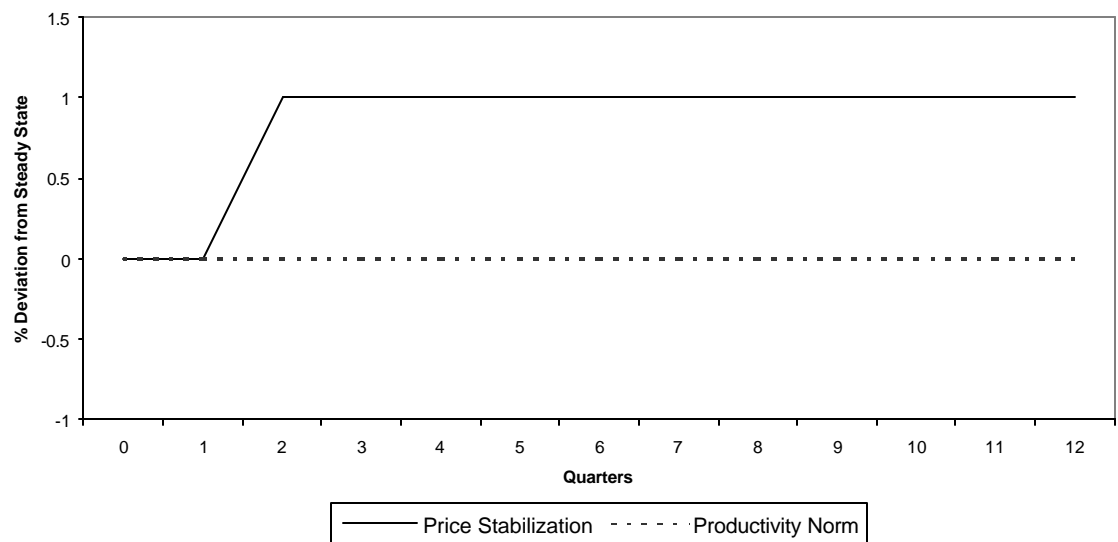

Figure 3.3 - Nominal Wage Response to Productivity Innovation

The productivity norm rule, however, generates a permanent 1% decline in the price level. This result is also consistent with the objective of the productivity norm rule, which allows productivity changes to be fully reflected in the price level. Figure 3.3 shows the response of the nominal wage to the productivity innovation. This figure reveals that the nominal wage level increases 1% under the price stabilization rule, but remains unchanged under the productivity norm rule. These results along with the results in figure 3.2 show a fundamental difference between the objectives of the monetary policy rules. The 1% increase in productivity under the price stabilization rule is offset by an increase in the nominal wage by 1% and a stable price level, while under the productivity norm rule the nominal wage is stabilized and the price level is allowed to fall by 1%. Simply, one policy is a price stabilization rule and the other is a nominal wage stabilization rule. Consequently, the question this paper is exploring could be equivalently stated as the consequences of the monetary authority stabilizing the price level versus the nominal wage during periods of rising productivity.

Given that the impulse response functions presented so far are predicated on an aggregate supply-aggregate demand (AS-AD) relationship, the simulations should be consistent with the story told in a standard AS-AD graph. [27] Consequently, I review the results using the standard AS-AD graph in Figure 3.4. Consider the steady state before the productivity innovation at Y^1. Here the economy is at full employment and in

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[27] The AD-AS framework includes a long-run aggregate supply curve (LAS) and a short-run aggregate supply curve (SAS). The former is vertical indicating that real activity is independent of monetary policy and prices in the long run while the latter is upward slopping allowing for short-run real effects by these nominal variables. The aggregate demand (AD) curve is a downward slopping, unit elastic, rectangular-hyperbola curve and shows the relationship between the price level (P) and real output (Y) for a given level of spending.

Figure 3.4 - AS-AD Representation

P | LAS¹ | LAS²
SAS¹
P¹   a   d   SAS²
c
P²   b   AD²
AD¹
0   Y¹   Y²   Y
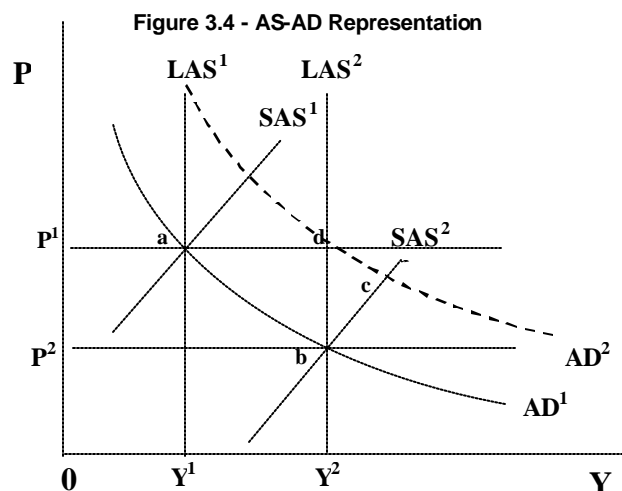
long run equilibrium at point **a**. The productivity innovation occurs and moves the long-runaggregate supply curve from **LAS¹** to **LAS²**. Full employment is now at **Y²**. Under the productivity norm rule the monetary authorities do not accommodate the innovation. This implies the AD curve does not shift and the economy ends up at point **b**. The price level stabilization rule, however, does accommodate the innovation so that price level stability consistent with the new full employment is obtained. This implies aiming for point **d**, but in order to get there aggregate demand must be increased. Given that relatively sticky input prices (i.e. preset nominal wages) generate an upward slopping **SAS** curve, this results in a short-run equilibrium at point **c** that is temporarily beyond full employment. Real output, therefore, has experienced an unsustainable increase and must decline to restore full employment, which gets the economy to its ultimate destination, point **d**. Consequently, under the price stabilization rule the economy goes through point **b**, **c**, and **d** which is a boom-bust scenario for real output. The productivity norm rule, conversely, moves to the new full employment level and remains there. These results, in conjunction with the performance of the price level under each rule, show that

Figure 3.5 - Real Stock Price Response (1 period sticky wage)
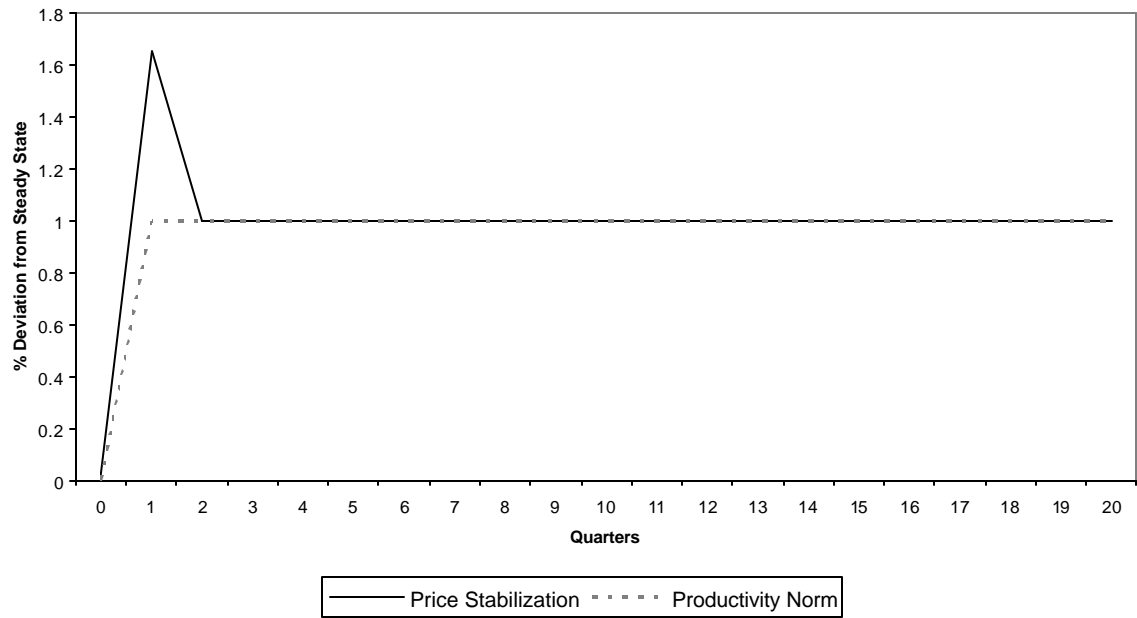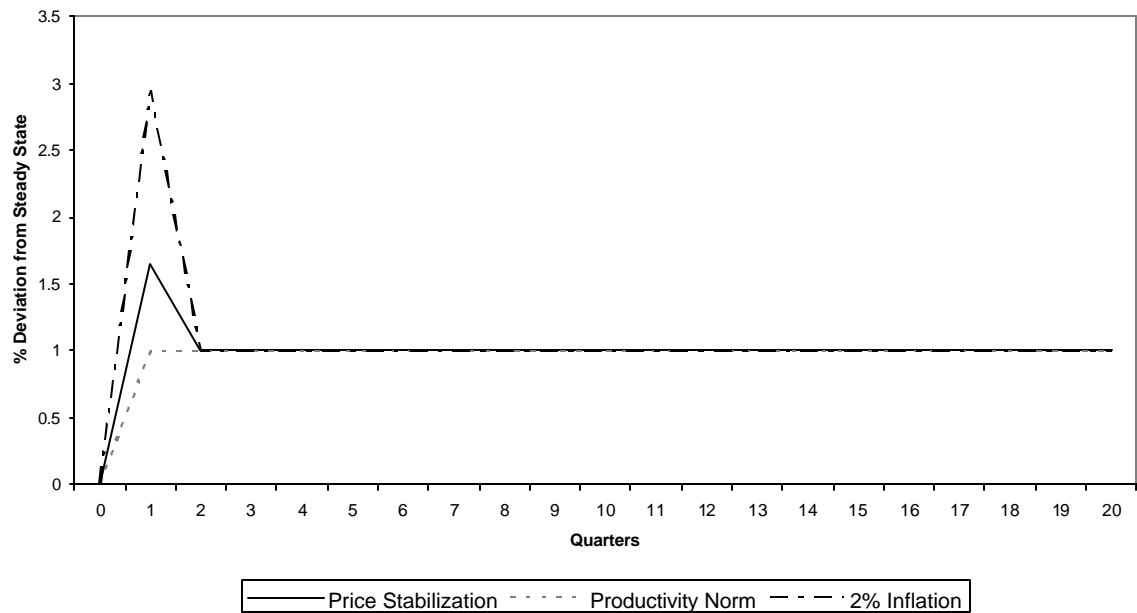

Figure 3.6 - Real Stock Price Response (1 period sticky wage)

not only are the simulations of the model consistent, but also identical to the story told in the standard AS-AD graph.

What implication do the results so far have for the real stock price? Figure 3.5 shows the real stock response to the productivity innovation. The price stabilization rule generates a 1.65% increase in the real stock price in period one followed by a drop to 1% in period two. The productivity norm creates a 1% increase in period one, which is sustained in the long run. Note that these results are almost identical to the real output response and reflect the fact that the real stock price equation is simply a function of real output.[28]

Consider next a scenario where the monetary authorities switch from stabilizing the price level to targeting 2% inflation. This extension is considered because relative price stability as it is actually practiced usually means a low, but stable inflation rate. A 2% inflation rate is used since a number of central banks have adopted target inflation rates either explicitly or implicitly around 2% (Mishkin, 2001). Figure 3.6 reveals that such an inflation-targeting rule results in a 2.93% increase in the real stock price followed a fall to 1%.[29] Both figure 3.5 and figure 3.6 show that any form of price stabilization that accommodates a productivity innovation results in some boom-bust cycle for real stock prices. The more accommodative the rule, the more pronounced is the cycle. Since nominal wages are preset for only one period, there is no significant persistence in the boom-bust cycle of the real stock price.

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[28] By substituting equations (3.22), (3.23), and (3.31) into equation (3.30), one can derive a real stock equation in terms of real output.

[29] The extension makes use of the original steady state of a stable price level and is equivalent to having the monetary authorities overshooting their target of price level stability. Also, since there is one to one relationship between the price level, the money supply, and productivity, $j_{\hat{a}}$ is set to 3 given unit shocks.

