Thai Monetary Policy Under the Inflation Targeting Regime

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Research

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Abstract

This paper explores the macroeconomic effects of inflation targeting in Thailand. Furthermore, this study uses a nonlinear new Keynesian model under the dynamic stochastic general equilibrium framework with price indexation to analyze the monetary policy under inflation targeting in Thailand. The model is estimated using a Bayesian statistic for the Thai economy. It shows that inflation is more stabilized and inflation persistence has fallen after adopting inflation targeting. The paper also indicates that the Bank of Thailand is more responsive to the deviation of inflation from its target using inflation targeting. The key monetary mechanism exists through changes in the real interest rate which affect aggregate demand. It is worth noting that the larger the inflation targeting rate is, the lower the steady state output from its steady state level given no trend inflation.

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1. Introduction

A nominal anchor is widely agreeing to be a way to achieve the primary objectives of monetary policy which are to maintain low and stable inflation and ultimately to stabilize output around potential. Establishing a credible nominal anchor delivers price stability because it attempts to pin down inflation expectations. Since early 1990 inflation targeting has been adopted by an increasing number of countries, including Thailand in 2000. The rational for this rising adoption is that inflation targeting provides conditions for a credible monetary policy. It creates a condition for a credible medium term anchor for inflation expectations. More importantly, inflation targeting results in independent monetary policy and by implication flexibly responds to short run shocks and keeps output at potential. As Mishkin (1999) argued inflation targeting has a key advantage that it is readily understood by the public and enables monetary policy to respond to shocks to domestic economy.

The attempt of economists to investigate interactions between the real economic performance at the aggregate level and monetary policy gives rise to a framework for monetary policy analysis. Gali (2008) suggested that it is commonly observed that the operation of monetary policy has an effective impact on real economic activities. The decisions of households and firms to consume and invest are inevitably influenced by the effects of monetary policy such as changes in interest rates, leading to changes in income, inflation, employment and growth. The monetary policy is pivotal and eventually transmitted throughout the economy. Under the inflation targeting regime that has been operated in Thailand for nearly two decades, the critical question then arises as to what extend we could evaluate Thai monetary policy.

This paper employs the new Keynesian theory to assess Thai monetary policy. The new Keynesian approach builds on a DSGE framework based on the underlying behavior of optimizing economic agents, combined with some form of price rigidity. This paper attempts to use the Bayesian statistic to estimate the DSGE model parameters for the Thai economy. It eventually employs the new Keynesian theory with specific reference to Thailand to assess the effectiveness of Thai monetary policy.

The purpose of this paper is to answer the following four questions. First, what are the effects of inflation targeting on Thai macroeconomic performance? Second, under inflation targeting regime what has happened to the monetary policy rule and how does the monetary policy rule actually have its transmission effect on inflation and interest rate and other macroeconomic variables? Third, given other exogenous shocks, what has happened to the Thai economy? Lastly, what would happen to the Thai economy if the Bank of Thailand decides to adjust its inflation target.

This paper is structured as follows. Section 2 reviews the monetary policy framework in Thailand. Section 3 describes the effects of inflation targeting on Thai macroeconomic performance. Section 4 introduces the nonlinear new Keynesian model with price indexation and price dispersion. Section 5 discusses the rational of the Bayesian estimation in a DSGE model. Section 6 conducts an empirical analysis based on zero inflation at the steady state, describing transmission mechanisms and impulse responses of monetary policy rules and exogenous shocks. Section 7 mentions how changes in inflation targeting influence the Thai economy. Section 8 discusses policy implications. Section 9 provides conclusions.

2. Monetary policy framework in Thailand

Targeting the exchange rate was the Thai monetary policy strategy from November 1984 to June 1997. The fixed exchange rate regime in Thailand involved fixing the baht to the U.S. dollar to support long term economic growth. Nonetheless, in the early 1990s the Thai financial market was liberalized and opened to the foreign capital market, leading to a lending boom, loan losses and banks' balance sheets deteriorated. The Thai baht had been overvalued for several years before 1997 due to a large current account deficit. The floating exchange rate system was then adopted on June 1997 and Thailand was under the IMF program. The monetary policy strategy after the adoption of a floating exchange rate was a monetary target by which Bank of Thailand targeted domestic money supply to control the fluctuation of interest rates and to stabilize prices and to lead to sustainable growth eventually. Under monetary targeting, a strong relationship between the money aggregate and goal variability such as inflation is necessary in achieving price stabilization. However, that relationship became inconsistent over time.

Therefore, the Bank of Thailand, after the IMF exit, decided to switch its monetary policy to a flexible inflation targeting regime in May 2000. The Bank of Thailand then adopted the policy rate as an operational tool in maintaining the target rate of inflation. The primary goals are to ensure sustainable growth and to maintain price stability. The Bank of Thailand anticipated that the inflation targeting regime would rebuild confidence and its credibility. The core inflation targeting was the Thai monetary anchor after May 2000. The core inflation excludes fresh food and energy prices which are highly volatile in the short run. The core inflation targeting results in low volatility of the target measure and emphasizes inflationary pressures coming from the demand side. Movement in overall prices can also be described by changes in core inflation. Although the headline inflation could deviate from the core in the short run, they move closely in the long run.

The Bank of Thailand adopted the target range for quarterly average core inflation from 0 to 3.5 percent from May 2000 to August 2009. The reason was that the ceiling of 3.5 percent was close to headline inflation of Thailand's main trading partners and competitors. The inflation targeting during this period therefore focused on export competitiveness with a sufficiently wide target range for the monetary policy to deal with any temporary shocks. After August 2009 the Bank of Thailand set a narrower range of inflation targeting from 0.5 to 3.0 percent. To reduce the chance of deflation , the lower bound was adjusted upward. The objectives of the low and narrow range were to build up confidence of consumers and businesses and ultimately to support sustainable growth.

However, the new target was set for an annual average of headline inflation at 2.5 percent with a tolerance band of ±1.5 percent in 2015. The rationales behind this new target are firstly the core inflation compared to the past failed to reflect the headline inflation for a much longer time period. Secondly, the Bank of Thailand wanted to improve its communication to the public on monetary policy decisions. The headline inflation reflected changes in the cost of living because it accounts for changes in prices of all goods and services in the CPI basket. Cost of living was crucial for consumption and the saving decisions by households and for investment and price setting by firms. The public was able to recognize what composed the cost of living under headline inflation targeting. The point target then enhances monetary policy effectiveness in anchoring long term inflation expectations. At the same time, the range band is wide enough to provide a cushion for temporary shocks.

Recently, at the end of December 2019, the Bank of Thailand decided to set the inflation range target of 1.0 – 3.0 percent for the medium-term horizon and for the year 2020.

This range target adoption is to support the potential growth and to reflect the changing inflation dynamics from technological progress and the transition into an aging society.

3. Thai macroeconomic effects of inflation targeting

One critical issue is whether the adoption of an inflation targeting framework affects Thai macroeconomic performance. This section attempts to survey Thai facts by investigating changes in Thai inflation, growth and interest rates prior and after the adoption of the inflation targeting regime. Figure 1 illustrates Thai inflation during the inflation targeting regime.

Corbo et al. (2001) argue that managing inflation to hit the target is not a proper way to measure the success of inflation targeting. The primary responsibility of the inflation targeting framework is to bring down the level of inflation to an appropriate level for longer term price stability. Schaechter et al., (2000) argue that a central bank is able to maintain its credibility with temporary deviations from the target.

Inflation targeting in Thailand started from 2000 and has proved largely successful in bringing down inflation. Table 1 shows the average level of inflation during monetary and inflation targeting. The table also reports average inflation using three different types of inflation targeting for comparison. Inflation went from 3.8 percent on average prior to adoption to approximately 2.1 percent after inflation targeting. Table 1 also compares inflation in different types of inflation targeting. Inflation went from 2.6 percent under core inflation targeting with a wide range to 2.5 percent under core inflation targeting within a narrow range. After the adoption of headline inflation targeting, the inflation level has been brought down significantly to 0.3 percent on average. Pétursson (2005) conclude from 21 inflation targeting countries that inflation targeting leads on average to a 2.5 percent to more than 3 percent fall in inflation.

One important question arises about how inflation targeting contributes to stabilizing inflation or reducing inflation fluctuations. It is obvious from Table 1 that for Thailand the volatility of inflation has been reduced after inflation targeting. The fluctuations went from 4.4 prior to adoption to 1.9 after inflation targeting. During the inflation targeting era, it is also clear that inflation volatilities have decreased. The fluctuation in headline inflation targeting is at 0.8. These results are consistent with findings in Mishkin (2003) and Neumann and von Hagen (2002) which argue that inflation targeting stabilizes inflation.

It is interesting to see how inflation targeting affects the inflation persistence. The univariate AR(2) model in line with Pétursson (2005) is used to find how inflation targeting changes inflation persistence in Thailand. The parameter θ is a constant term, π_t is the inflation at time t, π_{t-1} is the inflation at time $t-1$, π_{t-2} is the inflation at $t-2$. β_1, β_2 and ϑ are the coefficient. The variable IT_t is a dummy for after the adoption of inflation targeting $IT_t = 1$. Falling average inflation is described by the second order polynomial trend, $P(t)$ where $P(t) = t^2$ and ε_t is the error term at t.

$$\pi_t = \theta + \beta_1\pi_{t-1} + \beta_2\pi_{t-2} + \vartheta IT_t\pi_{t-1} + P(t) + \varepsilon_t \qquad [1]$$

Given the structure of the model, the persistency of inflation before targeting is explained by $\beta_1 + \beta_2$ and by $\beta_1 + \beta_2 + \vartheta$ after targeting.[2] The inflation persistence has reduced if ϑ

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[2] It is necessary to have enough data to estimate a reliable persistence. Thai data is divided only into two periods before and after targeting. Quarterly data from 1981q1 to 2000q1is for before targeting and from 2000q2 to 2019q1 for after targeting. The coefficients $\beta_1 = 1.307$, $\beta_2 = -0.473$ and $\vartheta = -0.123$ are all statistically significant at the 1 percent level. For a group of inflation targeting countries, inflation targeting has reduced inflation persistence (See Pétursson (2005)).

is statistically negative. As noted by Kuttner and Posen (1999), because inflation targeting is a monetary policy anchor to combat an increase in inflation, inflation should exhibit less persistence given a temporary price shock. Therefore, the issue on inflation persistence involves the credibility of monetary policy. The credibility of monetary policy has increased with the reduction in inflation persistence. In Thailand, table 1 documents that inflation persistence has fallen from 0.83 to 0.71 after adopting inflation targeting. The result indicates that the credibility of Thai monetary policy has been improved after adopting inflation targeting. The inflation targeting is likely to have a positive effect to the behavior of expected inflation. The medium-term inflation expectation over the pre-inflation targeting period was higher than that of the inflation targeting period. Buddhari and Chensavasdijai (2003) points that inflation expectations appear to become more firmly anchored to lower inflation following the change in the regime in 2000. The inflation targeting framework has convinced businesses and consumers that the Bank of Thailand will successfully resist any persistent movements of inflation from the target band.

Regarding the effectiveness of inflation targeting on the real economy and business cycle fluctuation, one may doubt that this anchor is sufficiently flexible and could obstruct an economic expansion as in Firedman and Kuttner (1996). However, Mishkin (1999) points out that inflation targeting will eventually benefit growth and provide a favorable growth record for many inflation targeting countries after the adoption. Truman (2003) and Ball and Sheridan (2003) also note that the inflation targeting regime has no harm on growth. As reported in Table 1, average real GDP growth in Thailand during the monetary targeting was approximately 2.5 percent but after the adoption of inflation targeting it clearly increased to 3.9 percent. These results suggest that the growth record of Thailand under inflation targeting was favorable compared to monetary targeting. Comparing results between the core and headline inflation periods, growth declined slightly under the headline inflation targeting. Output growth volatility measured by the output growth standard deviation has generally declined over time. The fluctuations of Thai output growth were 5.6 before and reduced to 3.1 after adoption. Table 1 shows that the headline inflation targeting regime provides the lower output growth variability at 0.6 comparing to core inflation regimes at 3.7 on average. Given the Thai experience, the inflation targeting regime in Thailand has not generally damaged output growth and at the same time has been flexible enough for monetary policy to curb temporary shocks in the variation in output.

