

The Role of Price Dispersion on the Inflation Targeting in Thailand

Nipit Wongpunya

Faculty of Economics, Chulalongkorn University, Thailand

Corresponding author: Nipit.W@Chula.ac.th

Abstract

This paper explores the macroeconomic effects of inflation targeting in Thailand. It uses a closed economy medium-scale New Keynesian model with price dispersion to analyze the Thai monetary policy under inflation targeting. It shows that inflation is more stable, and inflation persistence has fallen after adopting inflation targeting. The Bank of Thailand is more responsive to the deviation of inflation from its target using inflation targeting. Inflation is costly through price dispersion. The larger the inflation targeting rate is set by the Bank of Thailand, the lower the steady state output is from its steady state level, given no trend inflation.

Keywords: trend inflation, price dispersion, New Keynesian, Thailand.

1. Introduction

Since the early 1990s, inflation targeting has been adopted by an increasing number of countries, including Thailand in 2000. 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 the domestic economy.

Gali (2008) suggested that the monetary policy is pivotal and eventually transmitted throughout the economy. However, Ascari (2004) demonstrated that when trend inflation is considered, both steady state and dynamic properties of the model change dramatically. Ascari and Ropele (2007) showed 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. The level of the inflation target affects the slope of the Phillips curve. Therefore, a decline in the central bank's inflation targeting rate enhances the relationship between inflation and the output gap. The Phillips curve is steeper, and monetary policy is more effective. Ascari and Sbordone (2014) claimed that the conduct of monetary policy should be analyzed by appropriately accounting for the positive trend inflation targeted by policymakers. 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 al. (2001) introduced indexing to the past inflation. Nonetheless, both of these studies remove the effect of trend inflation in the long run and the short run.

In the long run, price dispersion and markup distortion are minimized when the level of the inflation target is low. Amano et al. (2007) explained that steady-state output and welfare losses are quantitatively important even for low values of trend inflation. Ambler (2007) reviewed that under the New Keynesian model with

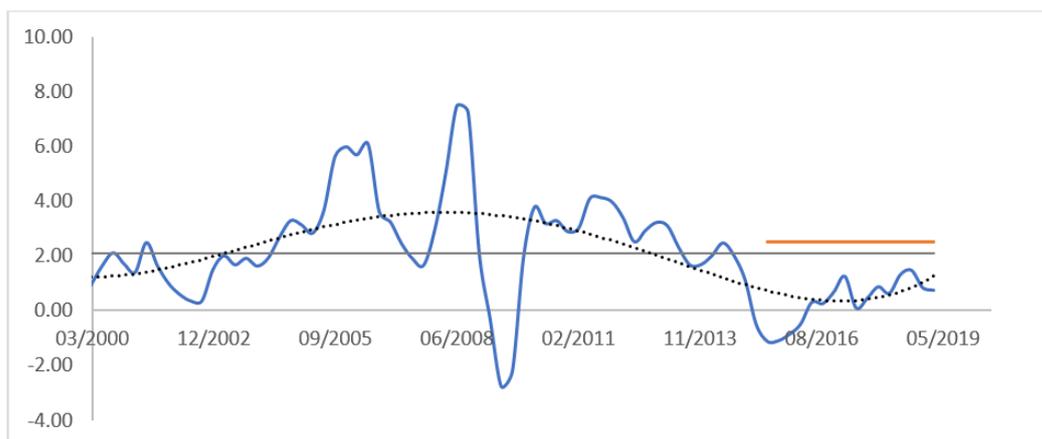
inflation targeting, price dispersion is an increasing function of trend inflation and causes long-run output to be a decreasing function of inflation targeting rates. Sheremirov (2015) argued that the level of price dispersion, which is typically approximated through its relationship with inflation, is a central determinant of the optimal rate of inflation and the tradeoff between inflation and output stability. Nakamura et al. (2017) used a new dataset on price behavior during the Great Inflation of the late 1970s and early 1980s in the United States. They found an important concern that high inflation will lead to inefficient price dispersion. Damjanovic and Nolan (2010) quantified how costly price dispersion is in a standard macroeconomic model with imperfect competition and price rigidity, as in Calvo (1983). Price dispersion impacts the economy like a negative productivity shock.

Much of the vast literature on monetary policy rules worked on the closed economy version of the New Keynesian model, e.g., Clarida et al. (2000), Gali (2008), and Woodford (2003). Particularly, the hypothesis of this paper has roots in the literature that examines the effects of positive trend inflation. Previous research uses the closed economy New Keynesian model to examine how the properties of the economy change as the trend inflation varies, e.g., Ascari (2004), Ascari and Ropele (2007; 2009), and Khan et al. (2020).

In the case of Thailand, it has been over two decades since May 2000 that the Bank of Thailand (BoT) has conducted monetary policy under the flexible inflation targeting framework. Figure 1 illustrates Thai inflation during the inflation targeting regime. The figure reports the estimate of trend inflation obtained from quarterly Thai data during 2000-Q3 to 2019-Q3. The thick line is the actual Thai inflation (year on year). The flat line at the end of the sample represents the mid-point headline inflation targeting rate at 2.5 percent. The dotted line is the trend inflation estimated by the polynomial approach. The thin line is the mean inflation at 2.08 percent. As the figure shows, trend inflation rose from 1 percent in 2000 to around 7.5 percent in 2008, then fell to just below 1 percent at the end of the sample. A time-varying

inflation trend implies that the inflation gap, measured as the deviation of inflation from the time-varying trend, is quite different from deviations of inflation from a constant mean. In the figure, long runs appear at the beginning, middle, and end of the sample, when inflation does not cross the mean line; instead, inflation crosses the trend line more often. Clearly, the idea of price stability in the BoT practice is usually associated with a moderate rate of inflation. Nonetheless, most theoretical studies have analyzed the performance of Thai monetary policy under a no-trend inflation assumption, e.g., Tanboon (2007) and Phrommin (2018). Although previous empirical works have examined monetary policy rules, e.g., Taguchi and Wanasilp (2018) and Tan and Mohamed (2020), the analysis of the level of inflation targeting rate for Thailand is still scarce.

Figure 1. Thai inflation during the inflation targeting regime



Note: The thick line is the actual Thai inflation percent (year on year). The flat line at the end of the sample represents the mid-point headline inflation targeting rate at 2.5 percent. The dotted line is the trend inflation estimated by the polynomial approach. The thin line is the mean inflation at 2.08 percent. Source: Bank of Thailand.

Under the inflation targeting regime, one of the main policy questions is how high or low an inflation rate the BoT should target. This paper employs the New Keynesian theory to assess Thai monetary policy. The approach builds on a DSGE framework, using the Bayesian technique to estimate the model parameters. It considers the role of price dispersion to assess the effectiveness of Thai monetary policy in the steady state.

The purpose of this paper is to answer the following four questions.

- 1) What are the effects of inflation targeting on Thai macroeconomic performance?
- 2) Under an 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, interest rate, and other macroeconomic variables?
- 3) Given other exogenous shocks, what has happened to the Thai economy? And
- 4) What would happen to the Thai economy if the BoT decides to adjust its inflation target?