Figure 3.7 - Real Stock Price Response (4 period sticky wage, 1 period unit shock)
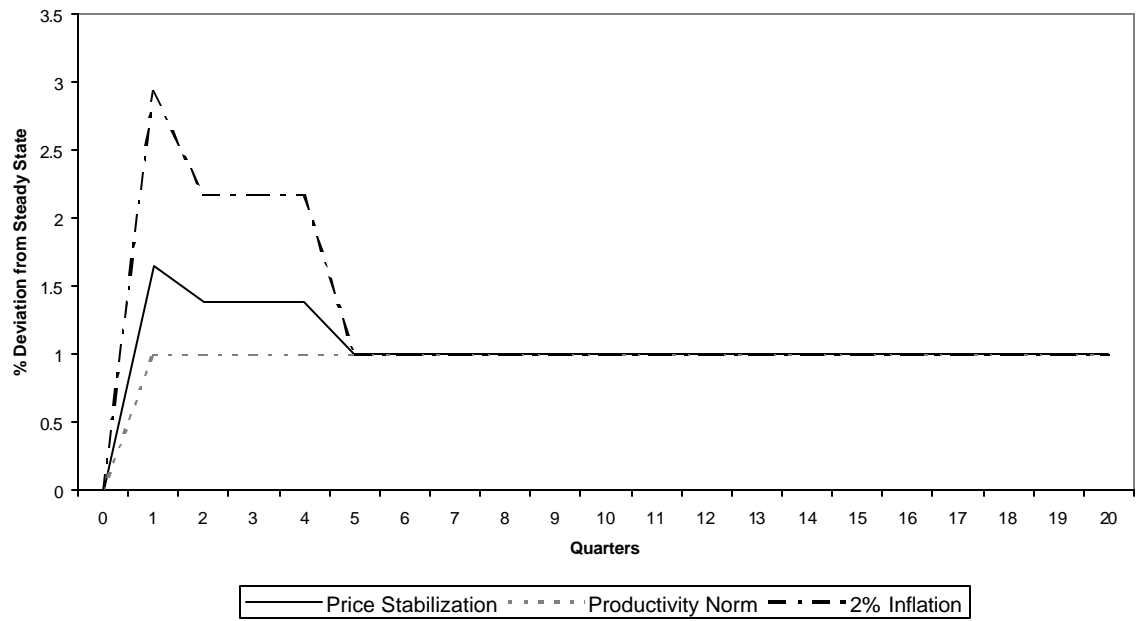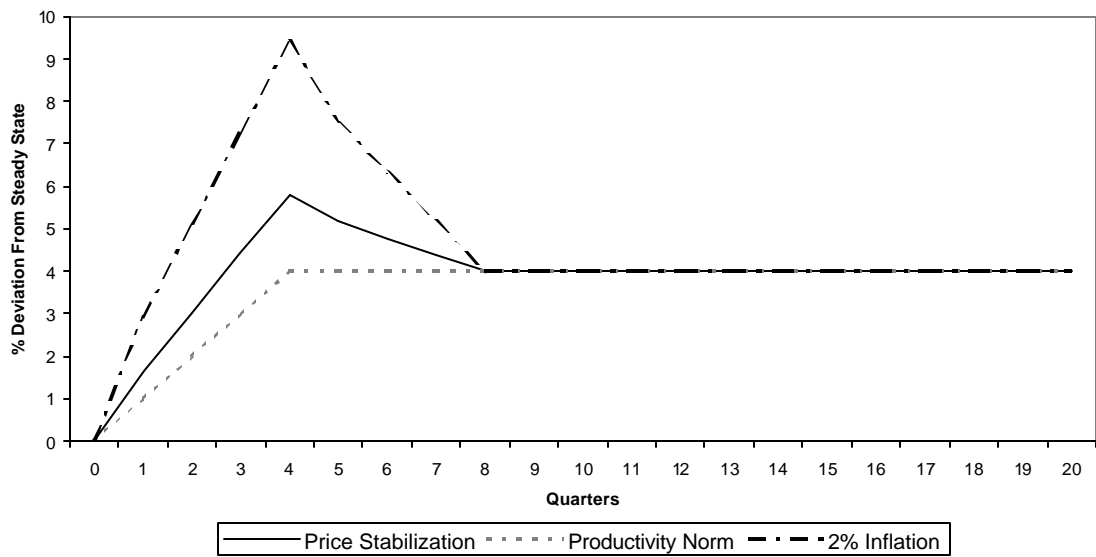

Figure 3.8 - Real Stock Price Response (4 period sticky wage, 4 periods unit shocks)

Let us suppose, instead, that wages are preset for more than a period. [30] Consider the case of setting wages for one year. Figure 3.7 shows the real stock price response from a unit shock to productivity in period one when the nominal wage is set a year ahead. The initial responses are now identical to those responses in figure 3.6 but now there is persistence in the boom-bust cycle that last just over a year. Figure 3.8 extends this example by shocking productivity one unit for four periods. Since four periods is the duration of the nominal wage contract, this permits an accumulation in the real stock price that is only gradually undone. Under the 2% inflation-target rule the real stock price rises about 9.4% above the steady state while the price stabilization rule reaches approximately 5.8% above the steady state. In both instance, the real stock price subsequently declines to 4%, the new steady state value. A productivity norm, in contrast, results in immediate adjustment of the real stock price to the new steady state value. Again, these examples show that monetary policy that in some form accommodates productivity innovations generates real stock price volatility.

Another extension worth considering involves adding a cyclical feedback term to the monetary policy rule. Monetary policy rules containing cyclical feedback terms are often used in monetary policy analysis (Taylor, 1993; McCallum and Nelson, 1999). These rules allow monetary authorities to respond to deviations from the target values of monetary policy. Applied to the price stabilization rule in this exercise, the cyclical feedback term allows monetary policy to respond whenever the price level deviates from zero. Similarly, with the inflation-targeting rule this modification includes a feedback response of the money supply to deviations in inflation from the targeted value. In

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[30] Although real output, the price level, and the nominal wage are not graphed under this extension, the implications as seen in the earlier figures remain the same.

Figure 3.9 - Real Stock Price Response (4 period sticky wage, 1 period unit shock, cyclical term)
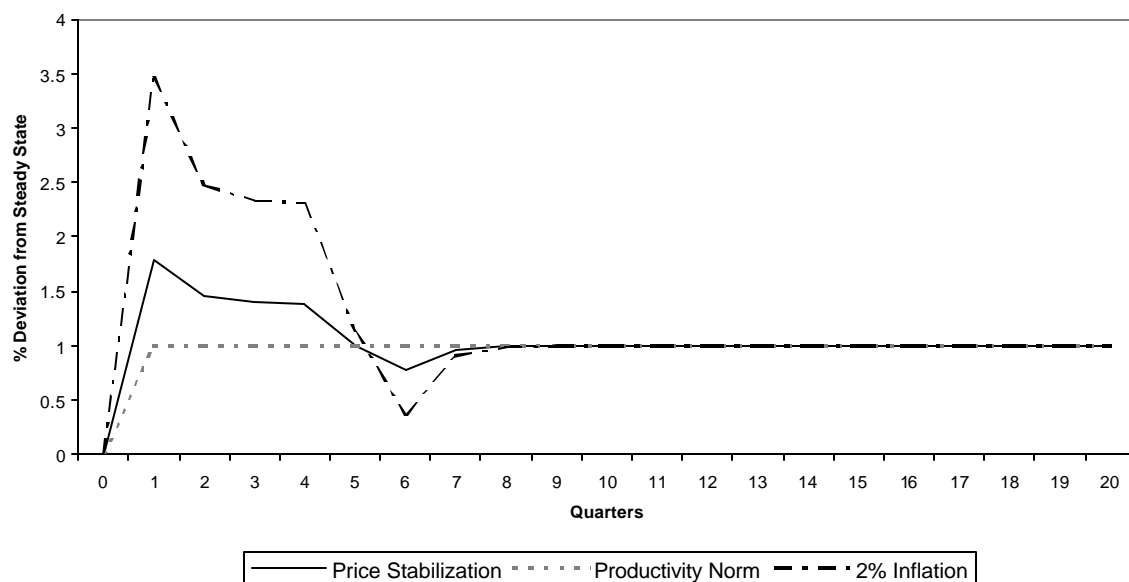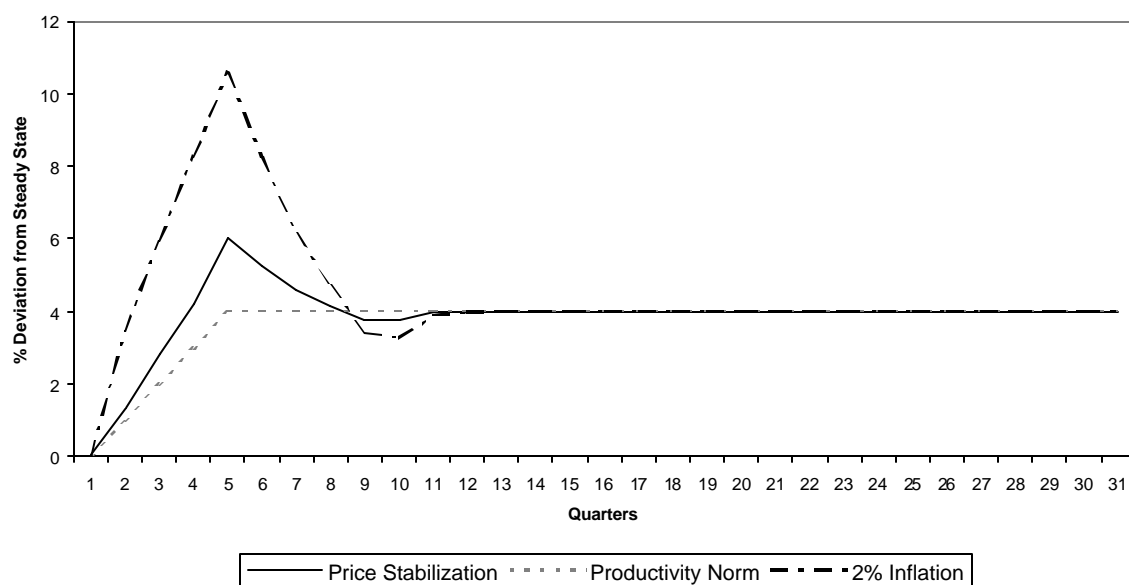

Figure 3.10 - Real Stock Price Response (4 period sticky wage, 4 periods unit shocks, cyclical term)

general, a monetary policy rule with the cyclical feedback term (3.33) can represented as

follows: (3.44) $$\hat{m}_t = \hat{m}_{t-1} + \boldsymbol{j}_A \boldsymbol{e}_{A_t} + \boldsymbol{t}\left(\hat{p}^*_{t-1} - \hat{p}_{t-1}\right),$$

where $\hat{p}^*$ is the target value and $\boldsymbol{t}$ is a feedback parameter set equal to one. Monetary

policy, therefore, additionally responds to last periods' deviation from the target price

level and creates the potential for overshooting and consequently more persistence. Since

the productivity norm rule remains agnostic about productivity induced price level

changes, the cyclical feedback term does not apply to it.

Figures 3.9 and 3.10 show the results of including the cyclical feedback term

under the same assumptions as figures 3.7 and 3.8. Figure 3.9 shows the real stock price

response when a unit shock to productivity occurs only in the first period. This figure

reveals that although the initial responses do change, the biggest difference is in the

downturn of the boom-bust cycle. The inflation-targeting rule generates a jump in the

real stock price of about 3.47% above the old steady state value in period one. The real

stock price then declines approximately 3.17% before recovering to a permanent increase

of 1% in period 8. The price stabilization rule creates a similar response with the real

stock price initially increasing approximately 1.78% and then decreasing 1% before

permanently settling at the new steady state value. Figure 3.10 reveals a similar story

with unit shocks occurring for four periods. The real stock price grows about 10.59%

under the inflation-targeting rule and then declines before returning to a permanent

increase of 4%. The price level stabilization rule similarly grows the real stock price

about 6.03%, which then falls before recovering to the permanent 4% increase. The

unique insight, therefore, revealed in both figures 3.9 and 3.10 is that monetary policy

that accommodates productivity innovations may even result in a decline in real equity

Figure 3.11 - Real Stock Price Response (4 period sticky wage, cyclical term, productivity values for 1995-2000)
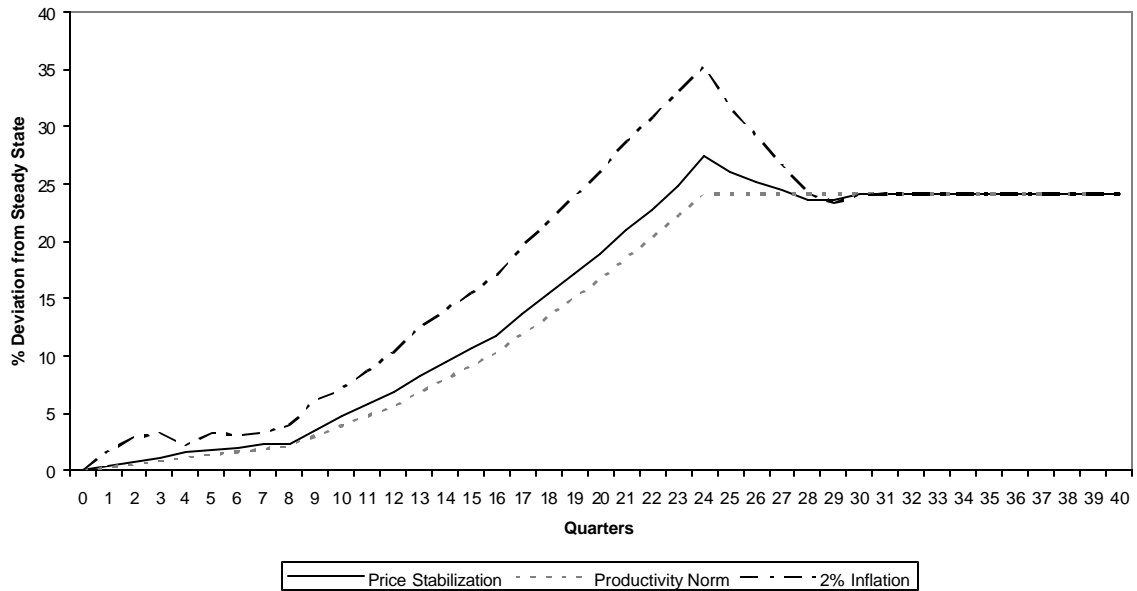
prices during the boom-bust cycle that temporarily places real stock prices below their new steady state value.

