Inflation Targeting, Learning and Q Volatility in Small Open Economies

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Abstract

—This paper examines the welfare implications of managing asset-price with consumer-price inflation targeting by monetary authorities who have to learn the laws of motion for both inflation rates. Our results show that the Central Bank can improve welfare if it targets both consumer and asset-price inflation with state-contingent Taylor rules rather than conventional linear Taylor rules.

Many countries now practice inflation targeting, but that has not immunized the economy from experiencing asset price volatility in the form of exchange rate instability in Australia or share-market bubbles in the United States. The practice of controlling changes in goods prices is taken for granted by many Central Banks, but there is no consensus about the management of asset-price inflation, except in the sense that it is not desirable for asset prices to be too high or too volatile. At the World Economic Forum in Davos in 2003, Lawrence Summers suggested that policy makers should use other tools, such as margin lending requirements or public jawboning, to combat asset-price inflation. He compared raising interest rates to combat asset-price inflation to a preemptive attack, and stated "it takes enormous hubris to know when the right moment has come to start a war" [Summers (2003), p.1].

There is some research which show that central bankers should not target asset prices [see. for example. Bernanke and Gertler (1999, 2001) and Gilchrist and Leahy (2002) for a closed economy study]. However, Cecchetti, Genberg and Wadhwani (2002) have argued that central banks should react to asset price misalignments. In essence, they show that when disturbances are nominal, reacting to close misalignment gaps significantly improves macroeconomic performance. Smets (1997) has also stressed that the proper response of monetary policy to asset-price inflation depends on the source of the asset-price movements. If productivity changes are the driving force, accommodation is called for, and real interest rates should remain unchanged. However, if the source is due to non-fundamental shocks in the equity market, in the form of bullish predictions about productivity, then monetary policy should raise interest rates.

In contrast to previous studies we evaluate monetary policy in a small open-economy framework, and in particular we are concerned with investment in a resource-rich small open economy subjected to the vagaries of international terms of trade shocks. Detken and Smets (2004) have shown that high cost asset-price booms are as common in small open economies subject to fundamental terms-of-trade shocks as they are in relatively closed economies driven by fundamental productivity shocks.

We highlight learning on the part of the central bank. For a small open economy subject to terms of trade movements, learning behavior on the part of the policy authority is an appropriate assumption, since movements of the terms of trade are determined in international markets far removed from the influence of domestic policy actions. The economy we study has an export sector and an imported manufactured goods sectors. The terms of trade are driven by movements in the commodity export price relative to the price of manufactured goods. The volatility of this relative price will in turn affects share prices and investment in the booming (or declining) export sector.

In this paper, we consider the rate of growth of Tobin's Q, first introduced by Tobin (1969), as a potential target variable for monetary policy. Our reasoning is that Q-growth would be small when the growth in the market valuation of capital assets corresponds roughly with the growth of replacement costs. Since asset prices (in the market value) are a lot less sticky than good prices (in the replacement cost), the presence of high Q-growth would be indicative of misalignment of market value and replacement cost, in other words an indication of an "excessive" change in the share price. Thus monitoring and targeting Q-growth may be viewed as a proxy policy for monitoring and targeting asset price inflation, but with the advantage that the asset price is evaluated relative to a benchmark (the replacement cost).

1. MODEL SPECIFICATION

The framework of analysis contains two modules - a module which describes the behavior of the private sector and a module which describes the behavior of the central bank. A full specification of this model may be found in a fuller version of this paper on the second author's web page.

A. Monetary Authority

We are concerned with Taylor rules, one with only annualized price inflation targeting, for the desired interest rate, $\overline{i_t}$, and one with inflation and Q-growth targeting. However, they are evaluated under two scenarios.