This issue has been addressed in view of the price dispersion in the New Keynesian economy. It extends the small-scale New Keynesian model to allow for positive trend inflation. It investigates the effect of the inflation targeting rate using the past and average inflation indexation.

This study addresses how inflation affects Thai macroeconomic performance. After adopting the inflation targeting framework, the volatility and persistence of inflation have been reduced, and growth has been more favorable. It stabilizes the real interest rate, leading to the stability of real economic activity. The BoT is more responsive to the deviation of inflation from its target. While the response to inflation in the policy function is 1.6105, the response to the output gap is 0.1566. The policy rate persistence is large at 0.9691. The monetary policy is effective in the way that the transmission mechanism exists. This paper provides the routes through which the level of inflation targeting is costly for monetary policy in the long run. The key policy question is how much of an inflation rate the BoT should target. This depends crucially on the costs of inflation, which are derived from price dispersion. A higher level of inflation target yields a higher price dispersion, leading to a loss of output. This paper finds, for Thailand, that both past and average inflation indexation provide the same conclusion that a lower level of the inflation targeting rate generates a higher output in the long run.

The structure of this paper is as follows. Section 2 describes the effects of inflation targeting on Thai macroeconomic performance. Section 3 introduces the

nonlinear New Keynesian model with price indexation and price dispersion. Section 4 discusses the rationale of the Bayesian estimation. Section 5 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 6 mentions how changes in inflation targeting influence the Thai economy. Section 7 provides conclusions.

2. Thai Macroeconomic Effects of Inflation Targeting

This section attempts to survey changes in Thai inflation, growth, and interest rates prior to and after the adoption of 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 in 2000 and has proved largely successful in bringing down inflation. Table 1 shows the average level of inflation during monetary and inflation targeting. It 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) concludes from 21 inflation-targeting countries that inflation targeting leads, on average, to a 2.5 percent to more than 3 percent fall in inflation.

Table 1. Thai macroeconomic performance prior to and during inflation targeting

<i>Anchor</i>	<i>Monetary</i>	<i>Inflation</i>	<i>Core inf.</i>	<i>Core inf.</i>	<i>Headline inf</i>
	<i>Targeting</i>	<i>Targeting</i>	0–3.5 %	0.5–3.0 %	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

Note: 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 2000-Q2 to 2019-Q1, Core inflation targeting 0–3.5% for the period 2000-Q2 to 2009-Q2, Core inflation targeting 0.5–3.0% for the period 2009-Q3 to 2014-Q4, and Headline inflation targeting for 2015-Q1 to 2019-Q1. Fluctuations are measured by standard deviation.

Source: CEIC.

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), who argue that inflation targeting stabilizes inflation.

It is interesting to see how inflation targeting affects 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 coefficients. 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 .

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

Given the structure of the model, the persistence of inflation before targeting is explained by $\beta_1 + \beta_2$ and by $\beta_1 + \beta_2 + \vartheta$ after targeting.¹ The inflation persistence has reduced if ϑ 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 of inflation persistence involves the credibility of monetary policy. The credibility of monetary policy has increased with the reduction in inflation persistence. For Thailand, Table 1 documents that inflation persistence has fallen from 0.83 to 0.71 after adopting inflation targeting. Moreover, we find that the variance of $\hat{\beta}_1$ is higher than the variance of $\hat{\vartheta}$. The result indicates that the credibility of Thai monetary policy has improved after adopting inflation targeting. The inflation targeting is likely to have a positive effect on 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) note that inflation expectations appeared to become more firmly anchored to lower inflation following the regime change in 2000. The inflation targeting framework has convinced businesses and consumers that the BoT 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 discussed in Friedman and Kuttner (1996).

¹ 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 1981-Q1 to 2000-Q1 is for before targeting, and from 2000-Q2 to 2019-Q1 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. $Var(\hat{\beta}_1) = 0.00575$, $Var(\hat{\beta}_2) = 0.00467$ and $Var(\hat{\vartheta}) = 0.003$. For a group of inflation-targeting countries, inflation targeting has reduced inflation persistence (Pétursson, 2005).

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, compared 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 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. Compared 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, the COVID-19 pandemic started and spread around the world. The economic impact of the pandemic severely affected the Thai economy due to Thailand's openness to trade and its status as a tourism hub. The BoT cut its policy rate several times from 1.25 percent in January to 0.5 percent in July 2020. In the first seven months of 2020, the nominal interest rate on average fell to 0.87 percent, and the average inflation during this period was -1.1 percent.

3. The Medium-Size New Keynesian Model

Previous work has examined the effects of positive trend inflation. Most of those studies employ a small-sized New Keynesian model characterized by only exogenous nominal rigidities represented by the pricing schemes of Calvo (1983) and Taylor (1980). Few studies use the medium-sized New Keynesian model based on Christiano et al. (2005), which embodies not only nominal rigidities but also some form of real rigidities, including consumer habit formation, investment adjustment cost, and roundabout production structure. This paper extends the small-scale New Keynesian model to allow for positive trend inflation for Thai monetary policy analysis during the inflation targeting regime. This paper follows Ascari and Sbordone (2014) to derive the price dispersion and to analyze the effects of a positive trend inflation.

3.1 Households

3.1.1 Household Cost Minimization Problem

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 minimizes the cost of achieving this level of the final good. Following Dixit and Stiglitz (1977), the consumption index is given by:

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

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 goods $C_t(i)$, 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).

3.1.2 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 a habit formation utility function as below:

$$U(C_t, L_t) = \frac{((C_t - \chi C_{t-1})^{(1-\varrho)} (1 - N_t)^\varrho)^{1-\sigma-1}}{1-\sigma} \quad (3)$$

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:

$$B_t = R_{t-1} B_{t-1} + r_t^k K_{t-1} + W_t N_t - C_t - I_t - T_t \quad (4)$$

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, I_t is investment, and T_t is lump-sum taxes. The law of motion of capital is governed over time by:

$$K_t = (1 - \delta)K_{t-1} + (1 - \phi(\frac{I_t}{I_{t-1}}))I_t \quad (5)$$

Capital formation incorporates investment adjustment costs, denoted by the function ϕ . The parameter ϕ refers to the existence of costs in terms of investment changes between periods (Christiano et al., 2005).

3.2 Production

Production is divided into three sectors: final goods, retail, and wholesale goods producers. A representative wholesale firm hires labor and capital from household and produces output, selling it to a continuum of retail firm at P_t^W . The retail firms purchase wholesale output, repackage it, and sell it to a competitive final goods firm at $P_t(i)$, where retail firms are indexed by $i \in [0,1]$. The final goods firm combines retail output into a final output goods, introducing a retail sector producing differentiated goods under monopolistic competition. This sector converts homogeneous output from a competitive wholesale sector. The separation of retail firms enable us to introduce sticky prices in a straightforward manner.