The simulations so far indicate that price level or inflation stabilization during periods of increasing productivity may give rise to unsustainable surges in the real stock price. However, the theory, or development so far can only account for relatively small stock price cycles. In particular, this model cannot generate either the magnitude or persistence of booms such as those experienced in the 1990s, owing in part to its assumptions of rational expectations and simple sticky wages. Thus, using the productivity information for 1995-2000 from figure 1.3 in chapter 1 and applying it to the version of the model with the most persistence (a four period sticky wage and a cyclical

term), results in figure 3.11.[31] This figure shows that the short-run real stock price response under the inflation-targeting rule surges approximately 35%, while under the price stabilization rule, it increases about 28% before both return to a permanent increase of 24%. These boom-bust cycles are notable but less than that of the real S&P Composite, which between 1995-2000 increased approximately 165% and subsequently fell about 43%. The model, therefore, shows the correct signs, but can only explain part of the actual magnitudes. Arguably, however, the model may be understating the magnitude effects of monetary policy if the values of future dividends and stock prices are partly formed from adaptive expectations, as some research has implied (Shiller 1990; Barsky and DeLong, 1993). Consequently, these real stock responses may be first approximations to the actual influence monetary policy may have had on stock prices during the time period. Nevertheless, the results suggest that by targeting a low, but positive inflation rate, U.S. monetary policy may have played a small but nontrivial part in generating the stock market boom-bust cycle of the late 1990s.

3.9 Conclusion

The simple general equilibrium model developed in this chapter incorporated sticky wages, monetary policy, and real stock prices. This allowed the dynamic effects of real stock prices under different monetary policy rules to be examined given positive productivity developments.

The results of this exercise suggest there is a natural tradeoff between stabilizing output prices and asset prices. Monetary policy, therefore, that systematically targets

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[31] I take the percentage deviation of the productivity level from trend in quarterly form and use these values as the shocks to the model for 6 years or 24 quarters covering 1995-2000. The average quarterly deviation value of each of the six years are as follows: .2724, .2631, .87, 1.17, 1.6, 1.86.

some form of price stabilization, whether price level stability or low inflation, in an economic environment of increasing productivity will fuel an unsustainable increase in stock prices and destabilize financial activity. In the case of the U.S. stock market, the model found that monetary policy may have contributed in a small but meaningful way to the destabilizing boom-bust cycle of the late 1990s.

In the next chapter, these results are checked against empirical findings using vector autoregressions, innovation accounting, and an attempted counterfactual simulation. Using these econometric tools, I specifically examine the extent to which monetary policy actually accommodated productivity innovations during particular periods and how such behavior may have contributed to movement in the stock market.

CHAPTER 4

AN EMPIRICAL INVESTIGATION INTO THE RELATIONSHIP BETWEEN

MONETARY POLICY AND STOCK PRICES

The theoretical model of the previous chapter showed how a monetary policy that accommodates productivity innovations in order to stabilize the price level could itself generate unsustainable surges in stock prices. The model also showed that by allowing the price level to reflect productivity innovations, monetary policy could reduce fluctuations in stock prices. However, an empirical investigation of these findings is limited by the lack of data for periods during which productivity-induced deflation actually occurred. [32] This constraint prevents a robust empirical examination between periods of productivity-induced deflation and price stabilization. Therefore, my approach in empirically examining these findings is twofold. First, I estimate a VAR and use innovation accounting to study the dynamic relationship between productivity, the money supply, and the real stock price for the postwar years. Second, I attempt a counterfactual simulation by imposing restrictions on the estimated VAR so that the money supply equation does not respond to productivity shocks. This latter exercise creates a counterfactual time series that allows a comparison between the actual postwar monetary policy and a hypothetical monetary policy that ignores movement in productivity. These exercises will provide insight as to whether monetary policy was accommodating

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[32] There is some data available for the late 1880s when productivity-induced deflation did occur (i.e. Balke and Gordon, 1986). However, the data does not include a productivity series that is central to this analysis.

productivity innovations during the periods examined and if so, whether this behavior contributed to the recent performance of the stock market as suggested the theoretical model in the previous chapter.

4.1   Empirical Method and Identifying Restrictions

I began the empirical analysis by considering a simple empirical model with a vector of endogenous variables defined as

$$(4.1) \qquad y_t = \begin{pmatrix} a_t \\ r_t \\ \dfrac{m_t}{p_t} \\ s_t \\ m_t \end{pmatrix},$$

where a_t is a measure of productivity, r_t is the nominal yield-to-maturity on government bonds, m_t/p_t is real money balances, s_t is a real stock price index, and m_t is the nominal stock of money. Although fewer than number of variables used in the theoretical model, this set of variables allows me to empirically examine the findings of the previous chapter by specifically looking at the interaction between productivity, the interest rate, money demand, the real stock price, and the money supply while keeping the size of the system tractable.[33] This set of variables also allows for an interpretation of the empirical shocks that is consistent with the theoretical model. Except for the interest rate, I transform the variables into natural logs. The y_t vector is assumed to evolve according to a linear, dynamic structural model of the form

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[33] Trial runs that included factor inputs in the set of endogenous variables and as an exogenous variable added nothing meaningful to the exercise. Consequently, I can run the VARs without losing any of the implications and gain degrees of freedom.

(4.2)
$$A_o y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + u_t,$$

where $A_0, \dots, A_p$ are 5 x 5 structural parameter matrices and u_t is a 5 x 1 vector of shocks that are assumed to have zero mean and be uncorrelated. The shocks are also normalized to have unit variance. The structural model, therefore, consist of equations representing structural relationships and exogenous structural shocks. Although not identical, this model will be consistent with the theoretical model once identifying restrictions are imposed.

The structural autoregressive model in equation (4.2) can be transformed into a structural moving average form so that the relationship between the endogenous variables and the structural shocks can be defined. This process can be easily demonstrated using a one-lag model. First premultiply equation (4.2) by A_0^{-1} and then solve for the moving average by the following steps:

(4.3)
$$y_t = A_0^{-1} A_1 y_{t-1} + A_0^{-1} u_t,$$

(4.4)
$$y_t = B y_{t-1} + A_0^{-1} u_t,$$

(4.5)
$$(I - BL) y_t = A_0^{-1} u_t,$$

(4.6)
$$y_t = (I - BL)^{-1} A_0^{-1} u_t,$$

(4.7)
$$y_t = (I + BL + B^2 L^2 + \dots) A_0^{-1} u_t,$$

(4.8)
$$y_t = (A_o^{-1} + B A_o^{-1} L + B^2 A_o^{-1} L^2 + \dots) u_t,$$

(4.9)
$$y_t = (D_o + D_1 L + D_2 L^2 + \dots) u_t,$$

and finally,

(4.10)
$$y_t = D(L) u_t,$$

where $D_0 = A_0^{-1}$, $D_i = \left(A_0^{-1}A_i\right)^i A_0^{-1}$, and the coefficient matrices in $D(L)$ represent the dynamic multipliers of the structural shocks as they influence the endogenous variables. The objective is to estimate $D(L)$ which can only be done indirectly by deriving a reduced form moving average model that is directly estimable and can be used to solve for the $D(L)$ estimates. The moving average model can be solved from the structural model as follows:

(4.11) $$y_t = (I - BL)^{-1} A_0^{-1} u_t$$

(4.12) $$y_t = (I - BL)^{-1} e_t$$

(4.13) $$y_t = \left(I + BL + B^2 L^2 + ...\right) e_t$$

(4.14) $$y_t = \left(I + C_1 L + C_2 L^2 + ...\right) e_t$$

or simply,

(4.15) $$y_t = C(L) e_t,$$

where $E e_t e_t' = \Sigma$. As a result of the above inversion of the VAR, the parameters of $C(L)$, the reduced form moving average model, and Σ, its covariance matrix, can be estimated. Obtaining estimates of $D(L)$, therefore, requires finding the correspondence between $D(L) u_t$ and $C(L) e_t$. The first step in establishing this relationship is to note from equation (4.11) and (4.12) that

(4.16) $$e_t = A_0^{-1} u_t = D_0 u_t$$

and therefore,

(4.17) $$E e_t e_t' = \Sigma = A_0^{-1} u_t u_t' A_0^{-1'} = D_0 D_0'.$$

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Given these results and the fact that it can be shown $D(L) = C(L)D_0$, there exist a mapping between the structural form and reduced form of the model. The mapping, however, is not unique and so restrictions must be imposed to fully identify the structural model.

One way to identify the model is to impose long-run restrictions on the relationship between structural shocks and endogenous variables, as developed by Blanchard and Quah (1989) and Shapiro and Watson (1988). This identification scheme can be applied in a manner consistent with the theoretical model. As shown in section 3.6 and summarized in table 3.1, there are 6 potential shocks in the theoretical model: a productivity shock, an interest rate shock, a money demand shock, a real stock price shock, and a money supply shock. The productivity shock was shown to have a permanent effect upon itself and all the endogenous variables. The interest rate could also permanently affect all endogenous variables, but not productivity. The money demand shock was able to permanently affect the endogenous variables except for the real interest rate. The real stock price and money supply shock could only permanently affect themselves. These theoretical restrictions can be largely reproduced in the estimated model if I apply the long-run restrictions following the ordering of variables in expression (4.1). These restrictions are applied to $D(1)$ matrix, the infinite horizon sum of $D(L)$, so that

$$
(4.18) \qquad D(1) = \begin{bmatrix} d_{11} & 0 & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} & 0 \\ d_{51} & d_{52} & d_{53} & d_{54} & d_{55} \end{bmatrix}.
$$

These restrictions on the estimated model imply the following relationships. First, productivity shocks can permanently affect all the other variables, but is itself not permanently affected by any other variable. Second, the interest rate shocks can influence all the endogenous variables permanently but not productivity. Third, money demand shocks can permanently affect all variables except productivity and the interest rate. Fourth, the real stock price shock can only permanently affect itself and the nominal money supply. Finally, the nominal money supply shock will have no permanent influence on the variables in the system except on itself. These empirical restrictions only differ from the theoretical restrictions in that the real stock price shocks can permanently affect the nominal money supply. However, since the focus of this exercise is only on productivity and money supply shocks, this difference is inconsequential. Consequently, using long-run restrictions to identify the estimated model allows me to empirically examine the findings of theoretical model.

I now show how long-run restrictions imply full identification. Consider the infinite horizon covariance matrix and its mapping between the structural and reduced form:

(4.19) $$C(1)\Sigma C(1)' = D(1)D(1)',$$

where $C(1)$ and $D(1)$ are infinite horizon sums of $D(L)$ and $C(L)$. If I assume that each of the variables contains a unit root so that in the structural model, y_t is now set to Δy_t,[34] which implies that

(4.20) $$\lim_{k \to \infty} \frac{dy_t}{du_{t-k}} = D_0 + D_1 + D_2 + ... = D(1).$$

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[34] I show in section 4.2 unit root tests that suggest first differencing the data is appropriate.

Differencing, therefore, allows the $D(1)$ matrix to become the infinite horizon multipliers for the levels of the endogenous variables. Taking the Cholesky decomposition of the left-hand side of (4.19) creates a cholesky factor R where

$$(4.21) \qquad\qquad\qquad RR' = C(1)\Sigma C(1)',$$

and R is a lower triangular matrix. Since the right-hand side of (4.19) and the left-hand side of (4.21) are equal, the cholesky factorization implies that $D(1)$ also becomes a lower triangular matrix and just identifies the structural model as there are exactly $\dfrac{n^2 - n}{2}$ or 10 restrictions. This creates long run restrictions in that it restricts the long-run effect of 10 elements in $D(1)$ to zero, as shown in expression (4.18). Using $D(1) = C(1)D_0$, I can now solve for the D_is and the A_is and perform innovation accounting that shows the response of the level of each variable to a shock.