- Standard Taylor Rules

For the pure inflation targeting regime, the desired interest rate has the following form:

$$\overline{i_t} = i^* + \phi_\pi(\widehat{\pi}_t - \widetilde{\pi}), \qquad \phi_\pi > 1 \tag{1}$$

with $\pi_t = ((P_t/P_{t-4}) - 1)$ representing an annualized rate of actual inflation, and $\widehat{\pi}_t$ the forecast of inflation based on central bank learning. The desired long run inflation rate is given by $\widetilde{\pi}$. The actual interest rate follows the following partial adjustment mechanism to allow for smoothing behavior:[1]

$$\begin{aligned} i_t &= \theta i_{t-1} + (1-\theta)\overline{i_t} \qquad (2) \\ &= \theta i_{t-1} + (1-\theta)\left[i^* + \phi_\pi(\widehat{\pi}_t - \widetilde{\pi})\right] \end{aligned}$$

In the goods price and asset price inflation regime, we change the formulation for the desired interest rate, to include the forecast of Q-growth, $\widehat{\eta}_t$ and a desired target rate, $\widetilde{\eta}$:

$$\overline{i_t} = i^* + \phi_\pi(\widehat{\pi}_t - \widetilde{\pi}) + \phi_\eta(\widehat{\eta}_t - \widetilde{\eta}), \qquad \phi_\pi > 1, \phi_\eta > 0 \quad (3)$$

with $\eta_t = ((Q_t/Q_{t-4}) - 1)$ representing an annualized rate of Q-growth and $\widetilde{\eta}$ represents the target for this rate of growth. In this case, actual interest rate with smoothing becomes:

$$\begin{aligned} i_t &= \theta i_{t-1} + (1-\theta)\overline{i_t} \qquad (4) \\ &= \theta i_{t-1} + (1-\theta)\left[i^* + \phi_\pi(\widehat{\pi}_t - \widetilde{\pi}) + \phi_\eta(\widehat{\eta}_t - \widetilde{\eta})\right] \end{aligned}$$

- State-Contingent Taylor Rules

We also assume that the Taylor rule applied is dependent on the conditions at time t and reflects the Central Bank's concerns about inflation. Under the inflation targeting only case, the rules are described in Table I.

Table I: Policy Rules for Inflation Targeting Only	
$\lvert\pi_t\rvert < 0.02$	$i_t = \theta i_{t-1} + (1-\theta)[i^*]$
$\lvert\pi_t\rvert \geqq 0.02$	$i_t = \theta i_{t-1} + (1-\theta)[i^* + \phi_\pi(\widehat{\pi}_t - \widetilde{\pi})]$

In this pure anti-inflation scenario, if the absolute value of inflation is below the target level π^* then the government only engages in smoothing behaviour. However, if inflation is above or below the target rate, the monetary authority implements the Taylor rule.

In the inflation and Q-growth case, the state contingent Taylor policy rules follow a similar patter.

In this setup the central banks shows a strong anti-inflation or anti-deflation bias, in both the CPI and in the share price index. In other words, the central bank worries a lot about absolute inflation being above targets, either in the CPI, or in Q, or both. But it worries little about inflation or deflation in either of these variables if the absolute value of the rate is below targets. There are thus four sets of outcomes: (1) if both inflation and asset-price growth are below the target levels, then the government follows a "do no harm" cautionary approach with $\phi_\pi = \phi_\eta = 0$; (2) if inflation is above the target rate, and asset-price inflation is below the target, the monetary authority puts strong weight on CPI inflation and sets $\phi_\eta = 0$; (3) if only asset-price growth is above its target, the central bank puts strong weight on the asset-price growth target and sets $\phi_\pi = 0$; (4) if both asset-price growth and inflation are above targets, it adopts a Taylor rule on both inflation and Q-growth.

[1] This formulation of the Taylor rule is similar to the rule estimated by Judd and Rudebusch (1998).

Note that monetary policy in all instances operates symmetrically. The same weight applies to inflation or growth, with different signs, when they are above or below their targets. For simplicity, with no long run inflation nor trends in terms of trade, we set the targets for inflation and growth to be zero; $\widetilde{\pi} = \widetilde{\eta} = 0$.

- Central Bank Learning

We also assume, perhaps more realistically, that the monetary authority does not know the exact nature of the private sector model. Instead, it adopts a VAR forecasting model of lag order k for forecasting the evolution of the state variable, x_t. The model takes the general form:

$$x_t = \sum_{j=0}^{k} \Gamma_{1t,j} x_{t-j-1} + \Gamma_{2t} i_t + e_t$$

Under the inflation only policy scenario, the monetary authority estimates or learns the evolution of inflation as a function of its own lag as well as the interest rate. In this case $x_t = \pi_t$. We use six lags and $\Gamma_{1t,j}$ is a recursively updated matrix of coefficients, representing the effects of lagged inflation on current inflation.