3.2.1 Final Goods Sector

Final goods is produced by a firm that aggregates retail goods into a single composite goods using the following Dixit and Stiglitz aggregator:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\zeta-1}{\zeta}} d(i) \right)^{\frac{\zeta}{\zeta-1}} \quad (6)$$

The final goods firm takes, as given, the price of intermediate goods $P(i)$ and the price of the composite final goods P_t and then maximizes profits given a production function as in equation (6).

3.2.2 Retail Goods Sector

Retail goods are produced by a continuum of monopolistically competitive firms. Retailers transform wholesale output into retail output, and their production functions are simple. They purchase some wholesale output $Y_t^W(i)$ and repackage it into retail output $Y_t(i)$. Therefore, the real marginal cost of conversion for firm i is P_t^W/P_t . Each firm acknowledges the downward-sloping demand curve it faces, or $Y_t(i) = C_t(i)$.

The model adds the feature of price stickiness by considering the case of a staggered price setting established by Calvo (1983).² In any period, the probability that each retail firm will not adjust its price is ω , and the probability that each retail firm will change its price is $1 - \omega$. This makes their price-setting problem dynamic. 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:

$$P_t = (\omega P_{t-1}^{1-\zeta} + (1-\omega)(P_t^*)^{1-\zeta})^{\frac{1}{1-\zeta}} \quad (7)$$

Since all retail firms face the same marginal cost, the i index is dropped. The first order condition of profit maximization for optimal choice of P_t^* can be rearranged, resulting in optimal pricing behavior of intermediate goods:

$$\frac{P_t^*}{P_t} = \frac{\zeta}{\zeta - 1} \frac{E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\zeta}}{E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\zeta-1}} \quad (8)$$

where $\zeta/(\zeta - 1)$ represents the markup, describing the difference between the price and the marginal cost, and φ_{t+k} represents the real marginal cost. Equation (8)

² Ascari and Rossi (2012) report that the two most commonly used approaches to model firms' price-setting behavior within the standard New Keynesian framework of monopolistically competitive firms are the Rotemberg (1982) quadratic cost of price adjustment and the Calvo (1983) random price adjustment signal. However the two models differ substantially once trend inflation is considered.

While the long-run NKPC is negatively sloped in the Calvo model, it is positively sloped in the Rotemberg model. In contrast to the Calvo model, where an increase in trend inflation shrinks the determinacy region, positive trend inflation enlarges the determinacy area in the Rotemberg model. The literature on trend inflation, however, has so far focused mainly on staggered price models.

indicates that in the case of the sticky price model, the firm will mark up the price over the weighted average of the flow of future marginal costs.

3.2.3 Wholesale Goods Sector

The wholesale firm produces an output based on the following Cobb-Douglas production function:

$$Y_t^W = A_t N_t^\alpha K_{t-1}^{1-\alpha} \quad (9)$$

where A_t is the productivity process, and K_t is end-of-period t capital stock.

3.2.4 The Price Indexation

The price indexation is introduced to explain the inflation persistence (Christiano et al., 2005; Smets & Wouters, 2007). For a firm, m , that does not reoptimize with probability ω , their prices are partially indexed to last period's aggregate inflation:

$$P_t(m) = \pi_{t-1}^{\gamma_p} P_{t-1}(m) \quad (10)$$

where $\pi_{t-1} = P_{t-1}/P_{t-2}$ and $\gamma_p \in [0,1]$ is the magnitude of the indexation factor.

The optimal price setting under price indexation is that a firm chooses its price to maximize its discounted real profits using the firm's future demand, and the price behavior, with no reoptimization for the duration, cannot re-optimize its price. The first order condition with MS_t as a markup shock can be rearranged, further yielding the optimal pricing behavior:

$$\frac{P_t^*}{P_t} = \frac{\zeta}{(\zeta - 1)} \frac{E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} MS_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^\zeta \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{-\gamma_p \zeta}}{E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\zeta-1} \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{-\gamma_p(\zeta-1)}} \quad (11)$$

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

$$\frac{P_t^*}{P_t} = \frac{M_t}{MM_t} \quad (12)$$

$$M_t = \left(\frac{1}{1 - 1/\zeta} \right) Y_t \varphi_t MS_t + \omega E_t [\Lambda_{t,t+1} \hat{\Pi}_{t+1}^\zeta M_{t+1}] \quad (13)$$

$$MM_t = Y_t + \omega E_t [\Lambda_{t,t+1} \hat{\Pi}_{t+1}^{\zeta-1} MM_{t+1}] \quad (14)$$

Another way of indexing assumes that prices are indexed to a weighted average of last period inflation and trend inflation. Denoting the two weights by γ_p and $\bar{\gamma}_p$, the dynamic equations (13) and (14) can be replaced by $\hat{\Pi}_t = \pi_t / (\pi_{t-1}^{\gamma_p} \pi^{*(1-\bar{\gamma}_p)})$, 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.

3.3 Price Dispersion and Output Equilibrium

The aggregate production function is not explicitly presented in the new Keynesian model. Distribution of inputs among the various differentiated good firms influences the aggregate output, Y_t . Christiano et al. (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 unequal 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. We define Y_t^W as the integral of gross output across retail goods firms. Goods marketing clearing requires that:

$$Y_t^W = \int_0^1 Y_t(i) di = \int_0^1 (A_t N_t(i))^\alpha K_{t-1}(i)^{1-\alpha} di = (A_t N_t)^\alpha K_{t-1}^{1-\alpha} \quad (15)$$

Using the demand of retail goods i from the firm's final goods optimization.

$$Y_t^W = \left(\frac{P_t^*}{P_t}\right)^{-\zeta} Y_t \quad (16)$$

where $P_t^* = \left[\int_0^1 P_t(i)^{-\zeta} di\right]^{-1/\zeta}$ and $\left(\frac{P_t^*}{P_t}\right)^{-\zeta} = \Delta_t$, which measures output loss due to price dispersion (Yun, 1996). Therefore we obtain

$$Y_t = \frac{(A_t N_t)^\alpha K_{t-1}^{1-\alpha}}{\Delta_t} \quad (17)$$

where
$$\Delta_t = \zeta \pi_t^\zeta \Delta_{t-1} + (1 - \zeta) \left(\frac{M_t}{MM_t}\right)^{-\zeta} \quad (18)$$

The model is completed with a balanced budget constraint with lump-sum taxes.

$$G_t = T_t \quad (19)$$

3.4 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 as:

$$\log\left(\frac{R_{n,t}}{R_n}\right) = \rho_r \log\left(\frac{R_{n,t-1}}{R_n}\right) + (1 - \rho_r) \alpha_\pi \log\left(\frac{\pi_t}{\pi}\right) + (1 - \rho_r) \alpha_y \log\left(\frac{Y_t}{Y}\right) + \epsilon_{M,t} \quad (20)$$

where $0 < \rho_r < 1$. $\alpha_\pi > 0$, 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.