4.2 Data Description and Transformations

The data consist of monthly observations for U.S. macroeconomic variables that run from 1964:01 to 2003:01. I build a monthly series for productivity by taking the Federal Reserve Board's industrial production index and dividing it by the Bureau of Labor Statistics' hours index. This approach follows the NBER productivity series 01300-01202 and, as can be seen in figure 4.1, results in a productivity index that closely follows the annual multifactor productivity series.[35] I use the unborrowed monetary base

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[35] The graph compares manufacturing multifactor (mfp) productivity to the derived industrial production productivity (ipp). A simple AR1 regression where the log of the mfp is regressed on the log of ipp resulted in the following equation:

$$ipp = .4186 + .9177 \text{ mfp} + .9147 \text{ rho},$$
$$(.7846) \quad (7.703) \qquad (13.305)$$

Figure 4.1 - Productivity Measures
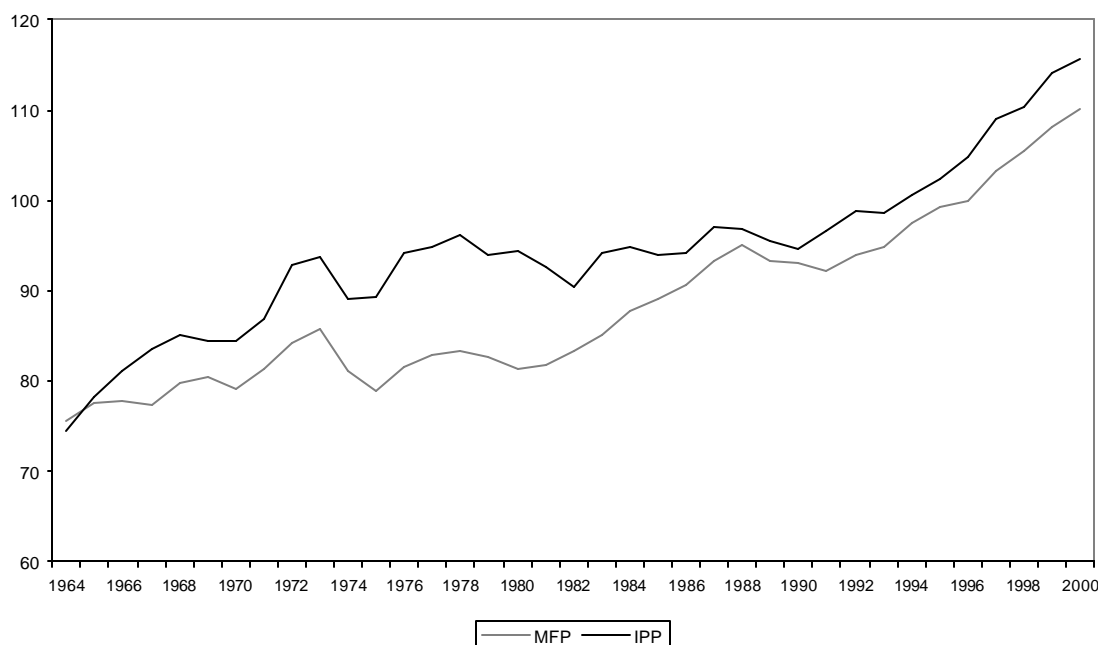
as the money supply given the Federal Reserve's complete control over it. This measure of the money supply best reflects monetary policy. Both the monetary base and the interest rates series I use, the interest rate of 6-month treasury bills, I get from the FRED database at the St. Louis Federal Reserve Bank.[36] For real money balances, I take the monetary base and divide it by the Bureau of Labor's Consumer Price Index.[37] Finally, I use the real S&P composite index (deflated by the CPI) from Robert Shiller's homepage for the real stock price.[38]

I check the stationarity properties of the data by running three unit root tests: the augmented Dicker-Fuller test, the Weighted Symmetric test, and the Phillips-Perron test. As noted in the appendix, all of the tests strongly suggest a unit root process in the levels.

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with R^2=.95, SE=.03, and DW=1.67. This suggests that my derived productivity index is consistent with actual productivity and is appropriate to use in the VAR.
[36] http://research.stlouisfed.org/fred2/
[37] http://www.bls.gov/cpi/home.htm
[38] http://aida.econ.yale.edu/~shiller/

These tests also suggest that each data series contains only a single unit root process. Differencing the variables to eliminate the single unit root, however, may ignore potentially useful information. Consequently, I also performed the Engle-Granger cointegration test and found no conclusive evidence of cointegrating relationships.[39] Together, these tests suggest first differencing the variables, a necessary step for imposing long-run restrictions in the VAR, is an appropriate transformation of the macroeconomic data.

I include in each equation of the VAR a constant, a 1987 stock market crash dummy, and seasonal dummy variables. For each equation, the VAR contains 13 common lags. The Ljung-Box Q-Statistics indicate that the residuals are not serially correlated. Therefore, the 13 lags are sufficient to whiten the residuals.[40] Given the structure of the VAR, there are 456 observations and 378 degrees of freedom.

4.3   Dynamic Responses

I now consider the dynamic implications of the VAR model using innovation accounting as shown in figures 4.2 - 4.9, which are presented at the end of chapter. I specifically examine the consequences of monetary and productivity shock in the context of impulse response functions and variance decompositions. For the productivity shocks, I consider both a temporary shock to the growth rate of productivity and a permanent shock. A temporary shock to the productivity growth rate the monetary authorities might ignore under an inflation targeting regime, but a permanent shock they would have to accommodate. Consequently, I explore both shocks in order to get an accurate

[39] I report the p-values for this null of this test and the unit root tests in the appendix.
[40] The Q-statistic for each of the equations is 18.76, 4.96, 1.64, 1.44, 0.71. These values are well below the critical value for rejecting the null hypothesis of no autorrelation at the 5% significance level.

representation of how monetary policy was interacting with the economy and its consequences for the stock market during the period estimated.

Some caution, however, must be taken in interpreting a permanent shock to the growth rate of productivity, which is accomplished by second differencing the productivity series. Since the unit root tests indicate the productivity series is stationary after first differencing, second differencing the productivity may lose important information. More importantly, if the series is stationary after first differencing, then this result suggest there have been no permanent shocks to the growth rate of productivity during the period estimated. However, there have been instances, including the 1990s, during which productivity growth accelerated several years before returning to its long-run trend, and such periods may have caused policy makers to make corresponding upward adjustments to money growth. In fact, a unit root test of productivity first differenced for 1995-2000 indicates non-stationarity for this period.[41] Consequently, productivity for that period might properly be interpreted as involving changes in the growth rate (rather than the levels) of productivity from its long-run trend.

Let us consider first the VAR model constructed with productivity first differenced so that the response of productivity being graphed shows the level. Figure 4.2 reports the dynamic response of each variable to a money supply shock under this framework. The money supply shock leads to a temporary increase in the nominal money supply of 0.53% but permanently settles by 72 months out at a level that is 0.45% higher than its original value. Real money balances temporarily increase for almost 12 months and peak at a high of 0.36% before returning to their original level. This indicates the price level remains sticky for a year before slowly adjusting to its new

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[41] However, given the small sample size for the this period, the results may spurious.

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steady state value. Productivity also responds in the short run to the money supply shock by rising above its steady state level to a peak increase of about 0.09% but only after first declining.   Although the theoretical model explains productivity movements exogenously, these results show some short-run endogeneity in labor productivity, which is consistent with the labor hoarding literature.[42] A liquidity effect for yields on government securities is also evident in figure 4.2. The annualized yield drops almost 30 basis points two months after the shock and recovers rapidly for about a year before gradually ascending back to the original steady state value. These findings are consistent with other studies examining the affects of nominal money supply shocks (e.g. Potts, 2002).

Now consider the response of the real stock price. Upon impact, the real stock price begins an ascent that last for 9 months and tops out at a peak increase of 0.73%. Following this dramatic gain, the real stock price rapidly declines for 4 months before recovering for a 4-month gain. Eventually, the real stock price returns to the original steady state value. This finding can be explained, in a manner consistent with the real stock price equation of chapter 3, by noting that the positive money supply shock presumably affects the real stock price through an expected earnings channel, given the productivity response, and an interest rate channel, given the interest rate response. This finding is also consistent with a number of recent studies that confirm earlier but contested research showing money supply shocks temporarily influence real stock prices

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[42] Abel and Bernanke (2001) describe labor hoarding when firms "because of the costs of firing and hiring workers…retain these workers on the payroll to avoid the costs of laying off workers and then hiring and training new workers when the economy revives. Hoarded labor either works less hard during the recession (there is less to do) or is put to work doing tasks, such as maintaining equip ment, that aren't measured as part of the firms output. When the economy revives, the hoarded labor goes back to working in the normal way" (pp. 361-362). This provides one explanation for the pro-cyclical nature of labor productivity.

(Dhakal, Kandall, and Sharma, 1993; Patelis, 1997; Thorbeke, 1997; Lastrapes, 1998; Neri, 2001; Ewing, 2001). [43]

Consider now the dynamic responses of the variables to a money supply shock when productivity is twice differenced. This framework shows the response of the growth rate, not the level, of productivity given a shock. The results are reported in figure 4.3. This money supply shock also results in nominal money supply that temporarily increases above its new steady state value that is 0.55% higher than the original value. Real money balances temporarily increase about 0.32% by month 9 and hang around that value for a few more months before returning to its original level. Again, this indicates the price level is sticky for about a year. The productivity growth rate, not the level, experiences a temporary decline but very quickly returns to the original value and never significantly deviates from it. This response implies that a money supply shock has a more notable, but temporary, effect on the level of productivity than on its growth rate. A liquidity effect for yields on government securities is again evident. Here, the annualized yield drops 22 basis points and is back to its original value approximately 40 months later. The real stock price similarly experiences an 8-month surge with a peak increase of 0.42%. The real stock price subsequently falls for 6 months and then briefly recovers for another 6 months before resuming its descent to the original steady state value.

Both set of responses show that a positive money supply shock can have real economic effects in the short run, including a notable but temporary surge in the real

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[43] Sprinkel (1964), Palmer (1970), Homa and Jafee (1971), Keran (1971), and Hamburger and Kochin (1972) first noted that changes in the money supply generate similar movements in stock prices. These findings, however, were criticized by later research (Cooper 1974; Pesando, 1974; Rozeff, 1974; Rogalsk and Vinso, 1977), that argued the findings were inconsistent with the efficient market hypothesis, causality was backwards, and money demand was the driving factor. The recent studies cited above identify money supply shocks from money demand shocks and consequently confirm the initial findings.

stock price. This suggests, in turn, that monetary policy can matter to the real stock price. The response of the real stock price to a money supply shock, however, does not provide any indication of how monetary policy systematically responded to productivity shocks during this period and its consequences for the real stock price. Therefore, I now consider the dynamic behavior of the system given a productivity innovation.

Figure 4.4 reports the dynamic response of each variable from a shock to productivity first differenced. This is a shock, therefore, that only temporarily affects the productivity growth rate but permanently affects the level of productivity. The shock leads to a permanent increase in the productivity level of about 0.70%. Given the increase in productivity, real money demand increases, with real money balances achieving a permanent increase of 0.61% within 89 months. The unborrowed monetary base actually declines an about 0.30% following the shock. This result suggests that monetary policy at best did not accommodate temporary productivity shocks. Note that the money supply response implies a permanent decline of about 0.90% in the price level. This finding is consistent with a number of studies showing a negative relationship, ceteris paribus, between output shocks and the price level for the postwar period (Kydland and Prescott, 1990; Cooley and Ohanian, 1991, Spencer, 1996; Den Haan, 2000).[44] This downward pressure on the price level presumably explains the decrease in the interest rate following a productivity shock – inflationary expectations are lowered.

Now note the real stock price response. Following the productivity shock, the real stock price goes through a minor boom-bust scenario, where after a 20-month climb

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[44] The conventional wisdom prior to these studies was that the price level was procyclical. The research of Kydland and Prescott (1990), however, challenged this view and led to spate of papers examining the relationship. They provocatively stated, "We caution that any theory in which procyclical prices figure crucially in accounting for postwar business cycle fluctuations is doomed to failure" (p. 17). See Cover and Hueng (2002) for a recent survey of the literature.

the real stock price reaches a 1.75% increase and then falls for about 30 months to reach the new steady state level of 1.62%. Interestingly, the minor boom-bust response of the real stock price is not accommodated by monetary easing as predicted by the theory. However, since monetary authorities can only respond with a lag, monetary policy, even if targeting some form of price stability, may have let temporary productivity surprises be bygones. On the other hand, monetary authorities under such a regime could not ignore a permanent increase in the growth rate of productivity and would thus accommodate it. Therefore, I now examine the VAR with the productivity series twice differenced so that that the shock has a permanent effect on the growth rate of productivity.

Figure 4.5 shows the dynamic response of variables to the productivity shock under this framework. The growth rate of productivity temporarily jumps to a 0.03% increase, but permanently settles to an increase of 0.07% following the shock. The productivity shock drives up the real money demand so that real money balances permanently increase 0.05%. Now, the unborrowed monetary accommodates the lasting increase in the productivity growth rate by permanently increasing 0.14%. This response implies a permanent increase in the price level of 0.09%. More importantly, this response of the monetary base suggests that monetary policy was accommodating permanent increases in the growth rate of productivity. This finding is consistent with empirical record that shows both the level of productivity and the monetary base increasing during the postwar period.

The real stock price response shows several minor boom-bust cycles for the real stock prices as it moves toward its new steady state value. By month 9, the real stock price has increased 1.62% but then abruptly falls to a 1.27% value by month 12. Also,

the real stock price reaches a peak increase of 1.75% by month 20 but gradually descends to a permanent increase of 1.62%. This figure reveals that the volatility in the real stock price coincides with the initial volatility in the unborrowed monetary base. Given the explicit control of the unborrowed monetary base by the monetary authorities, there appears to be an association between the monetary accommodation and the real stock price response. Although these results are consistent with the idea that monetary policy can contribute to real stock price volatility by accommodating productivity shocks, the true effects of the monetary accommodating cannot be captured by the real stock price response since it reflects the combined influence of all the endogenous variables on the real stock price given a productivity shock, not just the monetary base.

Figures 4.6 through 4.9 report the estimated forecast error variance decompositions for the system. The forecast error variance shows how shocks to each variable on average contributed to the difference between the forecasted and actual value for a particular variable. The first two figures show the money supply shocks contribution to the forecast error variance of each variable. These figures reveal that the money supply shocks explain very little of the forecast error variance in the real stock price. Productivity shocks explain from 9.00% to 32.00% of the forecast error variance in real stock prices. The implications, however, of these larger numbers are not straightforward given that there is both a positive and negative monetary base response associated with the different productivity shocks.