Table 1 compares the average nominal interest rate before and after inflation targeting. Average inflation and nominal interest rates in Thailand have obviously fallen over time. These results are consistent with the relationship between inflation and nominal interest rates. Nominal interest rates consist of inflation expectations and the inflation risk premium which should be lower given a credible inflation targeting. Nominal interest rates in Thailand went from 6.8 percent before adoption to 2.2 percent after inflation targeting. Comparing between the core and the narrow range core inflation targets, the narrower range has a lower nominal interest rate. The headline inflation targeting results in the lowest level of nominal interest rates at 1.5 percent. These results suggest that inflation targeting has improved public understanding and increased the credibility of Thai monetary policy.

Table 1 also indicates that fluctuations in the Thai short run real interest rate will significantly decrease with inflation targeting from 4.1 prior to adoption to 1.6 after inflation targeting. Inflation targeting contributed to interest rate smoothing. Comparing to core inflation targeting, headline inflation targeting results in the lowest variability of short run real interest rates at 0.9 standard deviation. These results suggest that monetary policy is in fact more flexible under an inflation targeting framework. The flexibility of monetary policy stabilizes the real interest rate, by implication leading to the stability of real economic activity.

After adopting the inflation range target of 1.0-3.0 percent in December 2019, an outbreak of the Covid-19 started and spread around the world. The economic impact of the virus has severely been affected the Thai economy due to Thailand's openness to trade and as a tourism hub. The Bank of Thailand cut its policy rate several times from 1.25 percent in January to 0.5 percent in July 2020. The first seven months of 2020, the nominal interest rate on average falls to 0.87 percent and the average inflation during this period is -1.1 percent.

4. The New Keynesian Model

The phenomenon of economic fluctuations and money non-neutrality are believed by Keynesian proponents to happen because of imperfect competitiveness. Thus, the new Keynesian theory was developed based on the structure of the classical theory by combining the crucial assumptions of monopolistic competition and nominal rigidities. The model is composed of a single final good and a continuum of intermediate goods. Dixit and Stiglitz (1977) introduced monopolistic competition by which firms produce differentiated goods and have some market power to set the price of the goods they produce. Calvo (1983b) formulated a form of staggered pricing to capture the nominal rigidity. The non-linear new Keynesian model is built for Thai monetary policy analysis during the inflation targeting regime.

4.1 Households

4.1.1 Household cost minimization problem

The economy is populated by a representative household. Firstly, the household would like to consume a final consumption good C_t, at the lowest cost. Households choose an optimal combination of the intermediate goods that minimize the cost of achieving this level of the final good. Following Dixit and Stiglitz (1977), the consumption index is given by:

$$C_t = \left(\int_0^1 C_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{\zeta}{\zeta-1}} \qquad [2]$$

The monopolistically competitive firms produce intermediate goods for consumption. Assume the existence of a continuum of firms indexed by the subscript i, where i is distributed in the unit interval, $i \in [0,1]$. Therefore, a continuum of intermediate goods is produced. Firm i produces good $C_t(i)$ and its price is $P_t(i)$. ζ is the elasticity of substitution.

The household seeks to minimize its expenditure $\int_0^1 P_t(i)\, C_t(i) di$ subject to a basket of goods given by [2]. This results in the aggregate price index P_t and a consumption demand equation of each differentiated good i:

$$P_t = \left(\int_0^1 P_t(i)^{1-\zeta} d(i) \right)^{\frac{1}{1-\zeta}} \qquad [3]$$

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\zeta} C_t \qquad [4]$$

4.1.2 Household utility maximization problem

Secondly, given the cost of achieving any given level of C_t from [2], households optimally choose consumption good C_t and labor N_t to maximize their expected utility with respect to their period budget constraint. The preferences follow an external habit formation utility function as below[3]:

$$U(C_t, L_t) = \frac{\left((C_t - \chi C_{t-1})^{(1-\varrho)}(1-N_t)^{\varrho}\right)^{1-\sigma} - 1}{1-\sigma} \quad [5]$$

χ is a coefficient of persistence in habits. $\varrho \in (0,1)$ is the consumption and labor share and σ stands for the risk aversion coefficient while its inverse is the intertemporal elasticity of substitution. The proportions of time for leisure and work are L_t and N_t respectively. Thus, $L_t + N_t = 1$. The budget constraint is given by:

$$B_t = R_{t-1}B_{t-1} + r_t^k K_{t-1} + W_t N_t - C_t - I_t - T_t \quad [6]$$

where B_t is the stock of financial assets at the end of period t, R_t is the gross real interest rate paid on assets held at the beginning of period t to pay out interest in period $t+1$, r_t^k is the rental rate, W_t is the real wage rate and, I_t is investment and T_t are lump-sum taxes. The law of motion of capital is governed over time by:

$$K_t = (1-\delta)K_{t-1} + (1 - \phi(\frac{I_t}{I_{t-1}}))I_t \quad [7]$$

Capital formation incorporates capital adjustment costs denoted by the function ϕ.[4] The parameter ϕ refers to the existence of costs in terms of investment changes between periods

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[3] Assume that $U_C(C_t, L_t) > 0, U_L(C_t, L_t) > 0, U_{CC}(C_t, L_t) < 0$ and $U_{LL}(C_t, L_t) < 0$.

[4] Where $\phi(I_t/I_{t-1}) = \phi_X(I_t/I_{t-1} - 1)$ with $\phi(1) = \phi'(1) = 0$ and $\phi''(1) \geq 0$ implying that there is cost associated with changing the level of investment, that is cost is zero at steady state, and that this cost is increasing in the change in investment.

as in Christiano, Eichenbaum and Evans (2005). With the adjustment cost, the optimal capital stock and investment decision are now separated. All variables are expressed in real terms relative to the price of output.

The household's utility maximization leads to the optimal intertemporal allocation equations as below:

$$U_{C,t} = R_t \mathrm{E}_t[\beta U_{C,t+1}] \qquad [8]$$

$$\frac{U_{L,t}}{U_{C,t}} = W_t \qquad [9]$$

$$q_t = E_t \beta \frac{\lambda_{t+1}}{\lambda_t} (q_{t+1}(1-\delta) + r_{t+1}^K) \qquad [10]$$

$$1 = q_t - q_t \phi\left(\frac{I_t}{I_{t-1}}\right) - q_t \frac{I_t}{I_{t-1}} \phi'\left(\frac{I_t}{I_{t-1}}\right) + E_t \beta \frac{\lambda_{t+1}}{\lambda_t} [q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 \phi'(\frac{I_{t+1}}{I_t})] \qquad [11]$$

where $U_{C,t}$ is the marginal utility of consumption at t. [8] is the Euler consumption equation describing the intertemporal optimal consumption choices of the household between the current and the future period. However, R_t is the ex post real interest rate and is related with the ex ante gross nominal interest rate $R_{n,t}$ by the Fischer equation, $R_t = R_{n,t-1}/\pi_t$ where π_t is the inflation at t. The Euler equation [8] then take the form 1= $\mathrm{E}_t[R_{t+1}\Lambda_{t,t+1}]$ where $\Lambda_{t,t+1}$ is the real stochastic discount factor and is equal to $\beta \frac{U_{C,t+1}}{U_{C,t}}$. It shows that the expected discounted return on a riskless bond is equal to 1. The marginal rate of substitution between the consumption equation and leisure is equal to real wage as in [9]. Q_t is the Tobin's Q representing the market value of the total installed capital over the replacement cost of that capital. q_t is the Tobin's Q marginal ratio and is defined as $q_t = Q_t/\lambda_t$. [10] indicates that the value of current installed capital depends on its future expected value, taking into account the depreciation rate and the expected rate of return. [10] could be rewritten as $1 = \mathrm{E}_t[R^K_{t+1}\Lambda_{t,t+1}]$ where $R^K_{t+1} = (r^K_{t+1} + (1-\delta)q_{t+1})/q_t$ and R^K_t is the gross return on captial. It indicates that the expected discounted return on capital over the period t to $t+1$ is equal to 1. Therefore, the model equates the expected discounted return on a riskless bond with that of capital. The first order condition for investment is expressed in [11].

4.2 Firms

The production sectors are divided into two parts, a final good and intermediate good producers.

4.2.1 Final good sector

The final good is produced by a firm that aggregates intermediate goods into a single composite good using the following Dixit and Stiglitz aggregator:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\zeta-1}{\zeta}} d(i)\right)^{\frac{\zeta}{\zeta-1}} \qquad [12]$$

The firm takes as given the price of intermediate good $P(i)$ and the price of the composite final good P_t and then maximizes profits given a production function as in equation [12]. This results is the demand of intermediate good i:

$$Y_t(i) = \left(\frac{Y_t(i)}{P_t}\right)^{-\zeta} Y_t \qquad [13]$$

4.2.2 Intermediate goods sector

The intermediate goods are produced by a continuum of monopolistically competitive firms. Each intermediate good is produced by only one firm using labor and capital based on the following Cobb-Douglas production function:

$$Y_t(i) = A_t N_t^{\alpha}(i) K_{t-1}^{1-\alpha}(i) \qquad [14]$$

where A_t is the productivity process and K_t is end of period t capital stock. Each firm acknowledges the demand curve it faces or $Y_t(i) = C_t(i)$. In this stage, firms take as given the prices of production function factors, the nominal wage W_t and nominal capital rental rate r_t^K and determine the amount of labor and capital to be hired to minimize costs. The firm's cost minimization problem leads to the following conditions:

$$W_t = MC_t \alpha \frac{Y_t(i)}{N_t(i)} \qquad [15]$$

$$r_t^K = MC_t (1-\alpha) \frac{Y_t(i)}{K_{t-1}(i)} \qquad [16]$$

where MC_t represents a nominal marginal cost. [15] indicates that labor demand is the product of the nominal marginal cost and the marginal product of labor. Labor demand is equal to wage. The product of the nominal marginal cost and the marginal product of capital is capital demand. Capital demand is equal to rental rate, r_t^K as in [16].