In the inflation/Q-growth scenario, the central bank learns the evolution of goods price and asset-price inflation (proxied by Q-growth)[2] as functions of their own lags and the interest rate. In this case, $x_t = [\pi_t, \eta_t]$ and we have a bivariate forecasting model for the evolution of the state variables, π_t and η_t, with an equal number of lags. We use six lags and $\Gamma_{1t,j}$ is a recursively updated matrix of coefficients, representing the effects of lagged inflation and growth on current inflation and growth.

Uncertainly about the underlying longer-term inflation in the CPI or share price is a rationale for our approach. Swanson (2004), for example, poses the issue as a "signal extraction" problem for a policy-maker, with diffuse-middle priors. In our framework, policymakers are uncertain about the underlying rate of inflation or deflation in the range [-2, 2] percent, so they are unwilling to revise estimates within this interval. As observed inflation or deflation moves further away from their prior, they respond not at all for small surprises in the realized inflation rate but respond "very aggressively at the margin" [Swanson (2004): p.7]. The main feature of this type of learning is "policy attentuation for small surprises" followed by "increasingly aggressive responses" at the margin [Swanson (2004): p.7].

2. CALIBRATION AND SOLUTION ALGORITHM

In this section we discuss the calibration of parameters, initial conditions, and stochastic processes for the exogenous variables of the model. We then summarize the parameterized expectations algorithm (PEA) used for solving the model.

[2] We have obviously assumed that the central bank computes and monitors past values of Tobin's q based on data about market values and replacement costs.

A. Parameters and Initial Conditions

The parameter settings for the model appear in Table III.

Table III: Calibrated Parameters	
Consumption	$\gamma = 1.5$, $\beta = 0.009$
	$\alpha_x = 0.5$, $\alpha_f = 0.5$
Production	$\theta_m = 0.7$, $\theta_x = 0.3$
	$\delta_x = \delta_m = 0.025$
	$\phi_x = \phi_m = 0.03$

Many of the parameter selections follow Mendoza (1995, 2001). The constant relative risk aversion γ is set at 1.5 (to allow for high interest sensitivity). The shares of non-traded goods in overall consumption is set at 0.5, while the shares of exports and imports in traded goods consumption is 50 percent each. Production in the export goods sector is more capital intensive than in the import goods sector.

The initial values of the nominal exchange rate, the price of non-tradeables and the price of importable and exportable goods are normalized at unity while the initial values for the stock of capital and financial assets (domestic and foreign debt) are selected so that they are compatible with the implied steady state value of consumption, $\overline{C} = 2.02$, which is given by the interest rate and the endogenous discount factor. The values of $\overline{C}^x$, $\overline{C}^m$, and $\overline{C}^n$ were calculated on the basis of the preference parameters in the sub-utility functions and the initial values of B and L^* deduced. The steady-state level of investment for each sector is equal to the depreciation rate multiplied by the respective steady-state capital stock.

Similarly, the initial shadow price of capital for each sector is set at its steady state value. The production function coefficients A^m and A^x, along with the initial values of capital for each sector, are chosen to ensure that the marginal product of capital in each sector is equal to the real interest plus depreciation, while the level of production meets demand in each sector. Since the focus of the study is on the effects of terms of trade shocks, the domestic productivity coefficients were fixed for all the simulations.

Finally, the foreign interest rate i^* is also fixed at the annual rate of 0.04. In the simulations, the effect of initialization is mitigated by discarding the first 100 simulated values.

B. Solution Algorithm and Constraints

Following Marcet (1988, 1993), Den Haan and Marcet (1990, 1994), and Duffy and McNelis (2001), the approach of this study is to parameterize decision rules for C_t,$_t S_t$, I_t^x, I_t^x with nonlinear approximations or functional forms $\psi^S, \psi^C, \psi^{I^x}$, and ψ^{I^f} which minimize the Euler equation errors given in **??** through **??**:

$$C_t = \psi^C(\mathbf{x}_{t-1}; \Omega_C) \tag{5}$$

$$S_t = \psi^S(\mathbf{x}_{t-1}; \Omega_S) \tag{6}$$

$$I_t^x = \psi^{I^x}(\mathbf{x}_{t-1}; \Omega_{Q^x}) \tag{7}$$

$$I_t^m = \psi^{I^m}(\mathbf{x}_{t-1}; \Omega_{Q^m}) \tag{8}$$

The symbol $\mathbf{x}_{t-1}$ represents a vector of observable state variables known at time t: the terms of trade, the capital stock for exports and manufacturing goods, the level of foreign debt and the interest rate, relative to their steady state values:

$$\mathbf{x}_t = \ln\left[P_t^{x*}/P_t^{m*}, \frac{K_{t-1}^x}{\overline{K}^x}, \frac{K_{t-1}^m}{\overline{K}^m}, \frac{L_{t-1}^*}{\overline{L}^*}, \frac{1+i_{t-1}}{1+\overline{i}}\right] \tag{9}$$

The symbols $\Omega_\lambda, \Omega_S, \Omega_{Q^x}$, and Ω_{Q^m} represent the parameters for the expectation function, while $\psi^C, \psi^E, \psi^{Q^x}$ and ψ^{Q^f} are the expectation approximation functions.

Judd (1996) classifies this approach as a "projection" or a "weighted residual" method for solving functional equations, and notes that the approach was originally developed by Williams and Wright (1982, 1984, 1991). The functional forms for ψ^E, ψ^C, ψ^{Q^x}, and ψ^{Q^f} are usually second-order polynomial expansions [see, for example, Den Haan and Marcet (1994)]. However, Duffy and McNelis (2001) have shown that neural networks can produce results with greater accuracy for the same number of parameters, or equal accuracy with fewer parameters, than the second-order polynomial approximation.

We use a neural network specification with two neurons for each of the decision variables. The neurons take on values between [0, 1] for a logsigmoid function and between [-1, 1] for a tansigmoid function The functions were then weighted by coefficients, and an exponent or anti-log function applied to the final value. The functions were multiplied by the steady state values to ensure steady state convergence.

The model was simulated for repeated parameter values for $\{\Omega_C, \Omega_S, \Omega_{Q^x}, \Omega_{Q^m}\}$ and convergence obtained when the expectation errors were minimized. In the algorithm, the following non-negativity constraints for consumption and the stocks of capital were imposed by the functional forms of the approximating functions:

$$C_t^x > 0, \quad K_t^x > 0, \quad K_t^m > 0 \tag{10}$$

$$I_t^x > 0, \quad I_t^m > 0 \tag{11}$$

$$i_t > 0 \tag{12}$$

The usual no-Ponzi game applies to the evolution of real government debt and foreign assets, namely:

$$\lim_{t\to\infty} B_t \exp^{-it} = 0, \qquad \lim_{t\to\infty} L_t^* \exp^{-(i^*+\Delta s_{t+1})t} = 0 \tag{13}$$

We keep the foreign asset or foreign debt to GDP ratio bounded, and thus fulfill the transversality condition, by imposing the following constraint on the parameterized expectations algorithm:[3]

$$\sum\left(\frac{|S_t L_t^*|/P_t}{y_t}\right) < \widetilde{L}, \qquad \sum\left(\frac{|B_t|/P_t}{y_t}\right) < \widetilde{B} \tag{14}$$

where $\widetilde{L}$, and $\widetilde{B}$ are the critical foreign and domestic debt ratios.

[3]In the PEA algorithm, the error function will be penalized if the foreign debt/gdp ratio is violated. Thus, the coefficients for the optimal decision rules will yield debt/gdp ratios which are well belows levels at which the constaint becomes binding.

3. SIMULATION ANAYSIS

A. Accuracy Test

The accuracy of the simulations may be checked by the Judd-Gaspar statistic which is the maximum value of the absolute value of the Euler equation error for consumption ν_t relative to C_t. That is, for realization j, with size T, the accuracy measure is:

$$\begin{aligned} JG^{(j)}_{\max} &= \max\left[\frac{|\nu_t|}{C_t}\right] \\ \text{where} \quad \nu_t &= \vartheta_{t+1}\Lambda_{t+1}\frac{1}{P_{t+1}}(1+i_t) - \vartheta_t\Lambda_t\frac{1}{P_t} \end{aligned}$$

This statistic is a measure of the maximum error relative to a dollar spent on consumption for each realization.