Although these results indicate the monetary authorities during the postwar period did accommodate permanent increases in the productivity growth rate and that their response may have contributed slightly to stock market volatility, the findings do not

show the isolated consequences of such accommodation. The results also fail to specifically capture the real stock price response of monetary accommodation in the 1990s to permanent increases in the productivity growth rate. However, figure 4.10 makes it apparent that there was sufficient monetary accommodation during the stock boom period of the 1990s to ensure prices did not fall. Alan Greenspan said of this period, "we [The Federal Reserve] have kept or focus firmly on the ultimate goal of achieving price stability" (1997). He also said of this time, "nearly everyone perceives the resulting more rapid growth of labor productivity is at least partly enduring…For the most part, the Federal Reserve generally recognizes these changing fundamentals and calibrated American monetary policy" (2000). According to Alan Greenspan, therefore, monetary policy was calibrated in response to the increased growth rate of productivity to maintain the goal of price stability. The monetary accommodation by the Federal Reserve, however, coincided with a surge in real earnings as seen Figure 4.11.[45] This response of real earnings in turn contributed to higher real stock prices. Therefore, the monetary accommodation of productivity in the 1990s most likely had consequences for the real stock price. A number of studies suggest that even if this response was expected it still could have had real effects (Mishkin, 1982a; Mishkin 1982b; Gordon, 1982; McGee and Stasiak, 1985; Romer and Romer, 1994; Cochrane, 1998).

These results, however, are not conclusive. One way to extend this analysis and capture the general equilibrium consequences of accommodating the increased productivity growth rate is to run a counterfactual simulation. Specifically, a counterfactual exercise can show how the real stock price series would have responded

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[45] The earnings series is an weighted index of firms making up the S&P composite index. The series comes from Robert Shiller's web page.

with no monetary accommodation. This finding in turn could be used to determine how much of the boom-bust cycle of the stock market might be explained by monetary accommodation. Counterfactual simulations have been conducted in number of studies (McCallum, 1990; Fackler and Parker, 1994; Bordo, Choudhri, and Schwartz, 1995; Sims, 1998) to examine the effects alternative monetary policies could have had on real output, particularly during the Great Depression.[46] My dissertation attempted to build on this literature by considering how a counterfactual monetary policy, specifically the productivity norm, could have altered the performance of the stock market.

I initially followed McCallum (1990) who uses a simple set of reduced-form equations to create an estimated model that relates monetary policy to nominal income. This model allows him to show that a nominal income-targeting rule would have reduced the Great Contraction to a much milder recession. I extended his model by adding a real stock price equation, but found that his simple model displayed money non-neutrality when different monetary regimes where employed.[47]

I subsequently adopted the approach of Sims (1998) who estimates two VARs, one for the prewar and postwar periods, and then exchanges the two money supply equations. This exchange in effect changes all the coefficient estimates in the two money supply equations.[48] This allows him to consider whether different monetary policies, specifically monetary policies from different periods, would have generated different

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[46] All of the studies but Sims (1998) find that given an alternative monetary policy the Great Depression would have been only a recession in the early 1930s followed by a robust recovery.

[47] The monetary non-neutrality is apparent in this system, and many of the other counterfactual models, when one notes that if the money supply grows at different rates there are permanently different real consequences for output.

[48] It is not clear whether Sims actually changes the B_i or A_i matrices.

economic outcomes.[49] Following Sims, I changed the structural model estimates found in the A_i matrices so that the money supply equation does not respond to changes in productivity. This process is demonstrated below. However, I found that by changing the coefficients the system became unstable and generated unusable results. Many variations of this exercise were tried, but all resulted in explosive results. The counterfactual exercise for the dissertation thus proved to be unsuccessful, but there is still future research potential using this approach as I now show.

Two approaches can be followed in conducting the counterfactual simulation using VARs. Both strategies require ultimately changing the structural coefficients in the dynamic money supply equation so that money supply does not respond to productivity shocks. Technically this means setting all the (5,1) elements, which are the coefficients showing the monetary base response to changes in productivity, in the A_i matrices to zero and also adjusting the (5,3) elements so that the monetary response to money demand shocks is only capturing velocity shocks, not productivity shocks.[50] In matrix form, this can be in the following expression,

$$(4.12) \qquad A_i = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ 0 & a_{52} & \widehat{a}_{53} & a_{54} & a_{55} \end{bmatrix},$$

where $\widehat{a}_{53}$ is the adjusted money demand coefficient. The first approach, which I attempted, requires explicitly changing the elements in the A_i matrices, while the second

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[49] He shows that alternative monetary policies would not make significantly different economic outcomes.
[50] Otherwise, the monetary policy rule might encounter problems with double counting.

approach requires making changes in the $D(1)$ matrix and then making the implied changes in the A_i matrices.

Under the first approach, identifying restrictions must be made so that each A_i can be identified, extracted, and then modified. Given the long-run identifying restrictions, this can be accomplished by noting that $D(1) = C(1)D_0$ or $D(1)C(1)^{-1} = D_0$. Since $D_0 = A_0^{-1}$, A_0 can be extracted. To get the other A_i matrices recall that estimable reduced-form moving average, from which is derived the structural shocks given identification, is

(4.13)
$$y_t = (I - BL)^{-1}e_t,$$

for a one lag model. This can be restated in the estimable autoregressive form of

(4.14)
$$y_t = By_{t-1} + e_t.$$

Equation (4.14) is the actual estimated set of equations. Consequently, since $B = A_0^{-1}A_1$, A_1 can be solved for using B and A_0. The same process can be used for all the A_is in the VAR model. Using the one lag model and letting hats denote the modified model, equation (4.14) is now

(4.15)
$$\hat{y}_t = \hat{B}y_{t-1} + \hat{e}_t,$$

which can be used to generate a general equilibrium response in the real stock price level price to a productivity shock. As I discovered, however, this approach can generate unstable roots and create meaningless results. Consequently, one must be prepared to deal with complicated root issues in taking this approach.

The second approach requires adding an additional restriction to the $D(1)$ matrix so that productivity shocks have no permanent effect on the nominal money supply, which implies

$$D(1) = \begin{bmatrix} d_{11} & 0 & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} & 0 \\ 0 & d_{52} & d_{53} & d_{54} & d_{55} \end{bmatrix}.$$

This in effect prevents monetary policy from systematically responding to productivity shocks. However, imposing this restriction alone implies changes in all the A_i matrices so that there is no clear structural interpretation of the restriction. Consequently, other restrictions must also be imposed for the restriction to be meaningful. First, all the coefficients in the A_i matrices must remain the same except for the coefficients in the money supply equation. Second, the reduced form series or the B_i matrices must be allowed to change. Simply, find a combination of the money supply equation elements in the A_i matrices so that restriction in $D(1)$ holds and then use the new B_i matrices to find the general equilibrium, counterfactual time series path. One problem in this approach, however, is that there may be multiple solutions. Both approaches require sophisticated programming, but have the potential to generate insights regarding the relationship between monetary policy and the stock market.

4.4   Conclusion

A simple VAR model was estimated in this chapter to determine whether the findings of the theoretical model in the previous chapter, which showed monetary-accommodated

productivity innovations could generate stock market boom-bust cycles, are consistent with the empirical record. The VAR model, therefore, was identified using long-run restrictions so that productivity shocks could have a permanent effect on the real stock price, while the real stock price could only be temporarily influenced by monetary shocks. Using innovation accounting, real stock prices were found to overshoot their new steady state value following a productivity shock. Monetary policy as measured by the response of the monetary base apparently was found to accommodate permanent increases in the productivity growth rate and be associated with some of the initial volatility in the real stock price. The variance decomposition indicated that, although money supply shocks were not important contributors to the forecast error variance in the real stock price, productivity shocks did explain a notable portion. This in turn suggests that the monetary accommodation of productivity shocks may have contributed to the unexpected performance of the stock market. Although these results are consistent with the theoretical model, they fail to provide conclusive evidence that monetary accommodation was a significant factor in the stock market boom of the 1990s. I hope that a counterfactual simulation and other future research will shed further light upon this issue.