3.5 The Shocking Process Specification

The law of motion for the exogenous shocks are assumed to follow a first-order autoregression 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:

$$\log\left(\frac{A_t}{A}\right) = \rho_A \log\left(\frac{A_{t-1}}{A}\right) + \epsilon_{A,t} \quad (21)$$

$$\log\left(\frac{G_t}{G}\right) = \rho_G \log\left(\frac{G_{t-1}}{G}\right) + \epsilon_{G,t} \quad (22)$$

$$\log\left(\frac{MS_t}{MS}\right) = \rho_{MS} \log\left(\frac{MS_{t-1}}{MS}\right) + \epsilon_{MS,t} \quad (23)$$

The parameter ρ measures how persistent each shock is. The variables ϵ are innovations to each random shock, and they are normally distributed and serially uncorrelated.

4. The Bayesian Estimation

To assess the reliability of the model, we use the Bayesian estimation, which involves specifying prior parameters and updating them based on observed data. Finding the posterior distribution of the parameters conditional on the sample data by using the model likelihood and the prior data on the parameters is the objective of the Bayesian inference process. The posterior is the density of parameters given existing data. Using the Bayesian rule, the posterior distribution can be computed as:

$$p(\theta|Y^T, M) = \frac{p(Y^T|\theta, M)p(\theta|M)}{p(Y^T|M)} \quad (24)$$

where $p(\cdot)$ stands for a probability density function and M stands for the model. Therefore, $p(\theta|Y^T, M)$ is the posterior distribution of the parameters conditional on the model and the information set of an observed macro time series until period T or $Y^T = \{y_1, y_2, y_3, \dots, y_T\}$. $p(Y^T|\theta, M)$ is the likelihood density of the model parameter. The likelihood is the probability of obtaining the data given choices of parameter θ .

Following Lubik and Schorfheide (2006), this paper focuses on the main macroeconomic conditions, i.e., the aggregate output and inflation, to represent the Thai economy. For the interest rate, we use the BoT policy rate. The observables are the log difference of real GDP, the log difference of the GDP deflator, and the BoT

policy rate. The Thai data are transformed to ensure that they are stationary. The observables are on a quarterly basis and from 2001-Q1 to 2019-Q1, which is the period of the inflation-targeting regime. All series are seasonally adjusted. The data is from CEIC, a database system using data aggregated from the IMF and the BoT. Additionally, we have to give the long-run values to the model in order to represent the Thai economy. During the observation periods, the government spending-output ratio is 0.1504, and the depreciation rate of capital stock is 0.031. The quarterly steady state inflation rate is 0.83. The quarterly trend growth rate is 0.96, and the quarterly steady state nominal interest rate is 1.40. The choice of priors for the estimated parameters is usually determined by the theoretical implications of the model and evidence from previous studies. The value of β should be high and near 1 to imply greater patience and a stronger preference for future consumption by forward-looking households. Per Gali (2008), the baseline calibration of the model's preference parameter, the discount factor is $\beta = 0.99$, which is consistent to the steady state real return on financial assets of about 4 percent in Thailand. It is difficult and complicated to estimate the risk aversion σ . Following the previous studies, the risk aversion $\sigma = 2$. Regarding the consumption and labor share ϱ , we calibrate it to hit a steady state for the proportion of hours worked $N_{SS} = 0.34$, which is the product of the fraction of hours worked in a week and the fraction of the population that works during the observation periods in Thailand.

Regarding the substitution of elasticity of goods ζ , the values of this parameter commonly found in the business cycle literature are in the range of 6 to 10, which translates to an average markup of 1.2 to 1.1, or a 20 to 10 percent markup over marginal costs. Gali (2008) uses $\zeta = 6$, while Ascari and Sbordone (2014) use $\zeta = 10$. In the case of Thailand, we would like the price markup to be in the middle, between 20 to 10 percent. This study uses $\zeta = 8$, which is approximately a 16 percent markup. The prior distributions of the parameters are listed in Table 2, following Smets and Wouters (2007). Table 2 also shows the mean of the posterior distributions

compared to that of the 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 $1/(1 - \omega)$. Gali et al. (2001) estimated that the expected time a price remains unchanged in the US is between 2 and 3 quarters, whereas in Europe, it is between 3 and 4 quarters. However, Gali (2008) uses the degree of price rigidity of 0.6 for the US economy, translating to the duration of the price remaining unchanged for 3 quarters. Bils and Klenow (2004) report that half of all goods prices last more than 5.5 months. However, they vary dramatically over types of goods and the amount of competition in the industry. The theoretically estimated degree of price stickiness in Thailand is slightly stronger than that of other countries.

Table 2. Prior and posterior distributions

<i>Name</i>	<i>Density</i>	<i>Prior</i>	<i>Post.</i>		
		<i>Mean</i>	<i>Mean</i>	<i>90% HPD interval</i>	
<i>Structural parameters</i>					
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
Substitution elasticity of goods 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
<i>Policy parameters</i>					
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
<i>Shock parameters</i>					
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

Note: All figures are estimated by the Bayesian technique.

5. The Dynamic Effects of Monetary Policy Rules and Exogenous Shocks

After solving the model, we obtain the policy functions, which demonstrate the relationship between the control and state variables. Specifically, the control variables are functions of the state variables. The state variables, based on the model, are the lag of consumption, capital, investment, nominal interest rate, price dispersion, markup, technology, and government spending and inflation. Additionally, the exogenous shocks, namely technology, government spending, markup, and interest rate shocks, are the state variables. Consider a positive technology shock in Figure 2(a). 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 hours of work to a positive technology shock are in opposite directions (Gali, 2008), as the income effect dominates the substitution effect, resulting in fewer labor hours and a potential reduction in output after compensation from the initial increase due to the technology shock. 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 a high real-interest rate during the impact, then the increase in the supply of capital reduces the real interest rate. 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 a firm's marginal costs, driving up prices.

Figure 2(b) illustrates the results of the government spending shock. An increase in government spending could lead to a reduction in individuals' perceived wealth or the negative wealth effect, which may negatively impact consumer behavior. Their wealth is likely to diminish due to potential tax increases, as they

may choose to reduce their current spending. When a government increases its spending, it often competes for the same resources that private businesses would use. Therefore, government spending can lead to a crowding out of investments. Additionally, government spending shocks can influence monetary policy, potentially leading to lower interest rates. It can lead to higher economic growth, which may encourage the central bank to keep interest rates lower to support ongoing expansion or make borrowing more attractive. The real interest rate falls 40 basis points after the shock. The fall in consumption increases the marginal utility of consumption and induces the household to switch from consumption to leisure. Working hours, therefore, increase. For the sticky price, firms respond to the increase in demand by raising output. There is an increase in hours supplied, leading to a reduction in the real wage. However, the demand for labor increases, offsetting the decrease in the real wage, which in fact now increases. An increase in the level of labor supply, along with a decline in the capital stock, brings about a fall in Tobin's Q.

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 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 variations 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 persistence is large. For interest rate rule coefficients, if Thai inflation is lower than its target by 1 percent, the BoT reduces its policy rate by 20 basis points. However, if Thai output is lower than its potential level by 1 percent, the BoT reduces its policy rate by 2

basis points. The larger the value of α_π , the more responsive the BoT is to the deviation of inflation from its target.