Using [15] and [16], the cost function and the instantaneous real profit function of firm i can be written respectively as:

$$TC_t(i) = W_t N_t(i) + r_t^K K_{t-1}(i) = MC_t Y_t(i)$$

$$\pi_t(i) = \frac{P_t(i)}{P_t} Y_t(i) - \varphi_t Y_t(i) \qquad [17]$$

where $\varphi_t = MC_t/P_t$ is a real marginal cost. Having described the firm profit, the model then adds the feature of price stickiness by considering the case of a staggered price setting established by Calvo (1983). The Calvo model assumes that some firms can adjust prices but other firms cannot. In any period, the probability that each firm will not adjust its price is ω and the probability that each firm will change its price is $1 - \omega$. Given that, the expected time a price remains unchanged is $1/1 - \omega$ then the key parameter ω measures the degree of price rigidity. All firms adjusting in period t face the same problem, so all adjusting firms will set the same price. Let P_t^* be the optimal price chosen by all firms adjusting at time t. The aggregate of all prices in the economy will be:

$$P_t = (\omega \int_0^1 P_{t-1}^{1-\zeta}\, dt + (1-\omega)(P_t^*)^{1-\zeta})^{\frac{1}{1-\zeta}} \qquad [18]$$

we can rewrite the aggregate price level as:

$$1 = \omega\Big(\frac{P_t}{P_{t-1}}\Big)^{\zeta-1} + (1-\omega)\,\Big(\frac{P_t^*}{P_t}\Big)^{1-\zeta} \qquad [19]$$

Consider a firm, i, that has a chance $1 - \omega$ to reset its price at t. The firm's decision problem is to choose $P_t^*(i)$ to maximize its discounted real profits as below:

$$\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left(\frac{P_t^*(i)}{P_{t+k}} Y_{t+k}(i) - \varphi_{t+k} Y_{t+k}(i)\right) \qquad [20]$$

Using the demand curve for good i, the real profit is given by:

$$\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left(\left(\frac{P_t^*(i)}{P_{t+k}}\right)^{1-\zeta} - \varphi_{t+k} \left(\frac{P_t^*(i)}{P_{t+k}}\right)^{-\zeta}\right) Y_{t+k} \qquad [21]$$

where ω^k represents the fraction of firms that do not adjust price. All firms adjusting in period t face the same problem, so all adjusting firms will set the same price. Let P_t^* be the optimal price chosen by all firms adjusting at time t. The profit maximization results in the first order condition for optimal choice of P_t^* as:

$$\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \, \Lambda_{t,t+k} \left((1-\zeta) \left(\frac{P_t^*}{P_{t+k}} \right) + \zeta \varphi_{t+k} \right) \left(\frac{1}{P_t^*} \right) \left(\frac{P_t^*}{P_{t+k}} \right)^{-\zeta} Y_{t+k} = 0 \qquad [22]$$

Since all firms face the same marginal cost, the i index is dropped. The first order condition can be rearranged further resulting in optimal pricing behavior of intermediate goods:

$$\frac{P_t^*}{P_t} = \frac{\zeta}{(\zeta-1)} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} \left(\frac{P_{t+k}}{P_t} \right)^{\zeta}}{\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \left(\frac{P_{t+k}}{P_t} \right)^{\zeta-1}} \qquad [23]$$

where $\zeta/(\zeta-1)$ represents the mark up, describing the difference between the price and the marginal cost. [23] indicates that the firm will mark up the price over its current marginal cost if the degree of price stickiness or $\omega = 0$, which is the condition of the flexible price model. In the case of the sticky price model, nonetheless firm will mark up the price over the weighted average of flow of future marginal costs. When setting the price, the higher the value of ω, the further the distance in the future of marginal costs that the firm must take into account. Price dynamics with the introduction of markup shock is shown in the appendix.

4.2.3 The price indexation

The price indexation is introduced to explain the inflation persistence as in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007). For firms that do not reoptimize with probability ω, their prices are partially indexed to last period's aggregate inflation:

$$P_t(m) = \pi_{t-1}^{\gamma_p} P_{t-1}(m) \quad [24]$$

where $\pi_{t-1} = P_{t-1}/P_{t-2}$ and $\gamma_p \in [0,1]$ is the magnitude of the indexation factor. The aggregate price index [18] is then determined by the optimal price setting and no reoptimizing price setting:

$$P_t = (\omega \int_0^1 (\pi_{t-1}^{\gamma_p} P_{t-1}(m))^{1-\zeta}\, dm + (1-\omega)(P_t^*)^{1-\zeta})^{\frac{1}{1-\zeta}} \quad [25]$$

Rearranging further yields the expression that relates optimal price, current inflation and past inflation:

$$1 = \omega(\pi_{t-1}^{-\gamma_p} \pi_t)^{(\zeta-1)} + (1-\omega)\,(\frac{P_t^*}{P_t})^{1-\zeta} \quad [26]$$

A firm setting its price in period t and may not reset its price in future periods, its future demand is determined by the optimally chosen price takes into account future inflation. Recursively solving [24] and putting the results in the demand function [13] yields the firm's future demand:

$$Y_{t+k}(m) = \left(\frac{P_t^*(m)}{P_{t+k}}\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\gamma_p}\right)^{-\zeta} \; Y_{t+k} \quad [27]$$

The price behavior with no reoptimization is given by:

$$P_t^0(m) = P_t^*(m)\left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\gamma_p} \quad [28]$$

The discounted real profit [20] can be rewritten as:

$$\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left(\frac{P_t^0(m)}{P_{t+k}} Y_{t+k}(m) - \varphi_{t+k} Y_{t+k}(m) \right) \qquad [29]$$

The optimal price setting under the price indexation is that a firm chooses its price to maximize its discounted real profits [29] using [27] and [28] for the duration that it cannot reoptimize its price. The first order condition for the above profit maximization is:

$$\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left((1-\zeta) \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\gamma_p} + \zeta \left(\frac{P_t^*(m)}{P_{t+k}}\right)^{-1} \varphi_{t+k} \right) \left(\frac{1}{P_{t+k}}\right) \left(\frac{P_t^*(m)}{P_{t+k}}\right)^{-\zeta} \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{-\gamma_p \zeta} Y_{t+k} = 0 \qquad [30]$$

The first order condition can be rearranged further yielding the optimal pricing behavior:

$$\frac{P_t^*}{P_t} = \frac{\zeta}{(\zeta-1)} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\zeta} \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{-\gamma_p \zeta}}{\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\zeta-1} \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{-\gamma_p(\zeta-1)}} \qquad [31]$$

It is necessary to transform the first order condition for pricing to recursive definitions in order to set up the model in non-linear form. With MS_t as a markup shock and $\widehat{\Pi}_t = \pi_t \pi_{t-1}^{-\gamma_p}$, price dynamics evolve according to:

$$\frac{P_t^*}{P_t} = \frac{M_t}{MM_t} \qquad [32]$$

$$M_t = \left(\frac{1}{1-1/\zeta}\right) Y_t \varphi_t MS_t + \omega E_t\left[\Lambda_{t,t+1} \widehat{\Pi}_{t+1}^{\zeta} M_{t+1}\right] \qquad [33]$$

$$MM_t = Y_t + \omega E_t\left[\Lambda_{t,t+1} \widehat{\Pi}_{t+1}^{\zeta-1} MM_{t+1}\right] \qquad [34]$$

Another way of indexing assumes that prices are indexed to a weighted average of last period inflation and trend inflation. Denote the two weights by γ_P and $\bar{\gamma}_P$, the dynamic equations [33] and [34] can be replaced $\widehat{\Pi}_t = \pi_t / (\pi_{t-1}^{\gamma_p} \pi^{*(1-\bar{\gamma}_p)})$ in which π^* is the inflation target. Smets and Wouters (2007) assumed that $\gamma_P = \bar{\gamma}_P$ so that the effect of trend inflation is eliminated.

4.3 Output equilibrium

The model is completed with a market clearing condition. However, the aggregate production function is not explicitly presented in the new Keynesian model. Distribution of inputs among the various intermediate good firms influences the aggregate output, Y_t. Christiano, Trabandt and Walentin (2010) assert that under the Calvo staggering price assumption, $P(i)$ differs across i resulting in unequally allocated resources across intermediate good producers. Therefore price dispersion occurs in the Keynesian economy and generates an inefficient resource allocation. An unequally distribution of inputs causes the loss of aggregate output. Following Yun (1996), the price dispersion could be characterized by finding the relation between the aggregate output and aggregate factor inputs. Define $\hat{Y}_t$ as the integral of gross output across intermediate good firms:

$$\hat{Y}_t = \int_0^1 Y_t(i)\, di = \int_0^1 \left(A_t N_t(i)\right)^{\alpha} K_{t-1}(i)^{1-\alpha} di = (A_t N_t)^{\alpha} K_{t-1}^{1-\alpha} \qquad [35]$$

Using the demand of intermediate good i [13]:

$$\hat{Y}_t = \left(\frac{P_t^*}{P_t}\right)^{-\zeta} Y_t \qquad [36]$$

where $P_t^* = \left[\int_0^1 P_t(i)^{-\zeta} di\right]^{-1/\zeta}$ and $\left(\frac{P_t^*}{P_t}\right)^{-\zeta}$ measures output loss due to price dispersion as in Yun (1996). Therefore the equilibrium relation between aggregate demand and aggregate factor inputs is given by:

$$C_t + I_t + G_t = \left(\frac{P_t^*}{P_t}\right)^{\zeta} \hat{Y}_t = \left(\frac{P_t^*}{P_t}\right)^{\zeta} (A_t N_t)^{\alpha} K_{t-1}^{1-\alpha} \quad [37]$$

Notice from [37] that price stickiness causes an inefficiency through the price dispersion mechanism. Note that $\Delta_t = 1/(P_t^*/P_t)^{\zeta}$.

4.4 The effects of monetary policy

Taylor (1998) introduces monetary policy through control of the nominal interest rate. Following the Taylor rule, a central bank should adjust its interest rate policy instrument for developments in inflation and output. The Taylor rule in log form can be written as:

$$log\left(\frac{R_{n,t}}{R_n}\right) = \rho_r log\left(\frac{R_{n,t-1}}{R_n}\right) + (1-\rho_r)\alpha_\pi log\left(\frac{\pi_t}{\pi}\right) + (1-\rho_r)\alpha_y log\left(\frac{Y_t}{Y}\right) + \epsilon_{M,t} \quad [38]$$

where $0 < \rho_r < 1$. It measures how much nominal interest rate last period influences nominal interest rate in the current period, or in other words, it explain the interest rate inertia. $\alpha_\pi > 0$ and it captures how much the interest rate set by the central bank responds to the deviation of inflation from its target or its steady state. Similarly α_y captures how much the interest rate set by the central bank responds to the output gap.

4.5 The shocking process specification

Suppose the model economy experiences an unanticipated variation in total productivity, government spending and mark-up shocks. The effects of the aggregate supply and demand shocks can be evaluated through the technology shock and monetary policies. The law of motion for the exogenous shocks are assumed to follow a first-order auto-regression process AR(1) and they can be expressed in log form around the steady state. The exogenous forcing processes to technology, government spending and mark-up shocks are respectively shown below:

$$log\left(\frac{A_t}{A}\right) = \rho_A log\left(\frac{A_{t-1}}{A}\right) + \epsilon_{A,t} \quad [39]$$

$$log\left(\frac{G_t}{G}\right) = \rho_G log\left(\frac{G_{t-1}}{G}\right) + \epsilon_{G,t} \quad [40]$$

$$log\left(\frac{MS_t}{MS}\right) = \rho_{MS} log\left(\frac{MS_{t-1}}{MS}\right) + \epsilon_{MS,t} \quad [41]$$

The parameter ρ measures how persistent each shock is. In other words, how important is that last period shock in determining how large the shock is in this period. The variables ϵ are innovations to each random shock and they are normally distributed and serially uncorrelated.

5. The Bayesian estimation

Before the late 1990s, researchers used optimization methods such as the maximum likelihood estimator, generalized method of moments and indirect inference to estimate the DSGE model. The optimization methods generally depend on the log likelihood function and equilibrium relationships.[5] However, these methods involve restrictions and complexities in estimating the DSGE model parameters. The Bayesian estimation of the DSGE model has become increasingly popular since the late 1990s. Finding the posterior distribution of the DSGE parameters conditional on the sample data by using the DSGE

[5] Some important illustrations of works in these areas. Kydland and Prescott (1982) use a calibration procedure by choosing parameter values that are consistent with a long run historical average. Alrug (1989) and Bencivenga (1992) use maximum likelihood to estimate the DSGE model. Christian and Eichenbaum (1992) advocate the GMM to optimally approximate the equilibrium conditions. Based on the difference between the DSGE model impulse response function and VAR, Rotemberg and Woodford (1997), Eichenbaum and Evan (2005) use the minimum distance estimation method.

model likelihood and the priors on the DSGE parameters is the objective of the Bayesian influence process. The posterior is the density of parameters given existing data. Using the Bayesian rule, the posterior distribution can be computed as:

$$p(\theta|\Upsilon^T, M) = \frac{p(\Upsilon^T|\theta, M)p(\theta|M)}{p(\Upsilon^T|M)} \qquad [43]$$

where $p(.)$ stands for a probability density function and M stands for the DSGE model. Therefore, the $p(\theta|\Upsilon^T, M)$ is the posterior distribution of the parameters conditional on the DSGE model and the information set of an observed macro time series until period T or $\Upsilon^T = \{y_1, y_2, y_3, \ldots, y_T\}$. The term $p(\Upsilon^T|\theta, M)$ is the likelihood density of the DSGE model parameter. The likelihood is the probability of obtaining the data given choices of parameter θ. It reflects information about parameters contained in the data. The likelihood is probability that the model is correct to actually obtain the data for each particular value of θ.