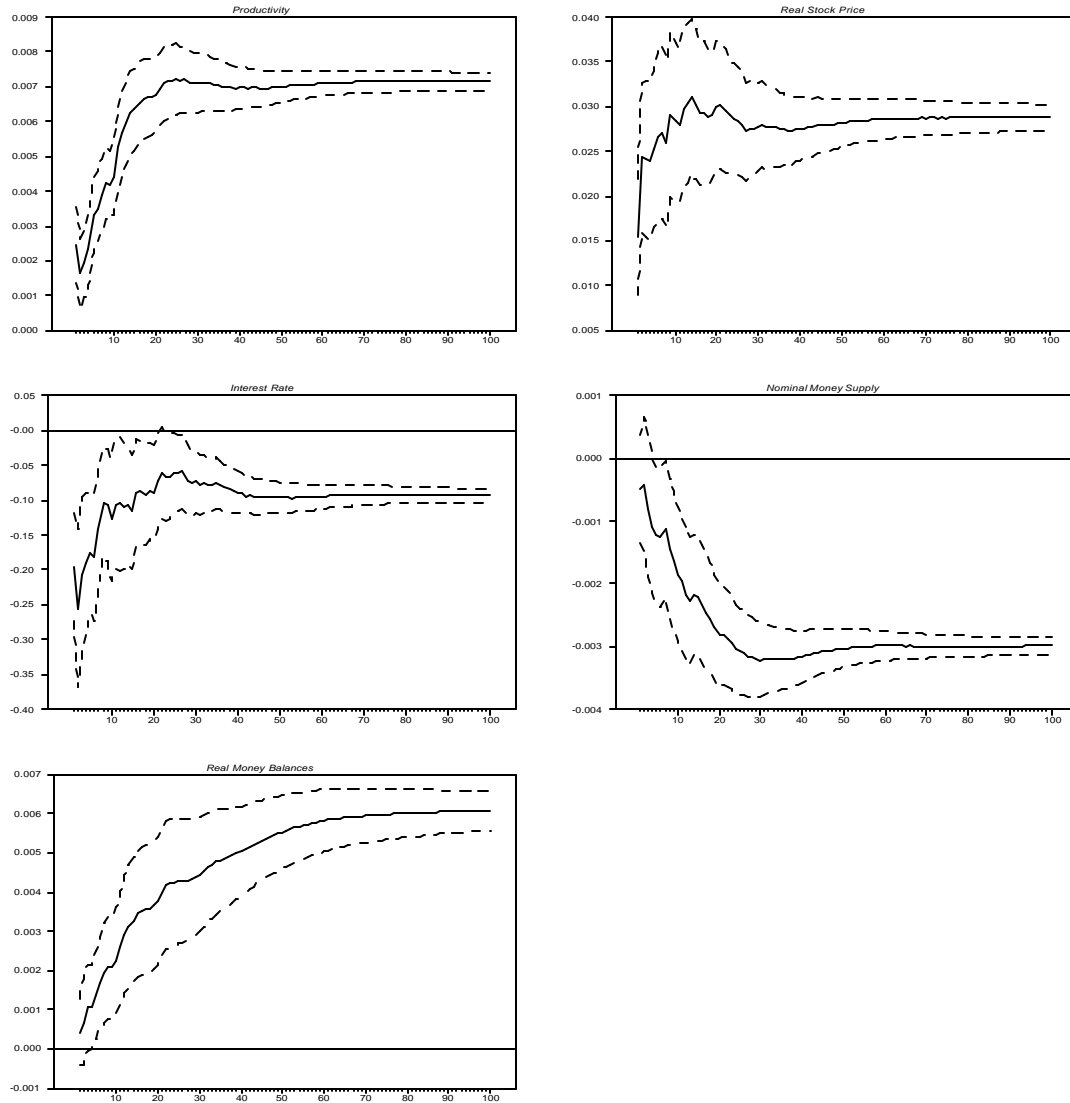**Figure 4.2 - Responses to Monetary Shocks**
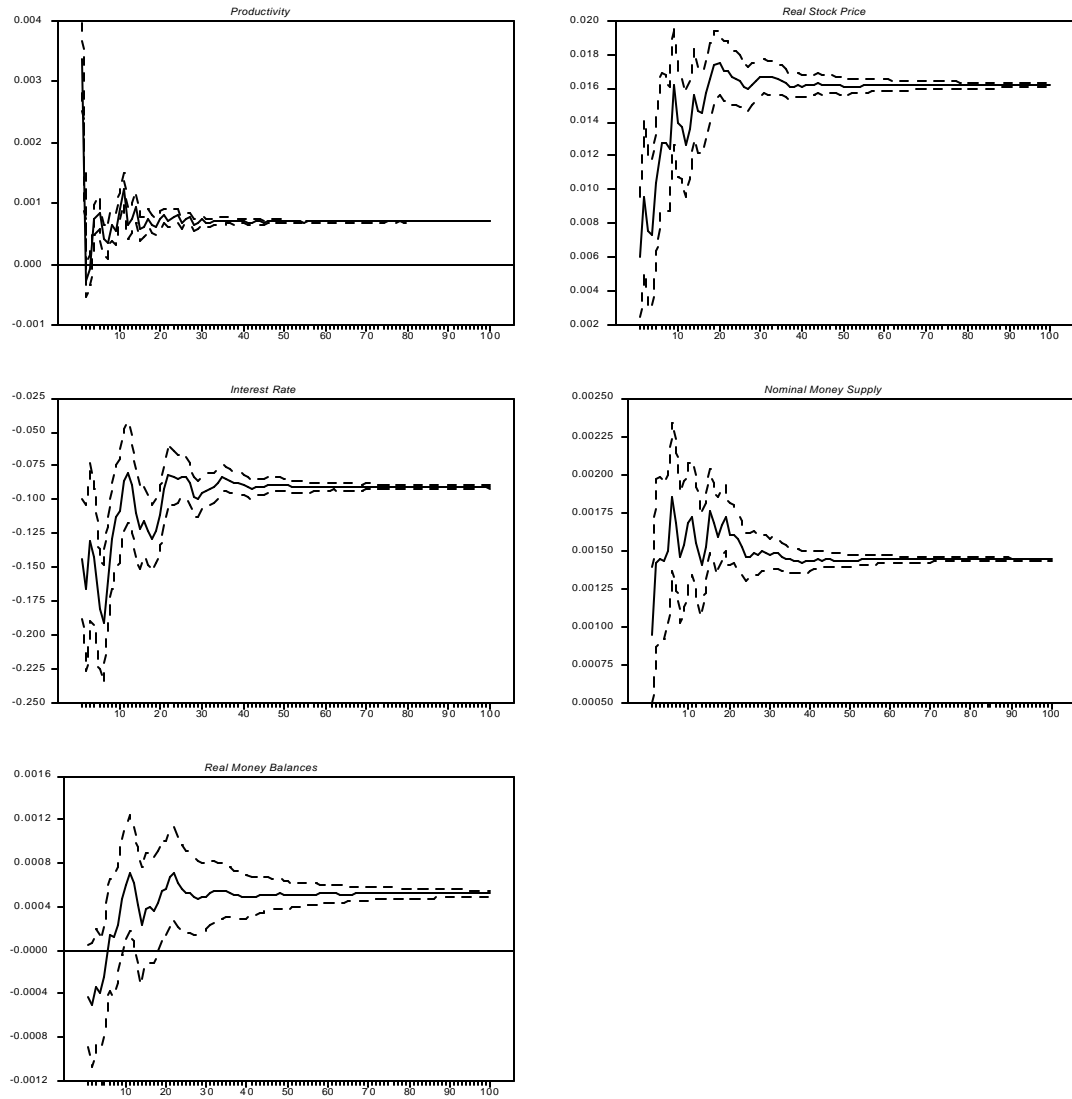**(Productivity First Differenced)**
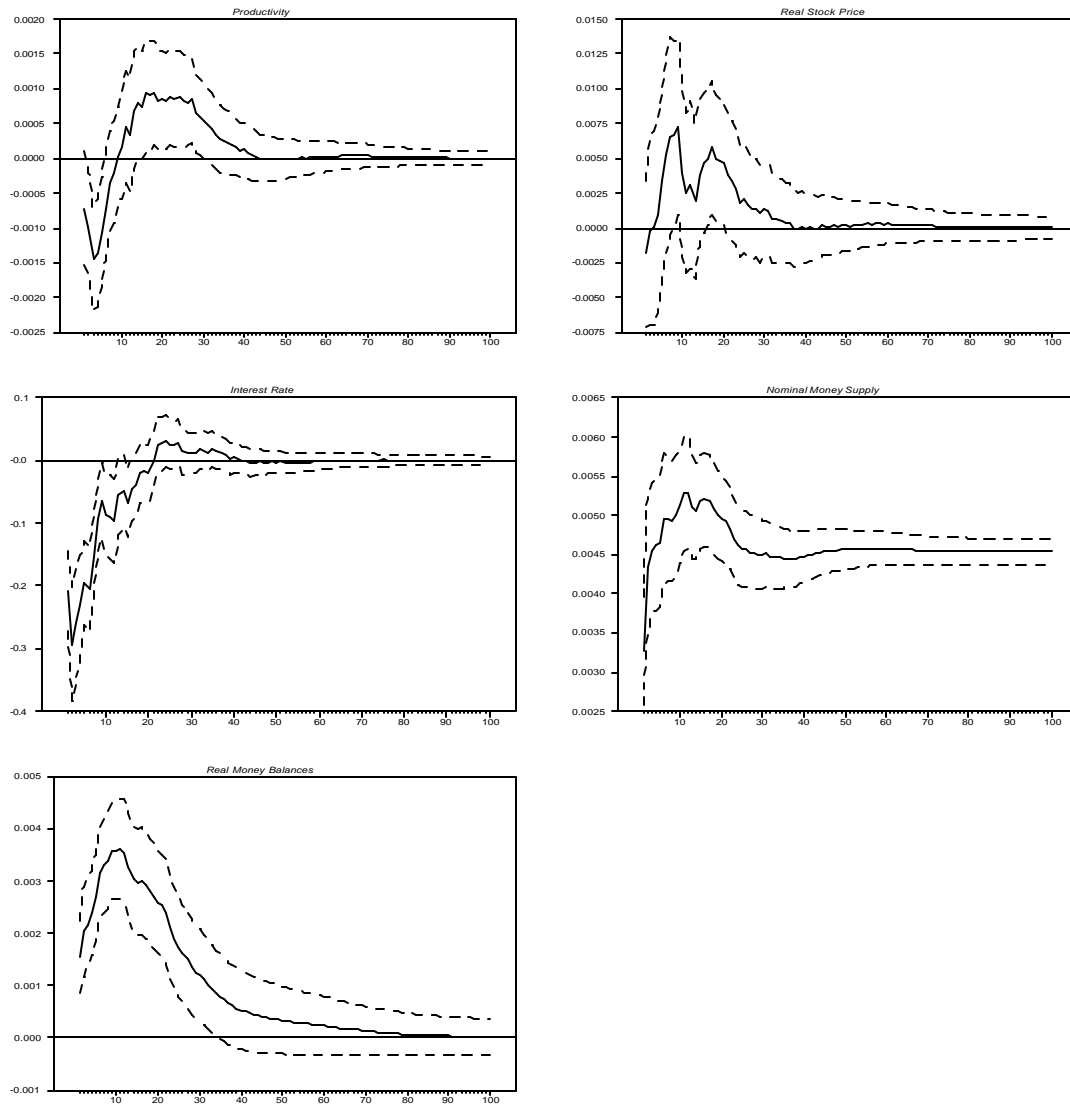
Figure 4.3 - Responses to Monetary Shocks
(Productivity Second Differenced)
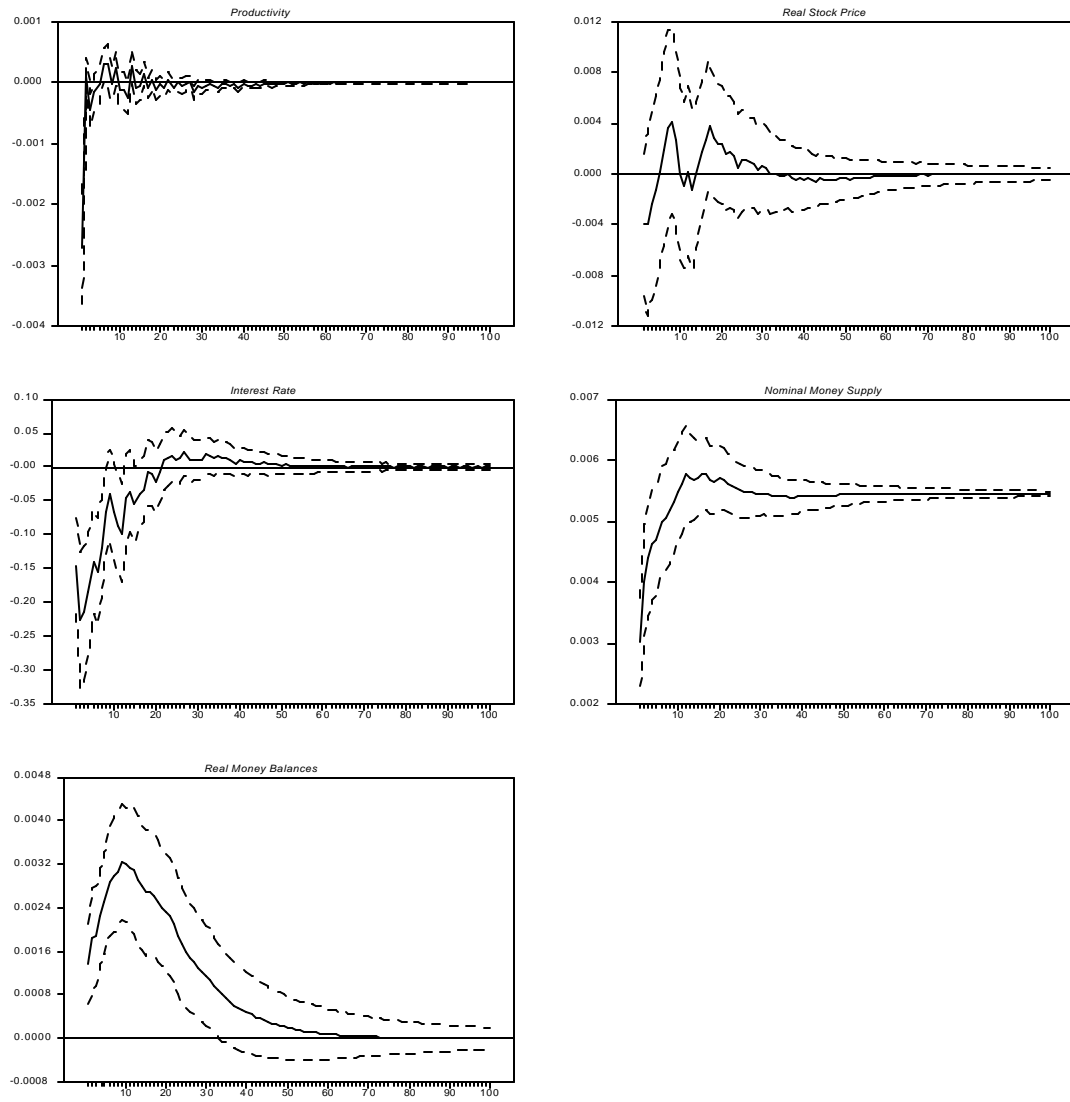
Figure 4.4 - Responses to Productivity Shocks
(Productivity First Differenced)

Figure 4.5 - Responses to Productivity Shocks
(Productivity Second Differenced)

Figure 4.6 - Contribution of Monetary Shocks to Variance
(Productivity First Differenced)
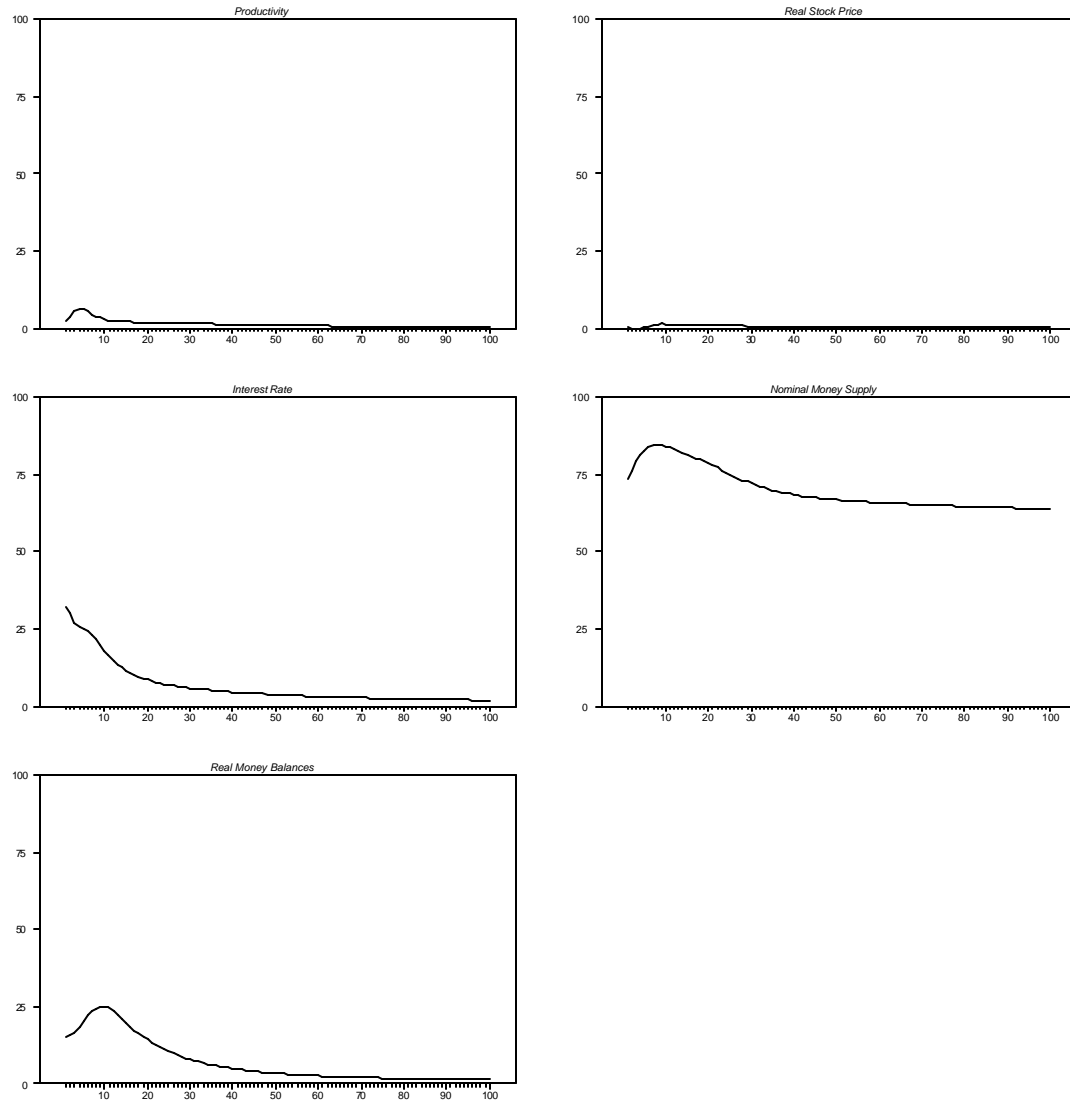
Figure 4.7 - Contribution of Monetary Shocks to Variance
(Productivity Second Differenced)