The key monetary mechanism exists through changes in the real interest rate, which affects consumption and investment. The increase in the real interest rate leads households to attempt to postpone their consumption and motivates firms to cut their investments. A rise in interest rates might lead to a decrease in bond prices. This can reduce consumers' wealth, leading to a reduction in spending. A rise in interest rates might signal that the central bank expects higher inflation or slower economic growth. This can lead consumers to become more cautious about their spending. Also, capital is less sensitive to the interest rate in the presence of costs associated with the flow of investment. Therefore, consumption could be more sensitive to the interest rate than 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 a 2 percent deviation from its steady state, and decrease in inflation by nearly the percentage points from its steady state and a decrease in output by approximately by 0.08 percent deviation from its steady state, as depicted in Figure 2(c). As long as the central bank can 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, the price of capital and investment falls due to the impact.

In the case of cost push or markup shock, Figure 2(d) shows the impulse responses 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 four quarters after the impact. The real interest rate reduces 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 output. The central bank responds by raising the interest rate, but the size is relatively small.

Figure 2. The impulse responses

Figure 2(a). Effects of a technology shock

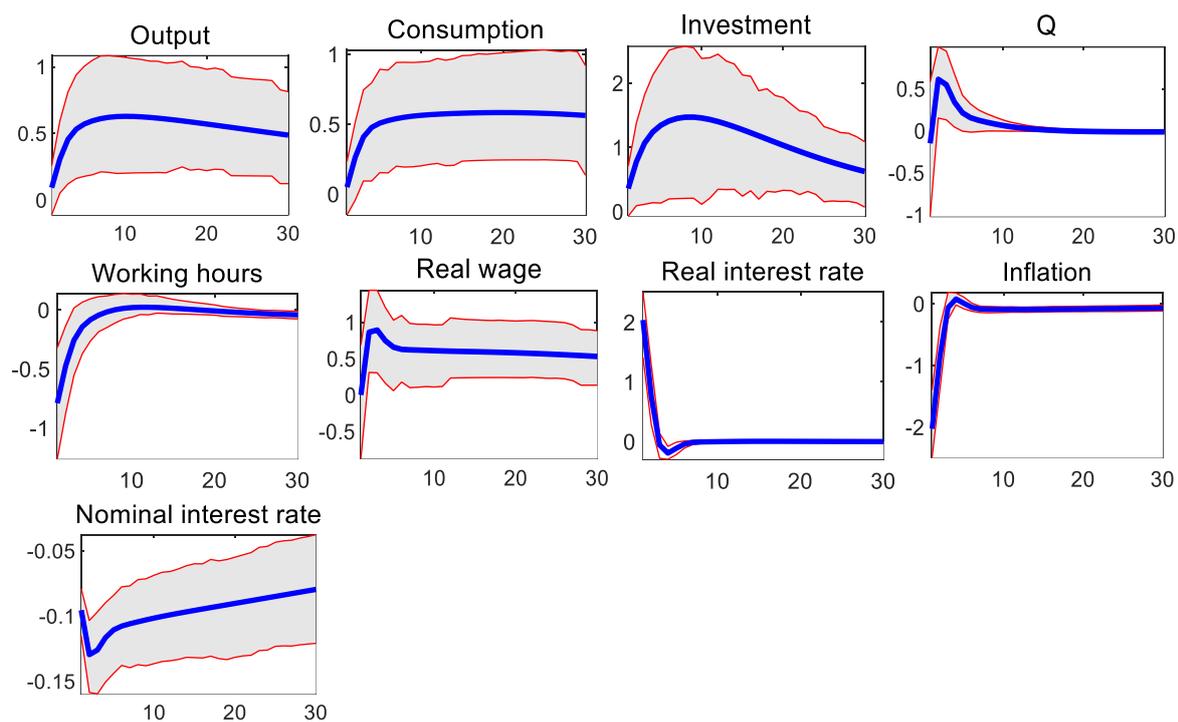


Figure 2(b). Effects of a government spending shock

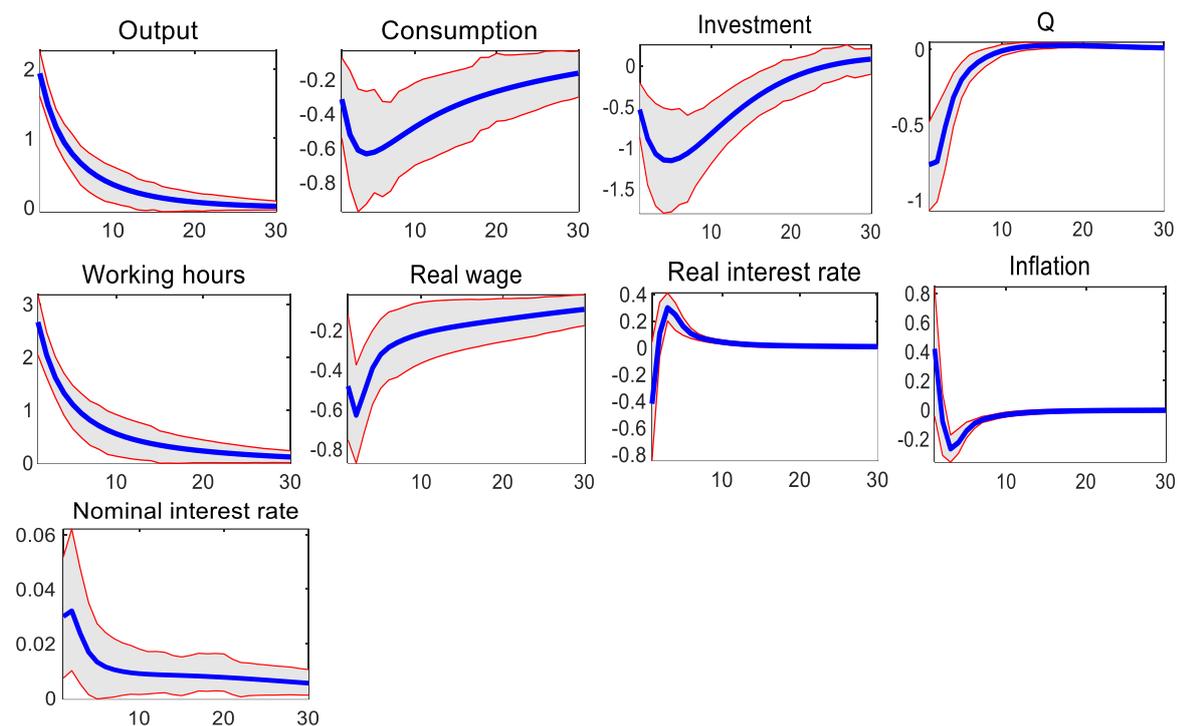
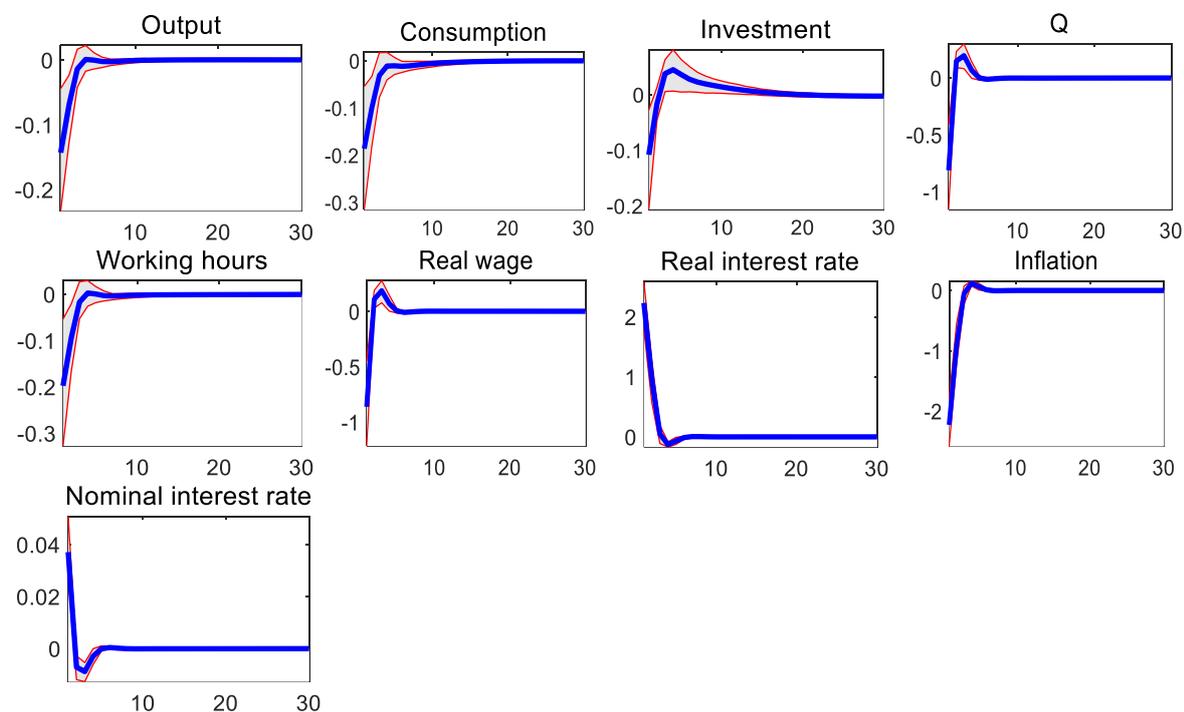
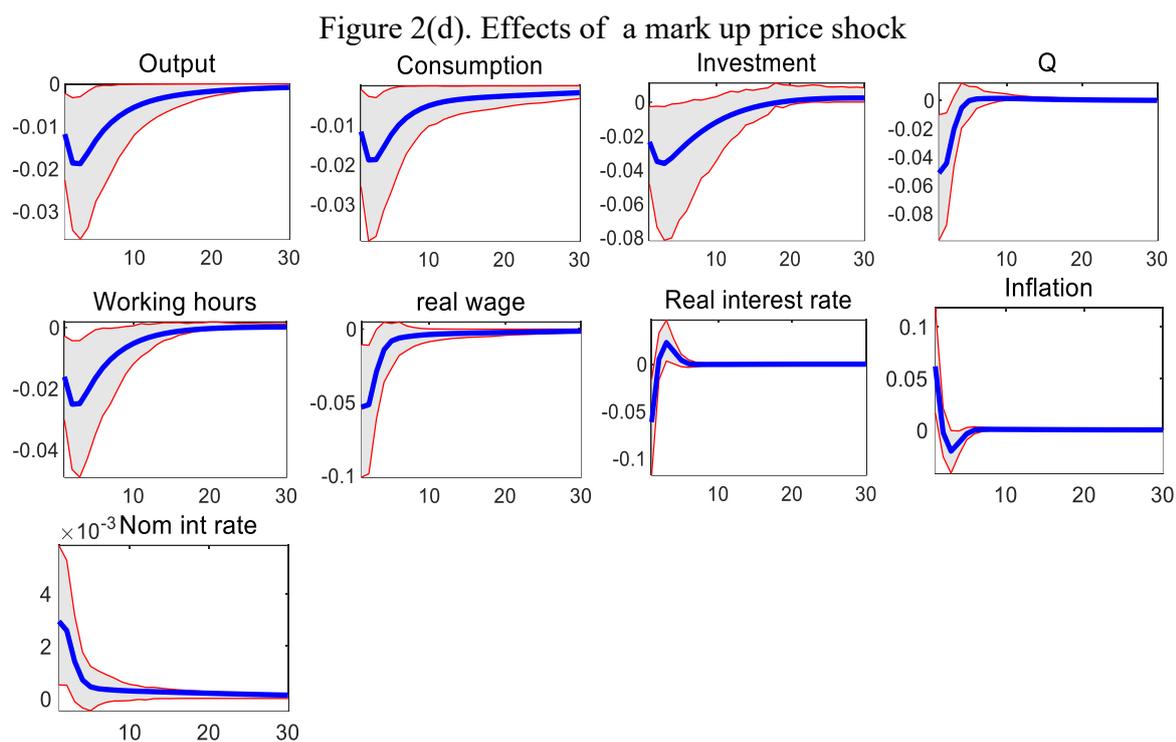


Figure 2(c). Effects of a monetary policy shock (interest rate rule)





Note: The estimated dynamic responses are generated by the Bayesian technique. The gray shaded areas provide the highest posterior density intervals HPDIs Bayesian confidence bands. The figure depicts posterior means and 90% credible bands. All variables are in the deviation from their steady state form. The vertical axis is percentage, and the horizontal axis is quarters.

6. The Inflation Targeting, Price Dispersion, and the Steady State

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 the steady state in order to analyze the effect of inflation targeting the Thai economy at its long-run level. Steady state inflation is equal to the exogenous inflation target π^* set by the BoT. 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, Δ as given below.

$$\frac{M}{MM} = \left(\frac{1 - \omega\pi^{*(\zeta-1)}}{1 - \omega} \right)^{\frac{1}{1-\zeta}} \quad (25)$$

$$MC = \left(1 - \frac{1}{\zeta} \right) \frac{M(1 - \beta\omega\pi^{*\zeta})}{MM(1 - \beta\omega\pi^{*(\zeta-1)})} \quad (26)$$