The prior is described by a density function of the form $p(\theta|\mathcal{M})$. The prior represents pre-experimental knowledge of parameter values. It quantifies what is known about the parameters before observing data. The probability of data is $p(\Upsilon^T|M)$. It is the marginal density of the data conditional on the DSGE model. The likelihood and the prior distribution can be combined to form the posterior distribution. The Metropolis Hasting-Markov Chain Montecarlo (MH-MCMC) algorithm simulator is frequently preferred to generate the posterior distribution.

Given that the model parameter values from the previous section are not known for certain, the uncertainty can be described by a probability distribution. The Bayesian method treats the model parameters as random variables. Their uncertainties are explained by probability distributions called prior distributions. The model is then solved and the observed data relevant to the parameters is collected. The data changes the uncertainty which is illustrated by a updated probability distribution called the posterior distribution. Thus, the posterior distribution reveals the information both in the data and the prior distribution.

The observables are the log difference of real GDP, the log difference of the GDP deflator and the Bank of Thailand policy rate. The observables are on a quarterly basis and from 2001Q1 to 2019Q1 which is the period of the inflation targeting regime. All series are seasonally adjusted. The data is from CEIC that is a database system using data aggregated from the IMF and the Bank of Thailand. A few structural parameters are calibrated or kept fixed in accordance with the usual practice in the literature. In the sample period for the Thai economy, the discount factor $\beta = 0.99$, depreciation rate of capital stock $\delta = 0.031$, substitution of elasticity of goods $\zeta = 7$, government spending-output ratio is 0.1504 are used.

The choice of priors for the estimated parameters is usually determined by the theoretical implications of the model and evidence from previous studies. In general, there are four common prior distributions. The priors are drawn from normal, beta, gamma and inverse gamma distribution. The beta distribution restricts priors on the model parameters to the open interval or particularly for the parameters between 0 and 1. The gamma distribution only requires priors that rule out non-negative draws or impose a lower bound. The gamma distribution is clearly for parameters restricted to be positive. The inverse gamma has support on an open interval that excludes zero and is unbounded. It is commonly the distribution for the standard deviation of the shock processes. The normal distribution reveals the extent of the uncertainty that surrounds the steady state value. The prior distributions of the parameters are listed in Table 2.

Table 2 contains the priors for the model, following Smets and Wouters (2007). For the auto regressive parameters, the priors on the exogenous shocks $\epsilon_{A,t}$, $\epsilon_{G,t}$ and $\epsilon_{MS,t}$ are drawn from the inverse gamma distribution. These priors exhibit the uncertainty associated with the exogenous process of the model with lower bounds near zero and larger upper bounds. The persistence parameters rely on the beta distribution. The mean and the standard deviation of the prior show the uncertainty about these model parameters. The shocks indicate a moderate persistence with the mean of ρ_A, ρ_G and ρ_{MS} at 0.5.

The Taylor's rule parameter ρ_r follows the beta distribution with mean 0.75 whereas the Taylor's rule parameters on output α_Y and inflation α_π rely on the normal distribution. The priors on the exogenous policy shocks $\epsilon_{M,t}$ are drawn from the inverse gamma distribution. The degree of price stickiness ω relies on the beta distribution due to the restriction of this distribution on the prior of model parameters to the open unit interval. The labor share in production function α also relies on the beta distribution. The beta distribution is applied on the indexation parameter γ_P. The quarterly steady state inflation rate follows the gamma distribution. The quarterly trend growth rate and nominal interest rate are described by the normal distribution.

The posterior probability distribution of model parameters are the conditional probability that is assigned after relevant data is taken into account. It reveals the relative credibility of the parameter values. The posterior is estimated by the MH-MCMC simulation.[6] Figure 2 illustrates the prior and posterior distributions of model parameters. The figures are reported with the 90 percent highest posterior density interval. Table 3 shows the mean of the posterior distributions comparing with that of prior distribution. The model predicts that the degree of price rigidity is $\omega = 0.1792$ in Thailand. Given that, the expected time a price remains unchanged is 1.22 quarters which comes from $1/(1-\omega)$.

6. The dynamic effects of monetary policy rules and exogenous shocks

Given the estimated parameters from the Bayesian estimation, the model structure enables us to study alternative monetary and fiscal policies and to analyze the economic impact of productivity and mark up disturbances. This section explores the Thai economy's equilibrium responses as percentage deviations about the steady state to four different shocks. The first shock is a 1 percent supply side shock to total factor productivity, $\epsilon_{A,t}$ and the second is a 1 percent demand side shock to government expenditure $\epsilon_{G,t}$. Figures 3 and 4 illustrate the impulse response as a proportional deviation about the steady state to the technology and the government spending shock respectively. The third shock is a 1 percent shock to monetary policy rules, $\epsilon_{M,t}$ and the last shock is a 1 percent mark-up shock, $\epsilon_{MS,t}$. Figure 5 and 6 display the impulse responses as a proportional deviation about the steady state to interest rate shocks and mark-up respectively.

[6] The general idea is to simulate the posterior distribution using the following steps. Firstly, the initial candidate parameter $\theta_{1,0}$ is chosen from the normal distribution and is passed to the Kalman filter to estimate the likelihood $p(\Upsilon^T|\theta_{1,0})$. Secondly, the $\theta_{1,0}$ is updated according to the MH random walk to obtain the purposed parameter or $\theta_{1,1} = \theta_{1,0} + \Im\mu_1$ where $\Im$ is the scale of the jumping distribution in the MH algorithm. By running the Kalman filter the purpose parameter $\theta_{1,1}$ and the likelihood $p(\Upsilon^T|\theta_{1,1})$ is calculated. Thirdly, using the posterior odds to decide which initial or proposed parameter and its associated likelihood is carried forward. These steps are repeated a large number of times thereby smoothing the histogram with an infinitely small width.

Consider a positive technology shock in Figure 3. The impulse responses are dominated by the fact that the productivity shock raises the desirability of production, investment and consumption. In general, the responses of output and employment to a positive technology shock are ambiguous as in Gali (2008). How demand responds to a technological improvement is unclear in the short run. For the Thai economy, output, consumption and investment rise and then fall back as the shock fades away. High productivity is associated with high real interest rate during the impact, then the increase in the supply of capital reduces the real interest rates. Therefore, the discounted sum of future profits rises bringing about a rise in Tobin's Q. The technological improvement leads to an immediate employment decline. The technology improvement is partly accommodated by the central bank which lowers the nominal interest rate. The real wage increases because the labor supply falls and output rises. The rise in output also increases firm's marginal costs driving up prices.

Figure 4 illustrates the results of the government spending shock. Since individuals experience a reduction in income after an increase in government spending, generally, an increase in government spending causes a negative wealth effect to representative agents. The negative wealth effect reduces private individuals' income and in turn individuals respond by cutting their level of consumption and leisure. The labor supply increases and then gradually returns to a steady state level. The real wage declines in response to a significant increase in labor supply. Time paths of consumption and investment depend on the real interest rate. There is an increase in the level of labor supply along with a decline in the capital stock, bringing about a fall in Tobin's Q. Nonetheless, firms respond to an increase in demand by raising output.

Turning to the monetary policy or the interest rate shock, the policy reaction function during the inflation targeting regime in Thailand is estimated by the non-linear New Keynesian model with price indexation and using the Bayesian approach to estimate the model parameters to explore how inflation targeting is connected with the monetary policy rule and how the transmission mechanism effect works in the Thai economy. Two important policy parameters are α_Y and α_π. They indicate how much the central bank allows the policy rate to respond to variation in output and inflation. The model predicts that $\alpha_Y = 0.1566$ and $\alpha_\pi = 1.6105$. However, the lagged interest rate parameter ρ_r is also estimated and its value is high at 0.9691, indicating that during an inflation targeting regime the policy rate persistency is large. As to interest rate rule coefficients, if Thai inflation is lower than its target by 1 percent, the Bank of Thailand reduces its policy rate by 20 basis points.[7] However, if Thai output is lower than its potential level by 1 percent, the Bank of Thailand reduces its policy rate by just only 2 basis points. The larger value of α_π indicates that the Bank of Thailand is more responsive to the deviation of inflation from its target.

The key monetary mechanism exists through changes in the real interest rate which affect consumption and investment. The increase in the real interest rate leads households to attempt to postpone their consumption and motivates firms to cut their investment. As a result, the aggregate demand falls. The rise in the nominal interest rate causes inflation and the output gap to fall immediately. During the inflation targeting regime in Thailand, it is seen that the 1 percent positive policy shock generates an increase in the real rate by 2 percent deviation from its steady state, and decrease in inflation by nearly percent from its steady

[7] The coefficient in front of the deviation of inflation from its target is equal to (1-ρ_r)α_π =0.05. Conversion to an annual rate requires that the coefficient be muliplied by 4, yielding 0.2 or 20 basis points.

state and a decrease in output by approximately by 0.08 percent deviation from its steady state as depicted in figure 5. During the inflation targeting regime, the past historical data shows the negative relationship between the Bank of Thailand's policy rates and lagged inflations. The time lag was slightly more than 1 year. For instance, the policy rates were on the rising trend from 2.5 percent in June 2005 to 5 percent in June 2006 whereas a year later the inflation significantly declined from 6.09 percent in June 2006 to 1.90 percent in June 2007. The policy rates went up from 1.25 percent in June 2010 to 3.50 percent in September 2011 while the inflation rate fell from 4.13 percent in June 2010 to 2.31 percent in June 2013.

As long as the central bank is able to affect the real interest rate through its control of the nominal interest rate, monetary policy can affect real output. Hours worked and real wage fall on the impact. An increase in the interest rate causes the discounted future profit of a firm to decline. Therefore, price of capital and investment falls from the impact.

In the case of cost push or markup shock, figure 6 shows the impulse response to a 1 percent increase in the markup shock. An increase in markup leads to a higher level of profits for companies operating in the economy. Firms raise prices because of a higher markup. A positive markup shock leads to a fall in output, consumption, investment and hours worked for 4 quarters after the impact. The real interest rate reduces on the impact and gradually goes back up. Consumption and investment fall along with output. The shock generates an increase in inflation at the same time reducing in output. The central bank responses by raising the interest rate but the size is relatively small.

7. The inflation targeting, price indexation and the steady state

Ascari (2004) shows that when trend inflation is considered, both steady state and dynamic properties of the model change dramatically. One way to add trend inflation to the model is indexation. Yun (1999) and Jeanne (1998) proposed indexing the prices that cannot be reset to trend inflation while Christiano et at., (2001) introduced indexing to the past inflation. Nonetheless, both of these studies remove the effect of trend inflation in the long run and short run.

The model structure with the price indexation in this study enables us to introduce a trend inflation at the steady state. It is important to determine the value of variables in steady state in order to analyze the effect of inflation targeting to the Thai economy at its long run level. Steady state inflation is equal to the exogenous inflation target, π^* set by the Bank of Thailand. This section investigates how changes in inflation targeting influence the Thai economy in the long run. For non zero inflation in the steady state, the main changes in the New Keynesian features at the steady state are dynamic inflation, marginal cost and price dispersion as given below.

$$\frac{M}{MM} = \left(\frac{1-\omega\pi^{*(\zeta-1)}}{1-\omega}\right)^{\frac{1}{1-\zeta}} \qquad [44]$$

$$MC = \left(\frac{1}{1-\zeta}\right)\frac{M(1-\beta\omega\pi^{*\zeta})}{MM(1-\beta\omega\pi^{*(\zeta-1)})} \qquad [45]$$

$$\Delta = \frac{(1-\omega)^{\frac{1}{1-\zeta}}(1-\omega\pi^{*\zeta-1})^{\frac{-\zeta}{1-\zeta}}}{1-\omega\pi^{*\zeta}} \qquad [46]$$

For zero inflation at the steady state, $\pi^* = 1$, we obtain $\frac{M}{MM} = \Delta = 1$ and $MC = \left(\frac{1}{1-\zeta}\right)$. Nonetheless if $\pi^* > 1$ we obtain that $MC < \left(\frac{1}{1-\zeta}\right)$ and $\Delta > 1$. In other words, the model with trend inflation generates lower output in the long run than that of the model with no trend inflation. Therefore, there is a long run inflation-output trade off in the choice of an inflation targeting rate. Changes in marginal cost and price dispersion lead to changes in output and other macroeconomic variables in the lone run. Over the headline inflation targeting period from 2015q1 to 2019q1 in Thailand, the change in the hours worked is 0.34 and the government spending-output ratio is 0.17.[8] The capital share in the production function is 0.7. Figure 7 plots the steady state marginal cost and price dispersion as a function of inflation targeting. If trend inflation is positive or $\pi^* > 1$ it causes a decrease in marginal cost but an increase in the price dispersion as shown in figure 7.