Interest Rate

Nominal Money Supply

Real Money Balances
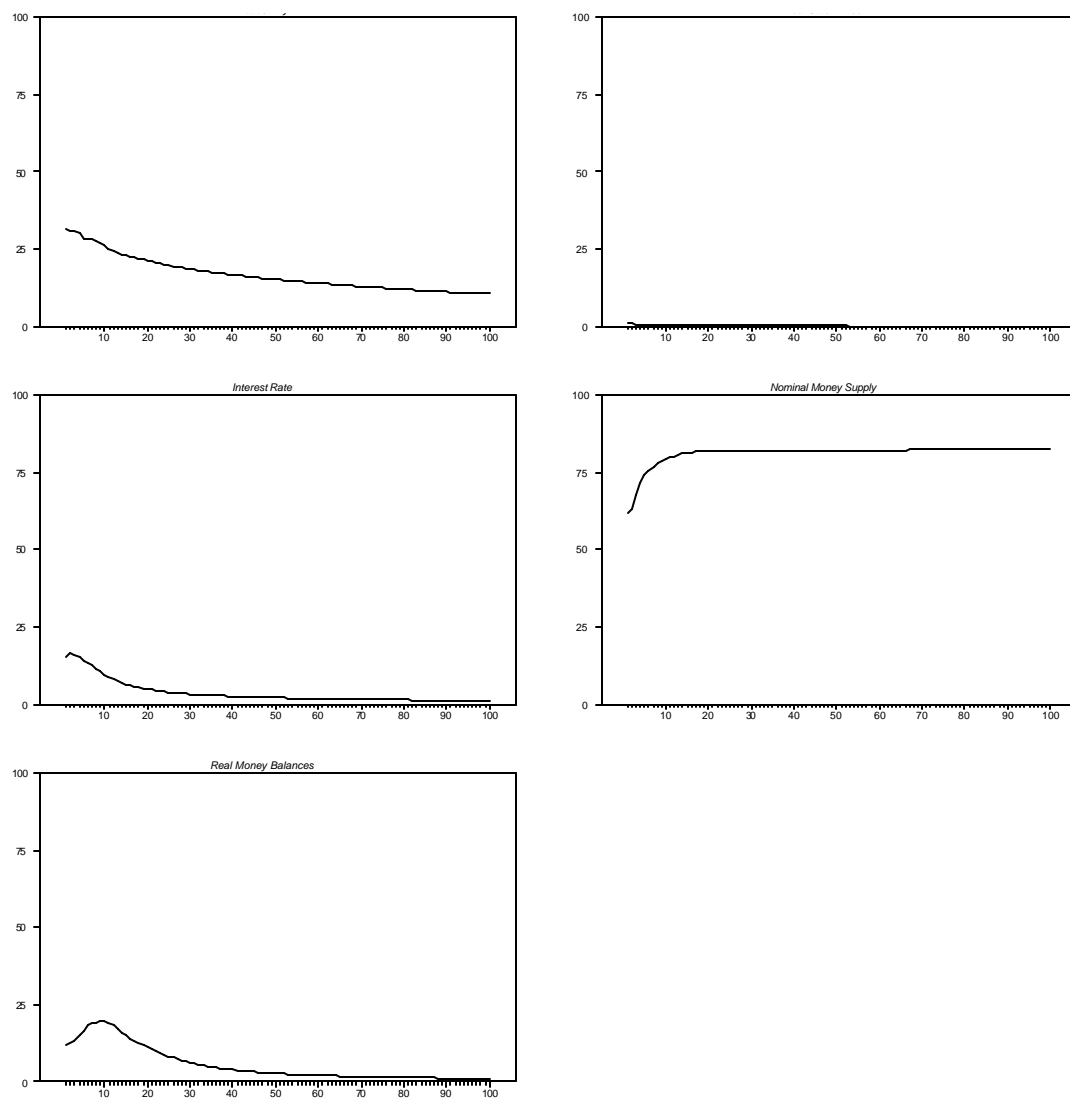
Figure 4.8 - Contribution of Productivity Shocks to Variance
(Productivity First Differenced)
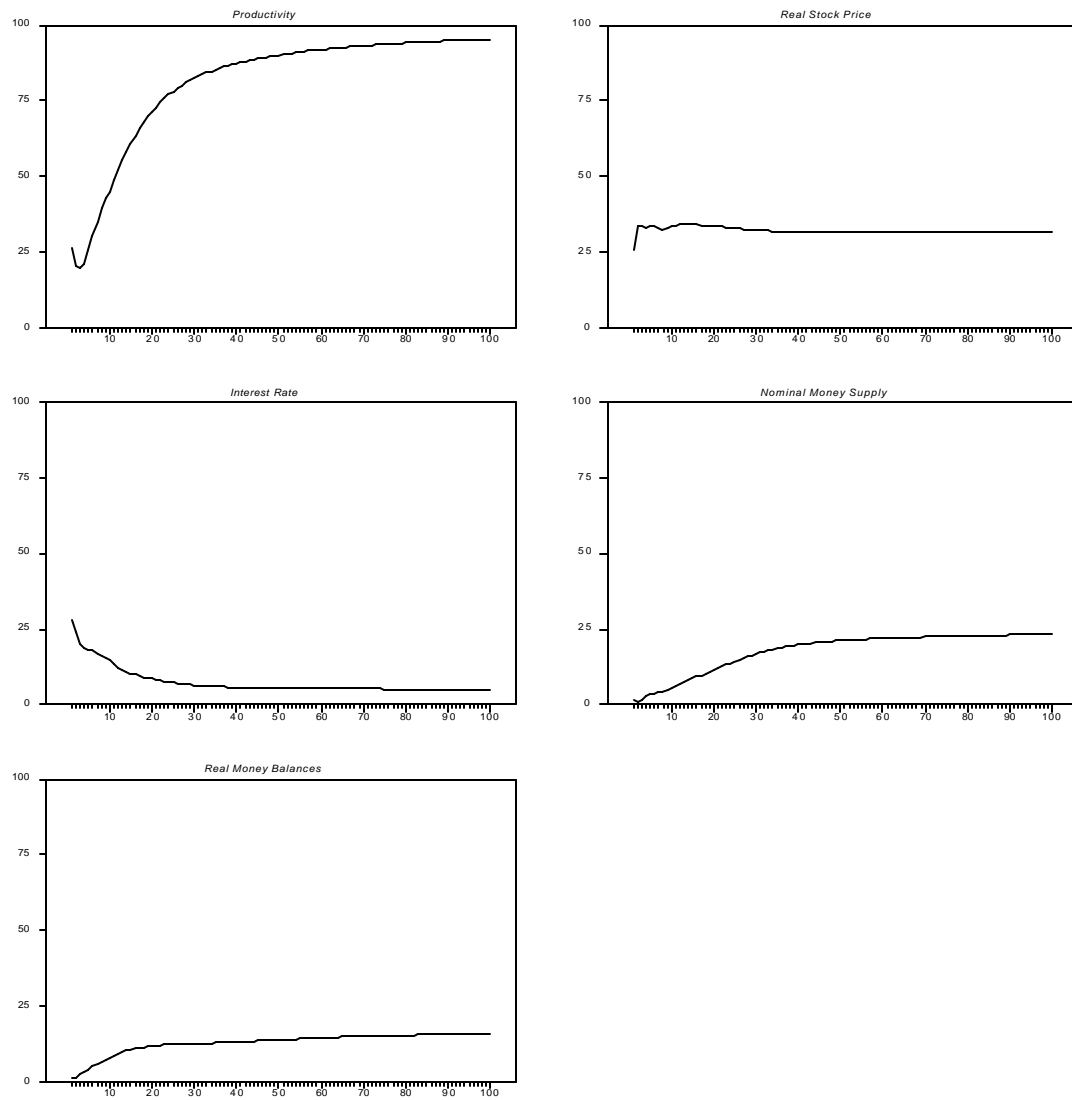
Figure 4.9 - Contribution of Productivity Shocks to Variance
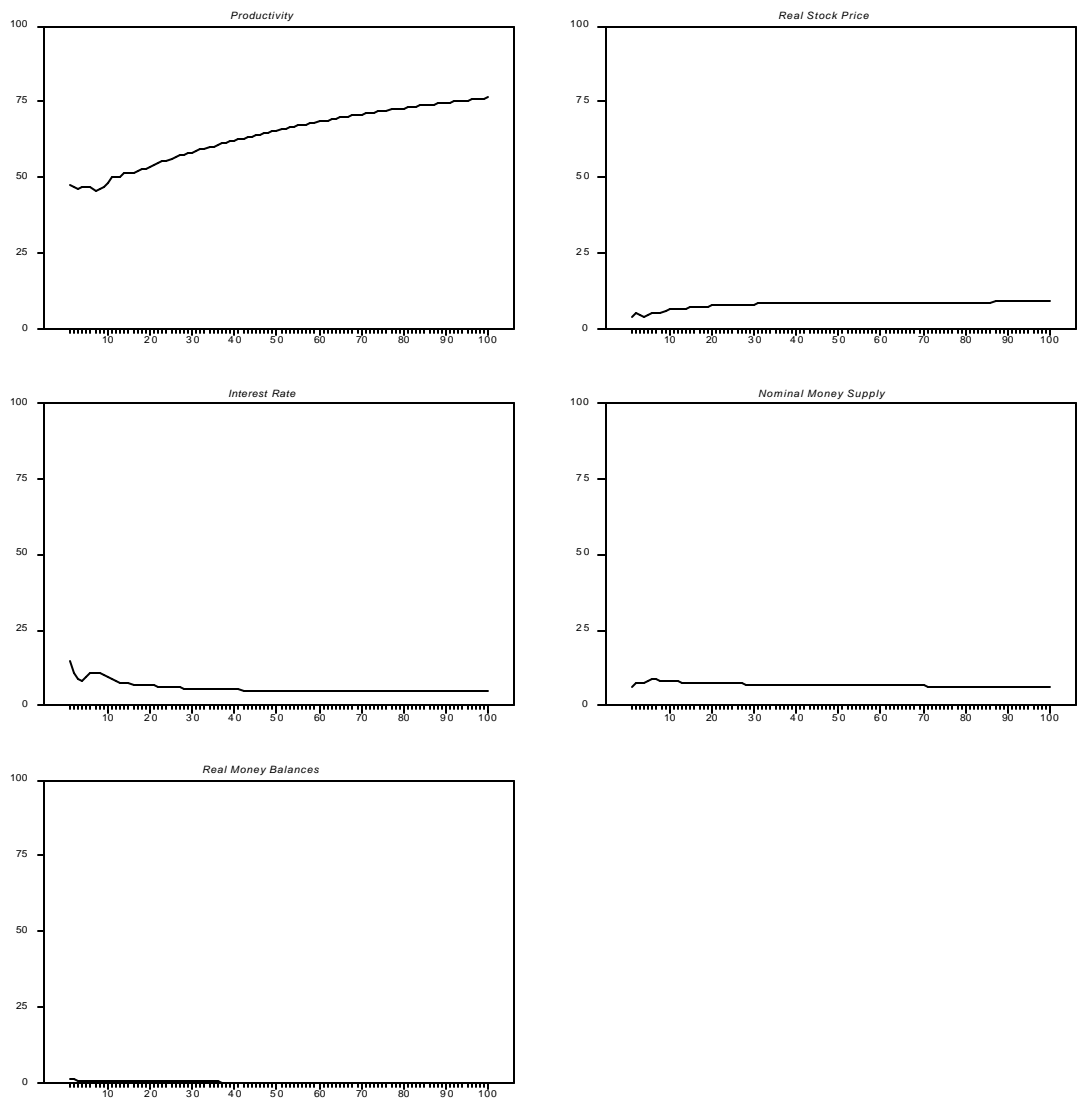**(Productivity Second Differenced)**