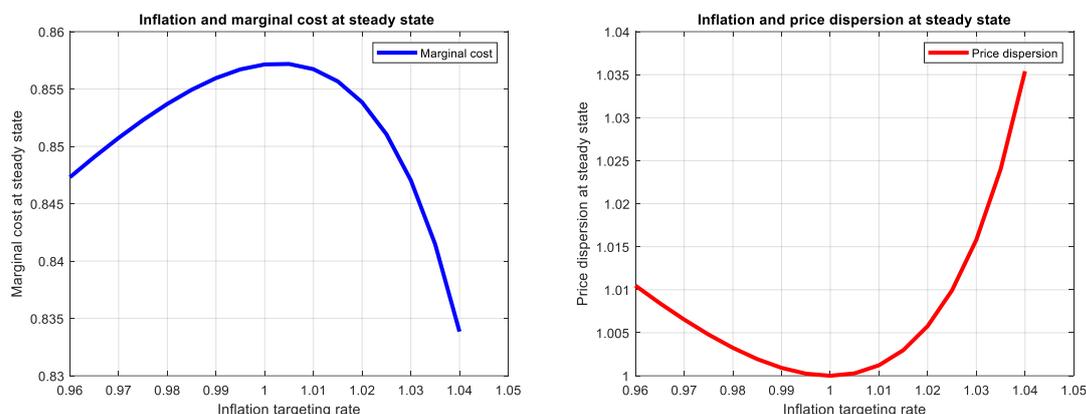
$$\Delta = \frac{(1 - \omega)^{\frac{1}{1-\zeta}} (1 - \omega\pi^{*\zeta-1})^{\frac{-\zeta}{1-\zeta}}}{1 - \omega\pi^{*\zeta}} \quad (27)$$

For zero inflation at the steady state, $\pi^* = 1$, we obtain $\frac{M}{MM} = \Delta = 1$ and $MC = \left(1 - \frac{1}{\zeta} \right)$. Nonetheless if $\pi^* > 1$, we obtain $MC < \left(1 - \frac{1}{\zeta} \right)$ and $\Delta > 1$. In other words, the model with trend inflation generates a 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 long run. Over the headline inflation targeting period from 2015-Q1 to 2019-Q1 in Thailand, the change in the hours worked is 0.34, and the government spending-output ratio is 0.17.³ The capital share in the production function is 0.7.

³ 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 days 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).

Figure 3 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 3.

Figure 3. Inflation targeting rate, the marginal cost, the price dispersion at steady state



Note: For zero inflation at the steady state, $\pi^* = 1$.

The marginal cost is equal to the inverse of the price markup. If $\pi^* > 1$, it is less than $\left(1 - \frac{1}{\zeta}\right)$, 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. 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 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 on aggregate output. Therefore, there is no price dispersion, and output is at the highest possible level.

Table 3. The effect of inflation targeting rate for Thai economy during headline inflation targeting $2.5\% \pm 1.5\%$

Inflation targets, π^*	The past inflation indexation				The average inflation indexation						
	2.5%	2.0%	1.5%	1.0%	2.5%		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	-3.16	-1.74	-0.84	-0.32	-0.29	-0.14	-3.16	-0.13	-0.04	-0.84	
Consumption	-2.63	-1.45	-0.71	-0.27	-0.22	-0.13	-2.63	-0.09	-0.04	-0.71	
Investment	-4.95	-2.70	-1.23	-0.46	-0.54	-0.19	-4.95	-0.24	-0.04	-1.28	
Gov. spending	-3.16	-1.73	-0.84	-0.31	-0.29	-0.14	-3.16	-0.12	-0.04	-0.84	
$\gamma_P = 0.5$											
Output	-1.29	-0.74	-0.37	-0.14	-0.69	0.00	-1.29	-0.30	0.00	-0.37	
Consumption	-1.08	-0.63	-0.32	-0.13	-0.53	0.00	-1.08	-0.22	0.00	-0.32	
Investment	-1.98	-1.12	-0.54	-0.19	-1.23	0.00	-1.98	-0.55	0.00	-0.54	
Gov. spending	-1.28	-0.74	-0.37	-0.14	-0.69	0.00	-1.28	-0.30	0.00	-0.37	
$\gamma_P = 0.7$											
Output	-0.37	-0.21	-0.11	-0.04	-1.18	-0.15	-0.37	-0.52	-0.06	-0.11	
Consumption	-0.32	-0.19	-0.10	-0.04	-0.92	-0.11	-0.32	-0.40	-0.04	-0.10	
Investment	-0.53	-0.30	-0.14	-0.04	-2.07	-0.28	-0.53	-0.94	-0.12	-0.14	
Gov. spending	-0.36	-0.22	-0.11	-0.04	-1.18	-0.15	-0.36	-0.52	-0.06	-0.11	

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

Table 3 compares the long-run values of the model with trend inflation and those of the model without trend inflation. The model with no trend inflation is the benchmark. It documents the effect of the inflation targeting rate and the past inflation indexation on the steady state for the Thai economy during headline inflation targeting from 2015-Q1 to 2019-Q1. 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 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 $\gamma_P = 0.5$, the 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 BoT 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 3 shows that if $\gamma_P = 0.5$, the steady state output is lower than its steady state level at no inflation 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, the table shows that the higher the degree of price indexation, the smaller the output is 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.

Moreover, Table 3 shows the effect of the inflation targeting rate and the average inflation indexation on the steady state for the Thai economy during headline inflation targeting 2015-Q1 to 2019-Q1. The experiment is that the prices are indexed to a weighted average of the 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 the 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 on 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, 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, the lower the steady state output from its steady state level, given no trend inflation.

7. Conclusion

It is clear that volatility and persistence of inflation have been reduced after inflation targeting in Thailand. 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 BoT is more responsive to the deviation of inflation from its target. If Thai inflation is lower than its target by 1 percent, the BoT 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.

There is a long-run negative inflation-output trade-off in the choice of a steady state inflation rate for the Thai economy. When the economy has a positive trend in inflation, the NAIRU theory does not hold in the long run. The divide coincidence does not hold because the policy trade-off exists. Typically, central banks use monetary policy to manage economic fluctuations and achieve price stability. Nonetheless, with trend inflation, the monetary policy that manages economic fluctuations may not guarantee maintaining price stability. When central banks conduct monetary policy analysis, it is therefore necessary to account for a positive trend in inflation. 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 BoT in December 2019 should be the proper policy.

In the end, since Thailand is a small open economy, it is worth emphasizing the impact of trend inflation in a small open economy. Although most models used in these studies are those of closed economy models, few work on open economy models to allow for trend inflation. Fernandez-Corugedo (2007) introduces trend inflation in both domestic and foreign economies. Recently, Zhao (2022) improved the previous model, providing the implications of trend inflation on the business cycle properties of open New Keynesian models in general. A domestic trend inflation increase leads to a domestic output loss and a relatively modest foreign output loss. Trend inflation affects the economy mainly through the standard channels of domestic price dispersion. In response to technology shocks, domestic trend inflation amplifies the spillover effects of a domestic technology shock on foreign countries. Trend inflation in foreign countries reinforces these spillover effects through the effect of price dispersion. For Thailand, the average import share as a percent of GDP from 2000 to 2019 was 0.6. A depreciation of the Thai Baht typically results in an increase in the prices of imports. If the Thai trend inflation increases, a depreciation of the Thai Baht crucially raises import prices and would stabilize the terms of trade. Nonetheless, the small open economy model with trend inflation of Thailand should be for future research and avenues for further exploration.