The marginal cost is equal to the inverse of the price mark up. If $\pi^* > 1$, it is less than $\left(\frac{1}{1-\zeta}\right)$, reflecting that the steady state markup will be higher than it would be if there were no trend inflation. At the steady state, the real wage is equal to the real marginal cost. The lower the marginal cost, the greater the difference between the wage and the marginal product of labor. Price dispersion also creates an inefficient resource allocation, leading to a loss of aggregate output. Therefore, the model predicts a negative relationship between the inflation targeting rate and aggregate output at the steady state. A higher inflation targeting rate should be associated with lower steady state output. The standard new

[8] The hours work at the steady state is estimated by using the average hours in a week is 48 hours (8 hours a day and 6 days a week), divided by total time available 98 hours (14 hours a day and 7 day a week), multiplied by the fraction of population that works is 0.69 (the average labor force divided by the population 15 years and older)

Keynesian model with no trend inflation creates a higher level of long run output relative to the one with trend inflation. The reasonable explanation is that in the model with no trend inflation, inflation in the long run is fully stabilized. Inflation enlarges the effect of price dispersion to aggregate output. Therefore, there is no price dispersion and output is at the highest possible level.

Table 4 and table 5 compare the long run values of the model with trend inflation and that of the model without trend inflation. The model with no tend inflation is the benchmark. Table 4 documents the effect of the inflation targeting rate and the past inflation indexation to the steady state for the Thai economy during headline inflation targeting 2015q1 to 2019q1. The experiment in this section is that the prices are indexed to last period's inflation. Given a price indexation parameter, γ_P, the higher is the inflation targeting rate, the greater the output is below its long run level of no trend inflation. For example, for inflation targeting at 2.5 percent and $\gamma_P = 0.5$, steady state output is lower than its steady state level of no inflation at the steady state by 1.29 percent. Long run investment is consistently lower than its long run level of no inflation at the steady state by 1.98 percent. However, given the new inflation target range is 1-3 percent, if the Bank of Thailand chose its inflation targeting at 2 percent which is the mid-point of the new range, long run output would be higher. The steady state output is lower than its steady state level of no inflation at the steady state by only 0.74 percent. Long run investment is lower than its long run level of no inflation at the long run by 1.12 percent.

Table 4 shows that if $\gamma_P = 0.5$, steady state output is lower than its steady state level at no inflation at the steady state by only 0.37 percent for inflation targeting at 1.5 percent. Long run investment is lower than its long run level at no inflation at the steady state by 0.55

percent. Additionally, given inflation targeting, table 4 shows that the higher is the degree of price indexation, the smaller is the output below its steady state level. The reasonable explanation is that at the steady state past inflation equals the inflation targeting rate and that at a higher degree of price indexation, the lower is the price dispersion at the steady state.

Table 5 shows the effect of the inflation targeting rate and the average inflation indexation on the steady state for Thai economy during headline inflation targeting 2015q1 to 2019q1. The experiment is that the prices are indexed to a weighted average of last period's inflation and trend inflation. If $\bar{\gamma}_P = 1$, the indexation is identical to the case of the past inflation indexation. Given the inflation targeting rate and $\bar{\gamma}_P = 0$, when price indexation parameter γ_P rises, the price dispersion rises and output is further below its steady state level. If $\gamma_P = \bar{\gamma}_P = 0.5$, the indexation is identical to the case of no trend inflation, leading to output at the benchmark. The deviation of the degree of past inflation indexation from 0.5 will have quite a similar impact to output. Given the inflation targeting and the price indexation parameter γ_P, an increase in the indexation parameter $\bar{\gamma}_P$ results in a u-shape in output deviation from its steady state level. In any case, from Table 5, an increase in the inflation targeting rate causes output to be further below its steady state level. Both the past inflation indexation and the average inflation indexation to the steady state yield the same result - that is, the larger the inflation targeting rate is, the lower the steady state output from its steady state level given no trend inflation.

8. Policy implications

The model suggests the routes through which the level of inflation targeting is costly for monetary policy in the long run. In the long run, price dispersion and markup distortion are minimized when the level of the inflation target is low. Ambler (2007) reviews that under the New Keynesian model with inflation targeting, price dispersion is an increasing function of trend inflation and causes long run output to be a decreasing function of inflation targeting rates. There is a negative trade off between the level of inflation target and output in the long run. The model according to this study predicts that in Thailand a lower level of the inflation targeting rate generates a higher output in the long run.

However, Ascari and Ropele (2007) show that in the short run the level of the inflation target alters the relation between inflation and output and in turn influences the dynamics of inflation. In other words, the level of the inflation target affects the slope of the Phillips curve. The output gap is decreasing in the inflation targeting rate. Therefore, a decline in the central bank's inflation targeting rate enhances the relationship between inflation and output gap. The Phillips curve is steeper and monetary policy is more effective.

In the second quarter of 2019, Thailand's economy grew at its slowest rate in nearly five years. According to Thailand's Office of the National Economics and Social Development Council, Thai growth slowed sharply. The first three quarters of 2019, the Thai economy grew only 2.5 percent which was clearly slower than growth in 2018 at 4.1 percent. Thai growth was not only lower than expected but also further below its potential growth. Thai potential growth is estimated at 3.7 percent. Under the condition that the economic activities and the employment rate below their natural levels, the economic growth is slower and the economy enters recession. Over time, wages and prices are falling in response to lower aggregate demand leading to low level of inflation. As we have seen, Thai inflation has continuously been low and below the inflation target for several years since adopting headline inflation targeting. The Thai average inflation for the first eleven months was slightly lower than 1 percent which was the lower bound set by the Bank of Thailand.

Failing to achieve a constant rate of inflation in line with inflation expectations, the Thai economy by implication cannot keep output at its potential level. Thai output has been lower than its potential output after adopting headline inflation targeting. If the Thai economy has persistently been operated below its normal level, this critically is the structural problem. Thailand needs to create skilled workers and Thai firms must exhibit innovation. The Thai educational system should deliver the required human capital. Investment and particularly investment in R&D must increase.

The relatively low level of inflation causes the Thai baht to appreciate in the long run. The Federal Reserve Bank has been able to manage US inflation around its target at 2 percent while Thai inflation has only been around 1 percent. Under purchasing power parity, Thailand inflation has been lower than US inflation for the last six years, resulting in the current situation that the Thai baht has appreciated against the US dollar to the highest level in last six year in October 2019. The low level of economic activity also leads to low inflation and a low expected future inflation. The low expected future inflation causes the real interest rate to rise and in turn lowers investment and output. The world inflation is on a decreasing trend according to the IMF report. Inflation is decreasing because of structural changes such as the expansion of e-commerce, price competitiveness, the low price of oil and technological progress. Beside the low demand in Thailand, these factors in some degrees cause Thai inflation to be low as well.

Therefore, the level of inflation targeting set by the Bank of Thailand should reflect the Thai current economic situation. Lowering the inflation target could describe better Thai actual inflation and result in increased effectiveness of monetary policy. Adjusting the inflation targeting down to the target range of 1.0-3.0 percent should be the appropriate strategy.

9. Conclusion

The variation in monetary policy rules in Thailand over the past twenty years allows for interesting studies of the effects of policy regimes, and has created a fertile ground for economic analysis. This study uses the nonlinear new Keynesian model incorporating price indexation along with the Bayesian approach to analyze Thai monetary policy under inflation targeting regimes.

It is clear for Thailand that volatility and persistency of inflation have been reduced after inflation targeting. The growth record of Thailand under inflation targeting was favorable compared to monetary targeting. Inflation targeting has improved public understanding and increased the credibility of Thai monetary policy as average inflation and nominal interest rates have fallen over time. The flexibility of monetary policy stabilizes the real interest rate, leading to the stability of real economic activity.

The model shows that the Bank of Thailand is more responsive to the deviation of inflation from its target. If Thai inflation is lower than its target by 1 percent, the Bank of Thailand reduces its policy rate by 20 basis points. Furthermore, the policy rate persistence is large. The monetary mechanism exists through changes in the real interest rate which affect consumption and investment.

This study suggests that under a positive technology shock, output, consumption and investment rise and then falls back to the steady state. The technological improvement leads to an immediate employment decline. The results of a government spending shock are that consumption and investment are crowded out in response to the shock. Tobin's Q and investment decreases. The rise in the nominal interest rate causes inflation and the output gap to fall right away. A positive markup shock leads to a fall in output, consumption, investment and hours worked. The shock generates an increase in inflation at the same time reducing output.

In the end, there is a long run negative inflation-output trade off in the choice of a steady state inflation rate for the Thai economy. The study finds that the higher the inflation targeting rate, the lower the output is below its long run level of no trend inflation. In addition, the higher the degree of price indexation, the smaller the output below its steady state level. Indeed, inflation is costly through price dispersion. This price dispersion increases at higher levels of inflation targeting and leads to a loss of output. Therefore, the study recommends continued use of inflation targeting with a reduced target level. Recently, the inflation target range of 1.0-3.0 percent adopted by the Bank of Thailand in December 2019 should be the proper policy.

Declarations

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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The author declares that they have no competing interests

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Appendix

1. Households

1.1 Household cost minimization problem

The Lagrangian function corresponding to this problem is:

$$\mathcal{L} = \int_0^1 P_t(i)\, C_t(i) di + \lambda_t (C_t - \left(\int_0^1 C_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{\zeta}{\zeta-1}})$$

The first order conditions for the minimization are given by:

$$\frac{\partial \mathcal{L}}{\partial C_t(i)}: \qquad P_t(i) = \lambda_t \left(\int_0^1 C_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{1}{\zeta-1}} C_t(i)^{\frac{-1}{\zeta}}$$

and solving results:

$$C_t(i) = \left(\frac{P_t(i)}{\lambda_t} \right)^{-\zeta} C_t$$

substitute $C_t(i)$ in the composite level consumption $C_t = \left(\int_0^1 C_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{\zeta}{\zeta-1}}$, yields:

$$C_t = \left(\int_0^1 \left(\left(\frac{P_t(i)}{\lambda_t} \right)^{-\zeta} C_t \right)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{\zeta}{\zeta-1}}$$

This results in the aggregate price index for consumption P_t which equals to λ_t:

$$P_t = \left(\int_0^1 P_t\,(i)^{1-\zeta} di \right)^{\frac{1}{1-\zeta}}$$

where λ_t is the Lagrangian multiplier. The consumption demand for each differentiated good *m* can be written as[9]:

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\zeta} C_t$$

[9] The price elasticity of demand for good *i* is ζ. If $\zeta \to \infty$, the individual goods become substitute goods and individual firms have less market power.