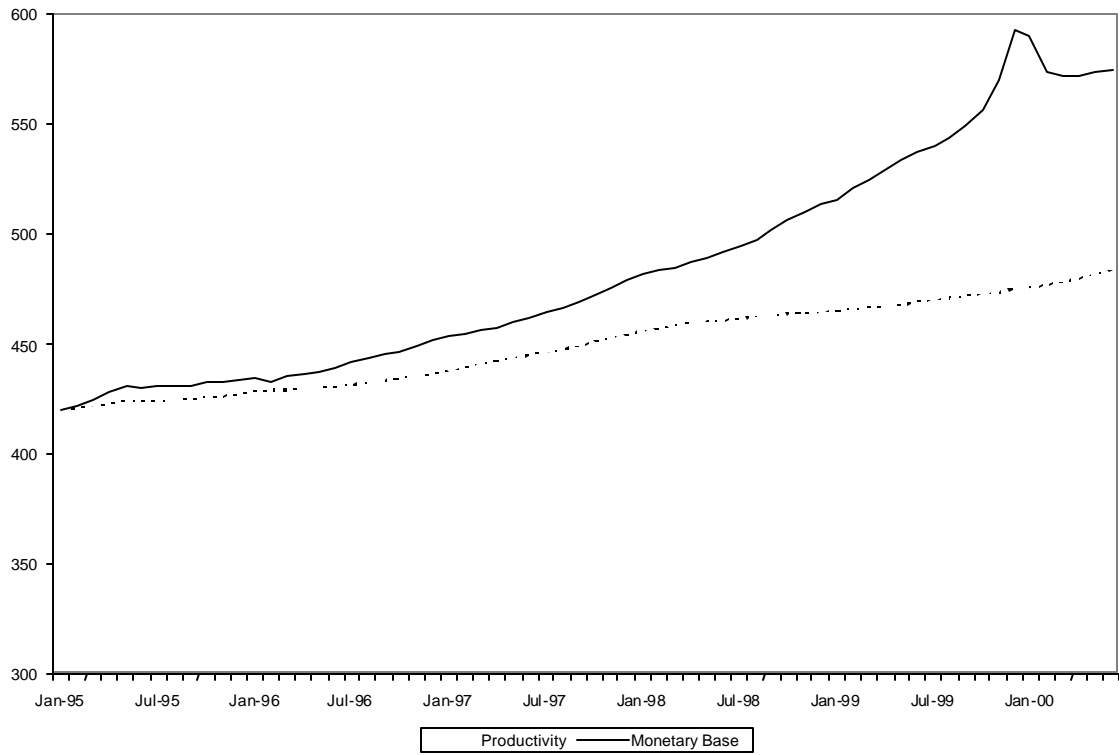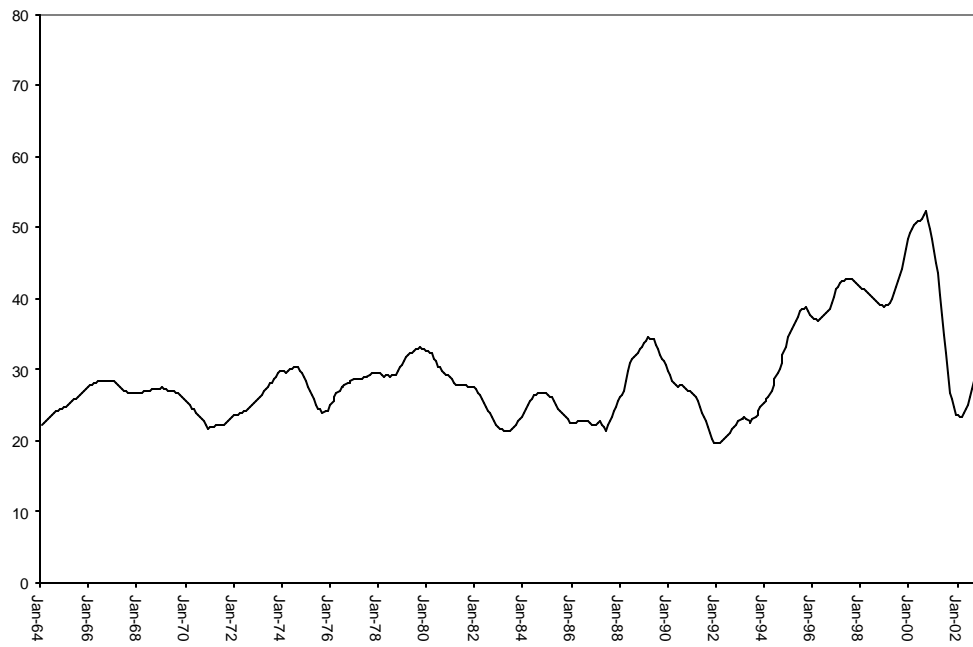**Figure 4.10 – Monetary Base and Productivity**

Figure 4.11 – Real Earnings Index

CHAPTER 5

CONCLUSION

I set out in this dissertation to examine the question of whether certain forms of systematic monetary policy are better able than others to avoid financial instability in periods of accelerated productivity growth. This question was motivated by the empirical observations in figures 1.1, 1.2, and 2.1 that showed output price stability may not always be consistent with financial stability - a finding contrary to conventional economic wisdom. Policy makers when confronted with this confluence of events attributed it largely to the surge in productivity. They argued that the increased productivity growth fostered price stability but created an unsustainable boom in the stock market. Some studies, however, suggested that targeting price stability during times of increased productivity growth might itself fuel an unsustainable boom in equity prices. Either way, productivity was considered an important factor in understanding the apparent inconsistency between output price stability and financial stability. Therefore, exploring the importance of systematic monetary policy during periods of accelerated productivity growth was set out as an objective of this paper.

The literature surveyed in the second chapter suggested two differing approaches to systematic monetary policy during period of increasing productivity. The first view argued that price stability is generally conducive to financial stability. Consequently, monetary policy should systematically target price stability regardless of productivity and deviate, if at all, when severe financial imbalances in the stock market arise. A second

view argued that maintaining price level stability during times of increasing productivity growth requires monetary easing that itself may contribute to unsustainable surges in equity prices. Monetary policy, therefore, should not accommodate productivity growth but allow it to be reflected in the price level to minimize stock market volatility.

These two approaches to monetary policy were explored in the third chapter where a simple general equilibrium model with sticky wages, monetary policy, and real stock prices was developed. This setup allowed the dynamic effects of real stock prices under the different monetary policy regimes to be examined given positive productivity developments. The results of this exercise showed that by accommodating productivity innovations, monetary policy can indeed lead to unsustainable surges in stock prices. Monetary policy, therefore, that systematically targets some form of price stabilization, whether price level stability or low inflation, in an environment of increasing productivity may contribute to stock price inflation. These results imply that U.S. monetary policy in the 1990s may have played a meaningful role in stock market boom.

The implications of the theoretical model were empirically examined in chapter four using an estimated VAR model and innovation accounting. Monetary policy shocks were found to have notable effects on the real stock price. Monetary policy was found to accommodate permanent increases in the growth rate of productivity and coincide with some stock market volatility. These results are consistent with the theoretical model and suggest monetary accommodation can contribute to stock market volatility. However, these results do not show the isolated effect of the monetary accommodation to the productivity shock and only reveal the real stock price response given a one standard

deviation shock. The estimated VAR is therefore not able to reveal the full, isolated consequences of monetary policy systematically responding to a series of productivity innovations.

Blanchard (2003) echoes this point about the limits of innovation accounting by noting the "type of money shocks whose effects are traced by VAR impulse responses are deviations from normal monetary behavior, and thus…are likely to have different effects from the non-deviation part of policy" (p.2). He argues, therefore, that innovation accounting understates the total effect of monetary policy because it ignores the systematic component. He cites as an example the performance of ex-ante real rates in OECD countries over the last thirty years, largely attributing the low ex-ante real rates in the 1970s and the high ex-ante real rates in the 1980s to monetary policy.[51] Blanchard concludes by noting that if "monetary policy can affect the real interest rate for a decade and perhaps more, then, we must accept, as a matter of logic, that it can affect activity, be it output or unemployment, for a roughly equal time" (p.3). The VAR literature, however, shows "the effect of an innovation in money on activity peaks after a year or so, and is largely gone within two or three years" and therefore cannot explain the total effect of monetary policy (p.1).

Blanchard's statements are consistent with the literature that shows even anticipated, systematic monetary policy can also have real economic effects (Mishkin, 1982a; Mishkin 1982b; Gordon, 1982; McGee and Stasiak, 1985; Romer and Romer,

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[51] Blanchard argues, "For most of the 1970s, ex-ante real rates were very low in most countries. This was due…to a large increase in inflation and a less than one-for-one increase in nominal interest rates. Who can doubt that the evolution of real rates was due to monetary policy? That, faced with an increase in inflation triggered by supply side shocks, central banks were too slow and too reluctant to increase nominal interest rates, leading to low or even negative real interest rates for a good part of the decade" (p.2). Later, he notes, "For most of the 1980s, ex-ante real rates were high in most countries. This was due…to a large increase in nominal interest rates, together with a decrease in the rate of inflation. Again, who can doubt this evolution was primarily due to monetary policy" (p. 3)?

1994; Cochrane, 1998). This literature suggests monetary disequilbrium and its consequences can arise under systematic monetary policy for some of the same reasons it arises under money supply shocks: fixed nominal contracts, menu costs, aggregate demand externalities, and monetary injection effects. Like Blanchard, this literature implies that while the VAR framework can provide important insights, it may not capture all the real effects of monetary policy. Consequently, monetary accommodation to productivity shocks may generate bigger responses in the real stock price than shown in the impulse response functions of chapter 4.[52]

In summary, this dissertation suggests that a productivity norm approach to monetary policy may minimize stock market boom-bust cycles and avoid the financial instability seen in recent years. Further empirical work examining the relationship between price stabilization policies and the stock market needs to done to reveal the true effect of such polices and thus the potential gains to adopting a productivity norm rule. Also, further theoretical work employing adaptive expectations may provide better theoretical estimates of the magnitudes of the stock market response to price stabilization policies. This topic provides fertile ground for future research.

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[52] Selgin (1997) discusses some of the ways systematic monetary policy that targets price stability during times of accelerated productivity could have real effects. First, he notes that since productivity growth puts downward pressure on prices, any attempt to stabilize the price level will create relative price distortions and temporarily add noise to the pricing system. Given menu costs, these distortions could have real effects. Second, he shows that while firms are generally willing to change output price in response to changes in production costs, they are less willing to change in response to changes in demand. Monetary policy, however, works through demand to stabilize the price level. This mix can lead to "aggregate demand externalities" where all firms need to change their prices to clear the macro market but fail to do so because of the feared cost of being a first mover. Third, he demonstrates that systematic attempts by the monetary authority to stabilize the price level can have real consequences because of monetary injection effects. Since the monetary accommodation works its way into the financial system unevenly, "[r]elative prices, including real interest rates, are thus displaced from their natural or full-information values" and create real disturbances (p. 32). For these reasons, U.S. monetary policy in the late 1990s may have had real effects and consequently contributed to the performance of the stock market.

A.1   Equations and Definitions

(A.1)
$$(1 + r_t) = E_t \left[\frac{C_{t+1}}{b C_t} \right],$$

(A.2)
$$1 = bE_t \left(\frac{C_t}{C_{t+1}} \left\langle \frac{D_{t+1} + S_{t+1}}{S_t} \right\rangle \right),$$

(A.3)
$$h \frac{1}{1 - L_t} = \frac{W_t}{P_t},$$

(A.4)
$$\frac{M_t}{P_t} = g_t C_t \left(\frac{R_t - 1}{R_t} \right)^{-1},$$

(A.5)
$$R_t^n = E_t (1 + r_t)(1 + p_t)$$

(A.6)
$$Y_t = A_t L_t^{1-a},$$

(A.7)
$$D_t = A_t L_t^{1-a} - W_t \, L / P_t$$

(A.8)
$$(1 - a) A_t L_t^{-a} = \frac{W_t}{P_t}$$

$$l_1 = \left(\frac{1}{(1 + r)(1 + m)} \right),$$

$$(1 + r) = \left(\frac{(1 + g_A + g_N)}{b} \right),$$

m = steady state money growth rate, $b = .99$, $a = .35$, $r_a = 1$, $r_g = r_q = .9$

A.2 Unit Root and Cointegration Tests

P-vaules for Null Hypothesis of Unit Root in the Levels

	Tbill	Prod	RSP	Base	Base/CPI
Wtd. Sym.	.3007	.8986	.9203	.9997	.9982
Dicker-Fulley	.2663	.1551	.8116	.1499	.9815
Phillips-Perron	.4329	.4531	.9261	.4239	.9974

P-vaules for Null Hypothesis of Unit Root in the First Differences

	TBond	Prod	RSP	Base	Base/CPI
Wtd. Sym.	.0026	.0000	.0000	.0000	.0000
Dicker-Fulley	.0011	.0000	.0000	.0000	.0000
Phillips-Perron	.0000	.0000	.0000	.0000	.0000

P-values for Null Hypothesis that $q = 0$
$$\left(\Delta\hat{e}_t = q\hat{e}_{t-1} + \hat{u}_T\right)$$

Prod	.0733
RSP	.9490
Base	.6742
Base/CPI	.4069
TBOND	.0450

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