Table IV present the means and standard deviations of the Judd-Gaspar accuracy measures based on the maximum absolute error measures. We see that the average size of the accuracy error measures are in the range 0.16 to 0.32 of one cent spent on consumption.?????

Table IV: Judd-Gaspar Accuracy Statistic: Maximum Absolute Error Mean and Standard Deviation (in parenthesis)

Taylor Rule Framework	
Inflation Targeting	0.0024 (0.0004)
Inflation/Q-Growth Targeting	0.0016 (0.0004)
State Contingent Taylor Rule	
Inflation Targeting	0.0017 (0.0003)
Inflation/Q-Growth Targeting	0.0032 (0.0006)

B. Learning and Quasi-Rationality

In our model, the central bank learns the underlying process for inflation in the pure inflation-target regime and the underlying processes for inflation and growth in the inflation-growth target regime. The learning takes place by updating recursively the least-squares estimates of a vector autoregressive model.

Marcet and Nicolini (1997) raise the issue of reasonable rationality requirements in their discussion of recurrent hyperinflation and learning behavior. In our model, a similar issue arises. Given that the only shocks in the model are recurring terms of trade shocks, with no abrupt, unexpected structural changes taking place, the learning behavior of the central bank should not depart, for too long, from the rational expectations paths. The central bank, after a certain period of time, should develop forecasts which converge to the true inflation and growth paths of the economy, unless we wish to make some special assumption about monetary authority behavior.

Marcet and Nicolini discuss the concepts of "asymptotic rationality", "epsilon-delta rationality" and "internal consistency", as criteria for "boundedly rational" solutions. They draw attention to the work of Bray and Savin (1986). These authors examine whether the learning model rejects serially uncorrelated prediction errors between the learning model and the rational expectations solution, with the use of the Durbin-Watson statistic. Marcet and Nicolini point out that the Bray-Savin method carries the flavor of "epsilon-delta" rationality in the sense that it requires that the learning schemes be consistent "even along the transition" [Marcet and Nicolini (1997): p.16, footnote 22].

Following Bray and Savin, we use the Durbin-Watson statistic to examine whether the learning behavior is "boundedly rational". Table V presents the Durbin-Watson statistics for the inflation and Q-growth forecast errors of the central bank, under both policy regimes - the Taylor rule and the Linear Quadratic setup. In all of the cases, we see that the learning behavior does not violate near rationality. TOO GOOD???

Table V: Durbin-Watson Statistics for Forecast Errors Percentage in Lower and Upper Critical Regions

Policy Regime	Inflation	Q-Growth
Tayor Rule Framework		
Inflation Targeting	0/0	—
Inflation/ Q-Growth Targeting	0/0	0/0
Linear Quadratic Framework		
Inflation Targeting	0/0	—
Inflation/ Q-Growth Targeting	0/0	0/0

C. Comparative Results

This section summarizes the results for 1000 alternate realizations of the terms-of-trade shocks (each realization contains 250 observations), for the Taylor rule and the State-Contingent Taylor rules for conducting monetary policy. We evaluated the mean and standard deviation of the coefficients of variations of the 1000 samples for consumption, inflation, Q-exports, X-investment, the exchange rate and the current account under the two policy regimes.[4] The only clear simulation results across policy frameworks when we change from an inflation only to an inflation Q-growth regime are the fall in the coefficient of variation for consumption and the increase for the exchange rate. The results for the other variables are mixed. For example, the coefficient of variation for inflation fell when Q-growth became a target under standard Taylor rules, but it was about the same under the state-contingent scheme.

However, the welfare implications are quite clear. We examine the welfare differences for different comparisons of the 4 possible regimes considered in the paper. These results show that the 3 alternative frameworks - $T(\pi,\eta), S(\pi), S(\pi,\eta)$ - do not always yield better welfare outcomes relative to the simpliest framework $T(\pi)$. In contrast, $S(\pi,\eta)$ unambiguosly generates better welfare outcomes compared to $S(\pi)$ and $T(\pi,\eta)$.

[4] We do not benchmark the welfare effects with respect to the steady state welfare, since the terms of trade realizations may lead to welfare outcomes either greater or less than the steady state welfare.