1.2 Household utility maximization problem

The Lagrangian function associated with the household maximization problem can be defined as:

$$\mathcal{L} = E_t \sum_{t=0}^{\infty} \beta^t U(C_t, L_t)$$

$$+E_t \sum_{t=0}^{\infty} \beta^t \lambda_t (R_{t-1}B_{t-1} + r_t^K K_{t-1} + W_t(1 - L_t) - C_t - I_t - T_t - B_t)$$

$$+E_t \sum_{t=0}^{\infty} \beta^t Q_t((1-\delta)K_{t-1} + (1 - \phi\left(\frac{I_t}{I_{t-1}}\right))I_t - K_t)$$

First order conditions for maximization are given by:

$$\frac{\partial \mathcal{L}}{\partial C}: U_{C,t} = \lambda_t$$

$$\frac{\partial \mathcal{L}}{\partial B}: \beta R_t E_t[\lambda_{t+1}] = \lambda_t$$

$$\frac{\partial \mathcal{L}}{\partial L}: U_{L,t} = \lambda_t W_t$$

$$\frac{\partial \mathcal{L}}{\partial K}: \beta E_t[\lambda_{t+1} r_{t+1}^K] + (1-\delta)\beta E_t[Q_{t+1}] = Q_t$$

using $Q_t = q_t \lambda_t$ then $q_t = E_t \beta \frac{\lambda_{t+1}}{\lambda_t}(q_{t+1}(1-\delta) + r_{t+1}^K)$

$$\frac{\partial \mathcal{L}}{\partial I}: \lambda_t = Q_t + Q_t\left[-\phi\left(\frac{I_t}{I_{t-1}}\right) - \frac{I_t}{I_{t-1}}\phi'\left(\frac{I_t}{I_{t-1}}\right)\right] + \beta E_t[Q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 \phi'(\frac{I_{t+1}}{I_t})]$$

using $Q_t = q_t \lambda_t$ then

$$1 = q_t - q_t \phi\left(\frac{I_t}{I_{t-1}}\right) - q_t \frac{I_t}{I_{t-1}} \phi'\left(\frac{I_t}{I_{t-1}}\right) + E_t \beta \frac{\lambda_{t+1}}{\lambda_t}[q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 \phi'(\frac{I_{t+1}}{I_t})]$$

Notice that if $= 0$, there are no adjustment costs in investment and $q_t = 1$ or $\lambda_t = Q_t$

2. Firms

2.1 Final good firm profit maximization problem

The maximization problem of a representative firm in the final good sector is:

$$Max\ \pi_t = P_t Y_t - \int_0^1 P_t(i)\, Y_t(i) di$$

using the following Dixit and Stiglitz aggregator

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{\zeta}{\zeta-1}}$$

The corresponding first order condition is:

$$\frac{\partial \pi_t}{\partial Y_t(m)}: \qquad P_t(i) = P_t \left(\int_0^1 Y_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{1}{\zeta-1}} C_t(i)^{\frac{-1}{\zeta}}$$

and solving the above expression we obtain the demand for intermediate good i:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\zeta} Y_t$$

The demand for intermediate good i depends positively on the production of the final good and negatively on the relative price.

2.2 Intermediate good firm profit maximization problem

The Lagrangian function corresponding to this problem is:

$$\mathcal{L} = W_t N_t(i) + r_t^K K_{t-1}(i) + \lambda_t (A_t N_t^{\alpha}(i) K_{t-1}^{1-\alpha}(i) - Y_t(i))$$

The corresponding first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial N}: \quad W_t = \alpha \lambda_t \frac{Y_t(i)}{N_t(i)}$$

$$\frac{\partial \mathcal{L}}{\partial K}: \quad r_t^K = (1-\alpha) \lambda_t \frac{Y_t(i)}{K_{t-1}(i)}$$

Notice that the Lagrange parameter associated with the technological restriction represents the shadow price of change in the ratio of the use of capital and labor services, implying that the Lagrange parameter measures nominal marginal costs $\lambda_t = MC_t$.

3. Price dynamic

Recall

$$\frac{P_t^*}{P_t} = \frac{\zeta}{(\zeta - 1)} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} \Pi_{t,+k}{}^{\zeta}}{\mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \Pi_{t,+k}{}^{\zeta-1}}$$

Let

$$M_t = \frac{1}{(1 - 1/\zeta)} \mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} \Pi_{t,+k}{}^{\zeta}$$

$$MM_t = \mathrm{E}_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \Pi_{t,+k}{}^{\zeta-1}$$

Using

$$\Omega_t = \mathrm{E}_t \sum_{k=0}^{\infty} \beta^k \mathrm{X}_{t,t+k} Y_{t+k} = Y_t + \beta E_t [\mathrm{X}_{t,t+1}, \Omega_{t,t+1}]$$

Therefore

$$M_t = \left(\frac{1}{1 - 1/\zeta}\right) [Y_t \varphi_t MS_t + \zeta E_t [\Lambda_{t,t+1} \Pi_{t+1}^{\zeta} M_{+1}]]$$

$$MM_t = Y_t + \zeta_t E_t [\Lambda_{t,t+1} \Pi_{t+1}^{\zeta-1} MM_{+1}]$$

Where MS_t is the markup shock.

4. Price dispersion

Define $\hat{Y}_t$ as the aggregate factor inputs and using $N_t = \int_0^1 N_t(i)\, di$, yields the aggregate factor inputs:

$$\begin{aligned} \hat{Y}_t = \int_0^1 Y_t(i)\, di &= \int_0^1 \left(A_t N_t(i)\right)^{\alpha} K_{t-1}(i)^{1-\alpha} di \\ &= A_t^{\alpha} \left(\frac{K_{t-1}}{N_t}\right)^{1-\alpha} \int_0^1 N_t(i)\, di \\ &= (A_t N_t)^{\alpha} K_{t-1}^{1-\alpha} \end{aligned}$$

Given that $Y_t(i) = \left(\frac{Y_t(i)}{P_t}\right)^{-\zeta} Y_t$, $\hat{Y}_t$ could be written as:

$$\begin{aligned} \hat{Y}_t &= \int_0^1 Y_t \left(\frac{P_t(i)}{P_t}\right)^{-\zeta} di \\ &= Y_t P_t^{\zeta} \int_0^1 P_t(i)^{-\zeta}\, di \end{aligned}$$

with $P_t^o = \left[\int_0^1 P_t(i)^{-\zeta} di\right]^{-1/\zeta}$:

$$\hat{Y}_t = \left(\frac{P_t^o}{P_t}\right)^{-\zeta} Y_t = Y_t \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\zeta} di$$

Table 1. Thai macroeconomic performance prior and during inflation targeting

Anchor	*Monetary Targeting*	*Inflation targeting*	*Core inf. 0-3.5 %*	*Core inf. 0.5-3.0 %*	*Headline inf 2.5 ±1.5 %*
Average inflation	3.8	2.1	2.6	2.5	0.3
Fluctuations in inflation	4.4	1.9	2.1	1.4	0.8
Persistency of inflation	0.83	0.71			
Average growth	2.5	3.9	4.2	3.8	3.6
Fluctuations in growth	5.6	3.1	3.1	4.3	0.6
Average short term nominal interest rate	6.8	2.2	2.5	2.2	1.5
Fluctuations in short term real interest rate	4.1	1.6	1.8	1.3	0.9

The table documents the year on year percentage changes in CPI quarterly data. Monetary targeting for the period 1998q1 to 2000q1, Inflation targeting for the period 2000q2 to 2019q1, Core inflation targeting 0-3.5% for the period 2000q2 to 2009q2, Core inflation targeting 0.5-3.0% for the period 2009q3 to 2014q4 and Headline inflation targeting for 2015q1 to 2019q1. Fluctuations are measured by standard deviation.

Sources: CEIC

Table 2 Prior distributions

Name	*Density*	*Prior* *Mean*	*stdev*
Structural parameters			
Habit χ	Beta	2.00	0.10
Calvo price ω	Beta	0.75	0.10
Investment adj. cost ϕ_X	normal	2.00	1.50
Consumption utility ζ	Normal	1.50	0.375
Price indexation γ_P	Beta	0.50	0.15
Labor share α	Beta	0.72	0.05
Inflation at steady state	Normal	0.834	0.10
Trend growth rate	Normal	0.956	0.10
Nominal interest rate	Normal	1.399	0.10
Policy parameters			
Lagged interest rate ρ_r	Beta	0.75	0.10
Feedback inflation α_π	Normal	0.75	0.10
Feedback output gap α_Y	normal	2.00	1.50
Shock parameters			
Technology $\epsilon_{A,t}$	inv gamma	0.10	2.00
Gov exp $\epsilon_{G,t}$	Inv gamma	0.50	2.00
Mark-up $\epsilon_{MS,t}$	Inv gamma	0.10	2.00
Tech persistency ρ_A	Beta	0.50	2.00
Gov exp persistency ρ_G	Beta	0.50	2.00
Mark-up persistency ρ_{MS}	Beta	0.50	2.00

Table 3 Prior and posterior distributions

Name	*Density*	*Prior Mean*	*Post. Mean*	*90% HPD interval*	
Structural parameters					
Habit χ	beta	2.00	0.7586	0.5957	0.9279
Calvo price ω	beta	0.75	0.1792	0.1073	0.2457
Investment adj. cost ϕ_X	normal	2.00	2.7750	0.9446	4.7069
Consumption utility ζ	normal	1.50	1.4199	0.8707	1.9506
Price indexation γ_P	beta	0.50	0.5007	0.2746	0.7483
Labor share α	beta	0.72	0.7322	0.6498	0.8062
Inflation at steady state	normal	0.834	0.8987	0.7030	1.0585
Trend growth rate	normal	0.956	0.9725	0.8852	1.0505
Nominal interest rate	normal	1.399	1.3305	1.1780	1.4766
Policy parameters					
Lagged interest rate ρ_r	beta	0.75	0.9691	0.9569	0.9818
Feedback inflation α_π	normal	2.00	1.6105	1.0549	2.0314
Feedback output gap α_Y	normal	0.125	0.1566	0.0966	0.2141
Shock parameters					
Technology $\epsilon_{A,t}$	inv gamma	0.10	0.9482	0.2754	1.6600
Gov exp $\epsilon_{G,t}$	Inv gamma	0.50	14.9967	11.8339	17.6081
Mark-up $\epsilon_{MS,t}$	Inv gamma	0.10	0.1451	0.1104	0.1791
Tech persistency ρ_A	beta	0.50	0.9778	0.9571	0.9984
Gov exp persistency ρ_G	beta	0.50	0.8841	0.8230	0.9469
Markup persistency ρ_{MS}	beta	0.50	0.5333	0.2032	0.8348

Table 4 The effect of the inflation targeting rate and the past inflation indexation on the steady state for the Thai economy during headline inflation targeting $2.5\% \pm 1.5\%$

Inflation targets	$\pi^* = 2.5\%$	$\pi^* = 2.0\%$	$\pi^* = 1.5\%$	$\pi^* = 1.0\%$
$\gamma_P = 0.3$				
Output	-3.1603	-1.7358	-0.8409	-0.3186
Consumption	-2.6251	-1.4475	-0.7084	-0.2748
Investment	-4.9528	-2.6971	-1.2775	-0.4563
Gov. spending	-3.1565	-1.7321	-0.8372	-0.3148
$\gamma_P = 0.5$				
Output	-1.2865	-0.7413	-0.3729	-0.1448
Consumption	-1.0765	-0.6259	-0.32016	-0.12865
Investment	-1.9839	-1.1199	-0.5409	-0.1893
Gov. spending	-1.2827	-0.7375	-0.3691	-0.1410
$\gamma_P = 0.7$				
Output	-0.3686	-0.2191	-0.1126	-0.0437
Consumption	-0.3165	-0.1914	-0.1012	-0.0416
Investment	-0.5341	-0.30269	-0.1410	-0.0410
Gov. spending	-0.3648	-0.2154	-0.1088	-0.0400

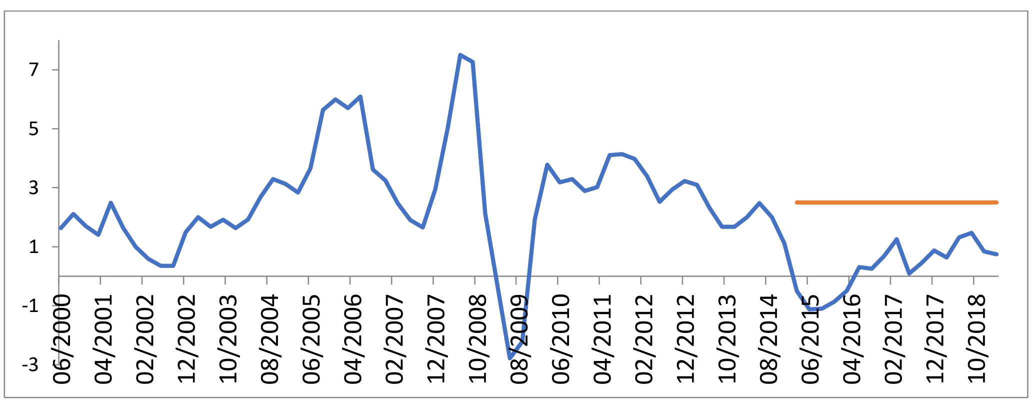
π^* is the inflation targeting at the mid range
γ_P is price indexation parameter, indexing to past inflation
The figures are the percent deviation of each parameter from its natural level of zero inflation at the steady state

Table 5 The effect of the inflation targeting rate and the average inflation indexation on the steady state for the Thai economy during headline inflation targeting $2.5\% \pm 1.5\%$

	$\pi^* = 2.5\%$			$\pi^* = 1.5\%$		
	$\bar{\gamma}_P = 0$	$\bar{\gamma}_P = 0.5$	$\bar{\gamma}_P = 1$	$\bar{\gamma}_P = 0$	$\bar{\gamma}_P = 0.5$	$\bar{\gamma}_P = 1$
$\gamma_P = 0.3$						
Output	-0.2960	-0.1423	-3.1603	-0.1257	-0.0435	-0.8409
Consumption	-0.2202	-0.1265	-2.6251	-0.0893	-0.0414	-0.7084
Investment	-0.5415	-0.1856	-4.9528	-0.2382	-0.0406	-1.2775
Gov. spending	-0.2923	-0.1385	-3.1565	-0.1219	-0.0397	-0.8372
$\gamma_P = 0.5$						
Output	-0.6925	-0.0021	-1.2865	-0.2985	-0.0021	-0.3729
Consumption	-0.5300	-0.0004	-1.0765	-0.2221	-0.0004	-0.3201
Investment	-1.2300	0.0016	-1.9839	-0.5459	0.0016	-0.5409
Gov. spending	-0.6887	0.0015	-1.2827	-0.2947	0.0015	-0.3692
$\gamma_P = 0.7$						
Output	-1.1837	-0.1489	-0.3686	-0.5243	-0.0639	-0.1126
Consumption	-0.9176	-0.1070	-0.3165	-0.3981	-0.0430	-0.1012
Investment	-2.0703	-0.2802	-0.5341	-0.9396	-0.1246	-0.1410
Gov. spending	-1.1800	-0.1452	-0.3648	-0.5205	-0.0602	-0.1088

π^* is the inflation targeting at the mid range
γ_P is price indexation parameter, indexing to past inflation
$\bar{\gamma}_P$ is price indexation parameter, indexing to inflation targeting
The figures are the percent deviation of each parameter from its natural level of zero inflation at the steady state

Figure 1 Thai inflation during inflation targeting regime



Thai inflation % (year on year)
The flat line represents the mid point headline inflation targeting rate at 2.5%
Source: Bank of Thailand

Figure 2 Estimated parameter distributions

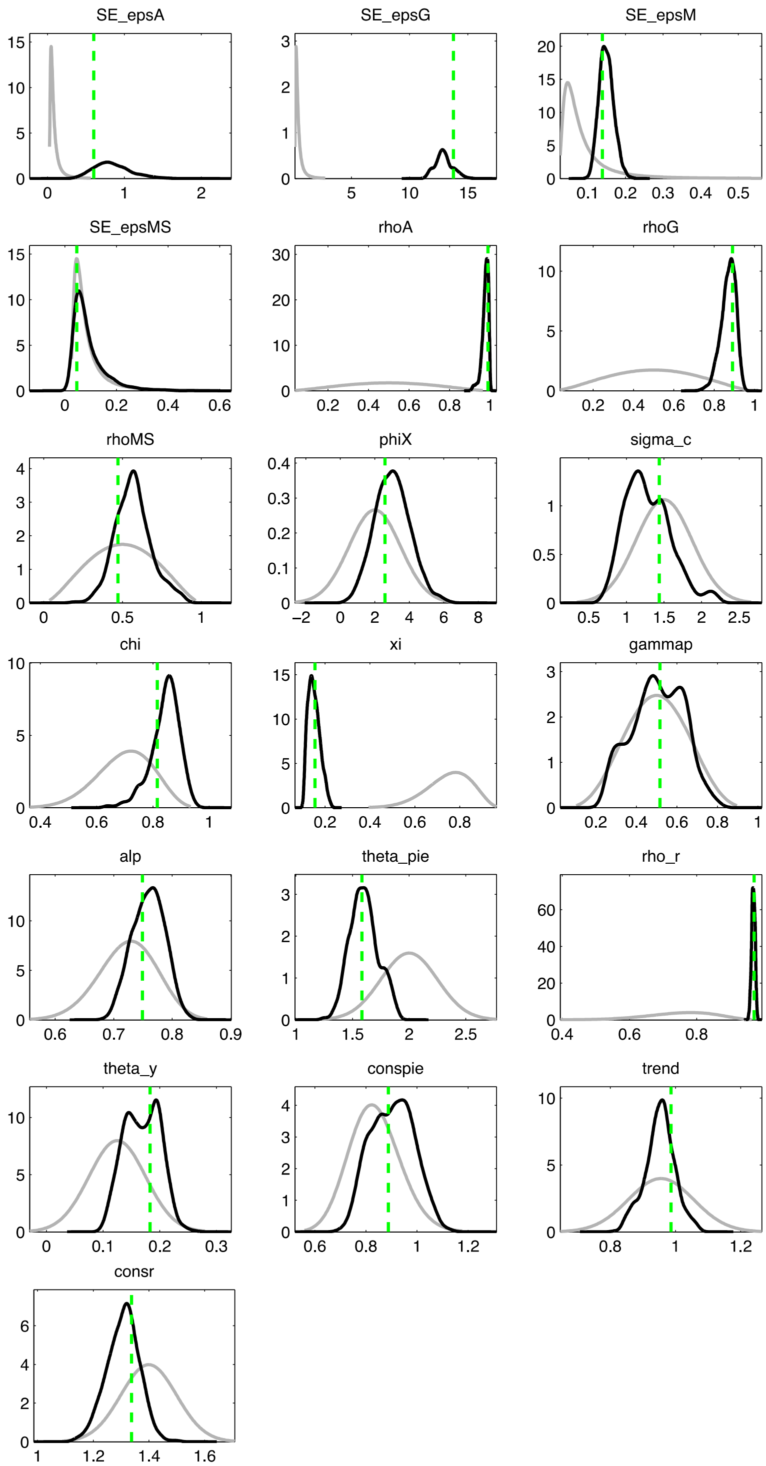
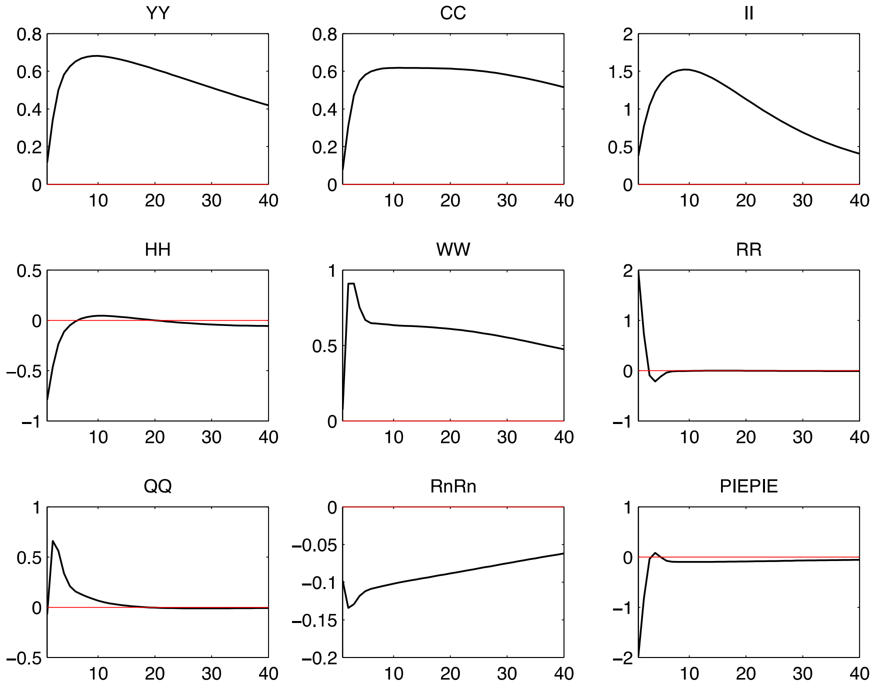
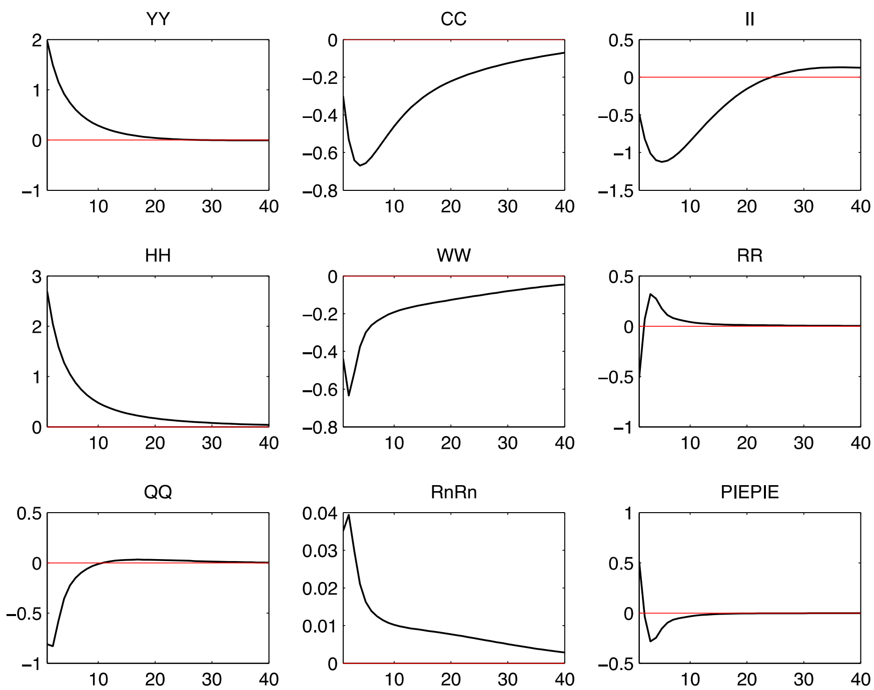


Figure 3 Technology shock



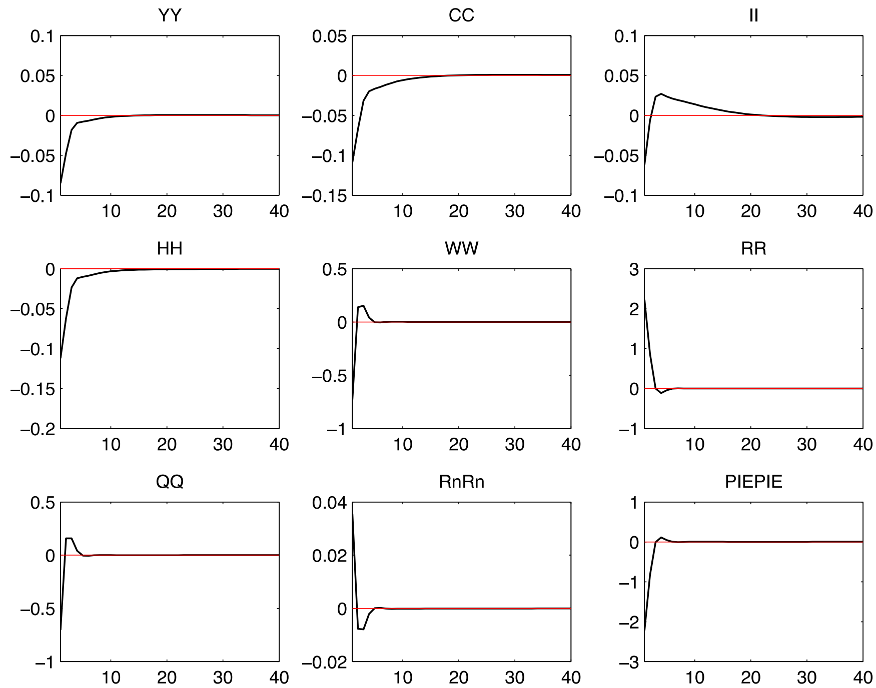
All variables are in the deviation from its steady state form. XX is X deviations from its steady state. Y is output. C is consumption. I is investment. H is working hours. W is real wage. R is ex post real interest rate. Rn is nominal interest rate. π is inflation. Q is Tobin's Q. The vertical axis is percentage and the horizontal axis is quarters.

Figure 4 Government spending shock



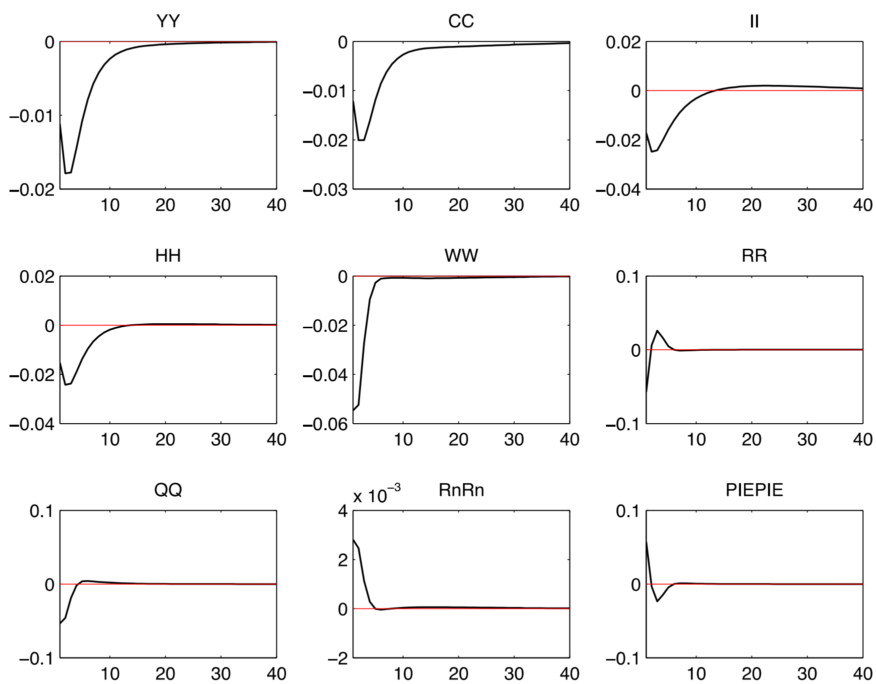
Note: Same as figure 3

Figure 5 Monetary policy shock (Interest rate shock)



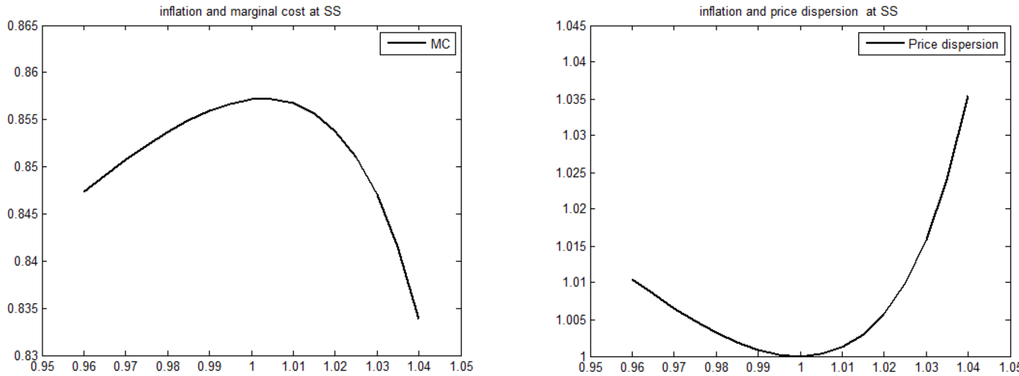
Note: Same as figure 3

Figure 6 Mark up price shock

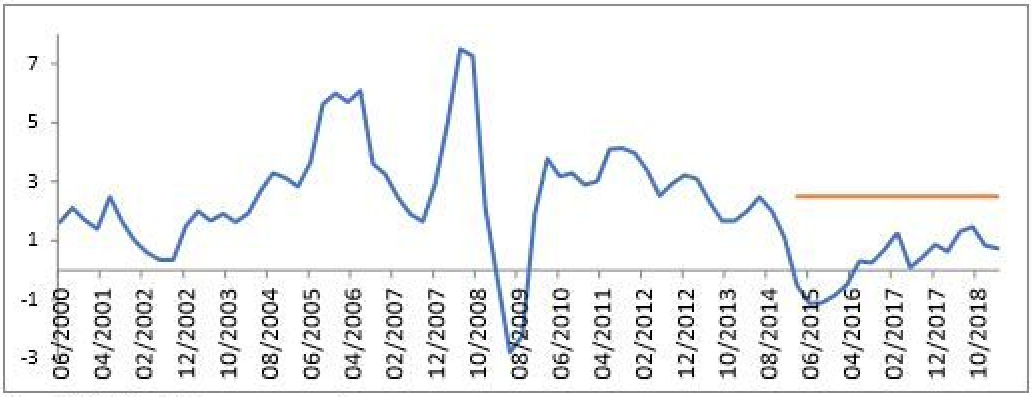


Note: Same as figure 3

Figure 7 Inflation targeting and marginal cost, price dispersion at steady state



Figures



Thai inflation % (year on year)
The flat line represents the mid point headline inflation targeting rate at 2.5%
Source: Bank of Thailand

Figure 1

Thai inflation during inflation targeting regime

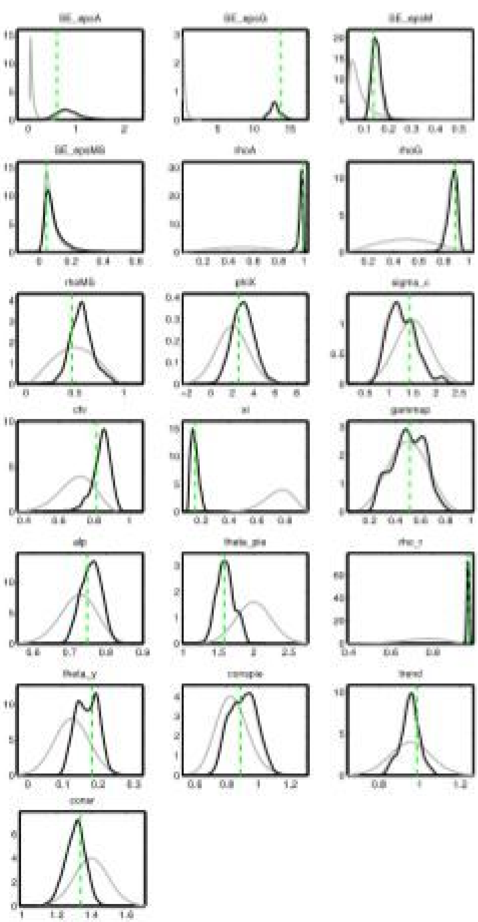
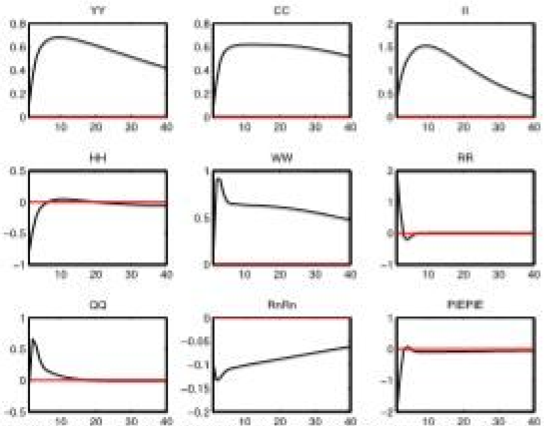


Figure 2

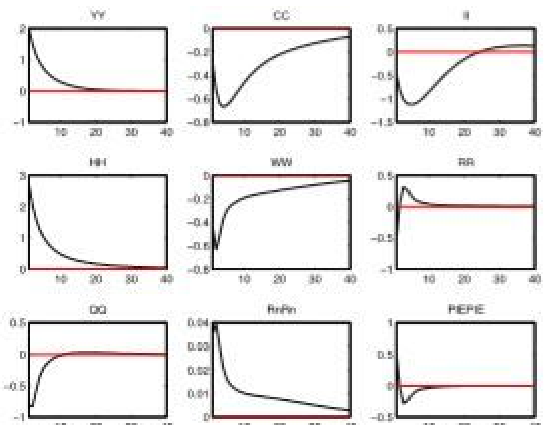
Estimated parameter distributions



All variables are in the deviation from its steady state form. XX is X deviations from its steady state. Y is output. C is consumption. I is investment. H is working hours. W is real wage. R is ex post real interest rate. Rn is nominal interest rate. π is inflation. Q is Tobin's Q. The vertical axis is percentage and the horizontal axis is quarters.

Figure 3

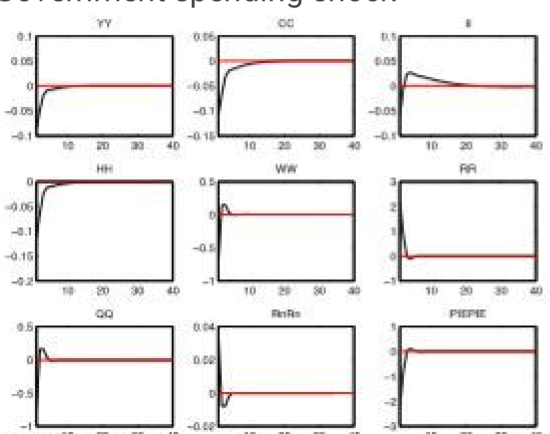
Technology shock



Note: Same as figure 3

Figure 4

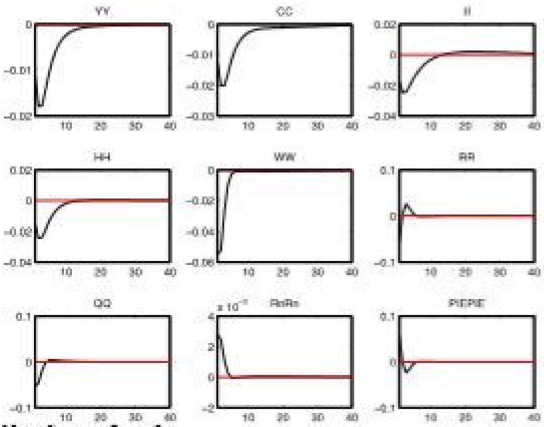
Government spending shock



Note: Same as figure 3

Figure 5

Monetary policy shock (Interest rate shock)



Note: Same as figure 3

Figure 6

Mark up price shock

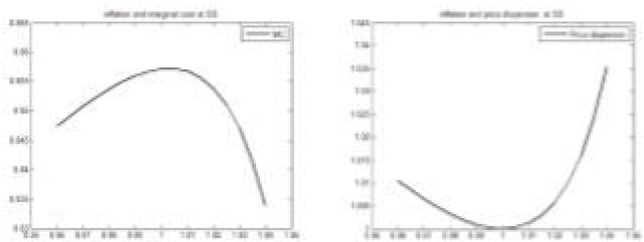


Figure 7

Inflation targeting and marginal cost, price dispersion at steady state