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Appendix I: The Model Specification

1. Households

1.1 Household Cost Minimization Problem

The Lagrangian function corresponding to this problem is:

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

The first order conditions for the minimization are given by:

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

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 :

$$P_t = \left(\int_0^1 P_t(i)^{1-\zeta} di \right)^{\frac{1}{1-\zeta}} \quad (A1)$$

where λ_t is the Lagrangian multiplier. The consumption demand for each differentiated good i can be written as:⁴

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\zeta} C_t \quad (A2)$$

⁴ The price elasticity of demand for goods i is ζ . If $\zeta \rightarrow \infty$, 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:

$$\begin{aligned} \mathcal{L} = & E_t \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \\ & + E_t \sum_{t=0}^{\infty} \beta^t \lambda_t (R_{t-1}B_{t-1} + r_t^K K_{t-1} + W_t(1 - L_t) - C_t - I_t - T_t - B_t) \\ & + E_t \sum_{t=0}^{\infty} \beta^t Q_t ((1 - \delta)K_{t-1} + (1 - \phi \left(\frac{I_t}{I_{t-1}} \right))I_t - K_t) \end{aligned}$$

First order conditions for maximization are given by:

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

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

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

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

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

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

$$\text{using } Q_t = q_t \lambda_t \text{ then}$$

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

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

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

$$U_{C,t} = R_t E_t [\beta U_{C,t+1}] \quad (A3)$$

$$\frac{U_{L,t}}{U_{C,t}} = W_t \quad (A4)$$

$$q_t = E_t \beta \frac{\lambda_{t+1}}{\lambda_t} (q_{t+1}(1 - \delta) + r_{t+1}^K) \quad (A5)$$

where $\Lambda_{t,t+1} = \beta \frac{U_{C,t+1}}{U_{C,t}}$ is the real stochastic discount factor over the interval $[t, t + 1]$. The rate of change of investment is $\frac{I_t}{I_{t-1}}$, and R_t^K is the gross return on capital and given by

$$R_t^K = \frac{q_t(1 - \delta) + r_t^K}{q_{t-1}} \quad (A6)$$

The Euler consumption equation (A3) is the marginal utility of consumption. It equates the marginal utility from consuming one unit of income in period t with the discounted marginal utility from consuming the gross income acquired R_t by saving the income. We can write the Euler consumption equation as

$$1 = R_t E_t [\Lambda_{t,t+1}] \quad (A7)$$

(A4) equates the real wage with the marginal rate of substitution between consumption and leisure. The first-order condition of investment is (A5). q_t is the Tobin's Q marginal ratio and is defined as $q_t = Q_t / \lambda_t$. The value of current installed capital q_t depends on its future expected value, taking into account the depreciation rate and the expected rate of return. With the nominal side of the model, we need to distinguish between the ex ante nominal gross interest rate $R_{n,t}$ set at time t and the ex post real interest rate R_t . These are related by the Fisher's equation

$$R_t = \frac{R_{n,t-1}}{\pi_t} \quad (A8)$$

The stochastic Euler equation must now take the form

$$U_{C,t} = \beta E_t [R_{t+1} U_{C,t+1}] = 1 \quad (A9)$$

which can be written as

$$1 = E_t [\Lambda_{t,t+1} R_{t+1}] \quad (A10)$$

Demand for capital by the wholesale firm owned by households equals to the supply of capital as

$$1 = E_t [\Lambda_{t,t+1} R_{t+1}] = E_t [\Lambda_{t,t+1} R_{t+1}^K] \quad (A11)$$

2. Firms

2.1 The Final Goods Firm Profit Maximization Problem

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

$$\text{Max } \pi_t = P_t Y_t - \int_0^1 P_t(i) Y_t(i) di$$

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:

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

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

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\zeta} Y_t \quad (A12)$$

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

2.2 The Wholesale Firm's Profit Maximization Problem

The Lagrangian function corresponding to this problem is:

$$\text{Max } \pi_t = P_t^W Y_t^W - P_t (W_t N_t + r_t^K K_{t-1})$$

The corresponding first-order conditions are:

$$\frac{\partial \pi_t}{\partial N_t}: \quad W_t = \alpha \frac{P_t^W Y_t^W}{P_t N_t} \quad (A13)$$

$$\frac{\partial \pi_t}{\partial K_{t-1}}: \quad r_t^K = (1 - \alpha) \frac{P_t^W Y_t^W}{P_t K_{t-1}} \quad (A14)$$

(A13) and (A14) describe the labor demand and capital demand respectively.

3. Price Dynamic

The retail firm's decision problem is to choose $P_t^*(i)$ to maximize its discounted real profits as below:

$$E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left(\frac{P_t^*(i)}{P_{t+k}} Y_{t+k}(i) - \varphi_{t+k} Y_{t+k}(i) \right)$$

Using the demand curve for good i (A7), the real profit is given by:

$$E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left(\left(\frac{P_t^*(i)}{P_{t+k}} \right)^{1-\zeta} - \varphi_{t+k} \left(\frac{P_t^*(i)}{P_{t+k}} \right)^{-\zeta} \right) Y_{t+k}$$

where ω^k represents the fraction of firms that do not adjust price, and φ_t is the real marginal cost. All firms adjusting in period t face the same problem, so all adjusting firms will set the same price. Since all firms face the same marginal cost, the i index is dropped. 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:

$$E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} \left((1 - \zeta) \left(\frac{P_t^*}{P_{t+k}} \right) + \zeta \varphi_{t+k} \right) \left(\frac{1}{P_t^*} \right) \left(\frac{P_t^*}{P_{t+k}} \right)^{-\zeta} Y_{t+k} = 0$$

The first order condition can be rearranged, further resulting in optimal pricing behavior of intermediate goods:

$$\frac{P_t^*}{P_t} = \frac{\zeta}{(\zeta - 1)} \frac{E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \varphi_{t+k} \left(\frac{P_{t+k}}{P_t} \right)^{\zeta}}{E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \left(\frac{P_{t+k}}{P_t} \right)^{\zeta-1}} \tag{A15}$$

We can write

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

Let

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

$$MM_t = E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t,t+k} Y_{t+k} \pi_{t,+k}^{\zeta-1}$$

The first-order conditions expressed as summations can be expressed as difference equations by using a useful lemma below

$$\Omega_t = E_t \sum_{k=0}^{\infty} \beta^k X_{t,t+k} Y_{t+k} = Y_t + \beta E_t [X_{t,t+1}, \Omega_{t,t+1}]$$

Therefore

$$M_t = \left(\frac{1}{1 - 1/\zeta} \right) \left[Y_t \varphi_t MS_t + \zeta E_t [\Lambda_{t,t+1} \pi_{t+1}^{\zeta} M_{t+1}] \right] \quad (A16)$$

$$MM_t = Y_t + \zeta E_t [\Lambda_{t,t+1} \pi_{t+1}^{\zeta-1} MM_{t+1}] \quad (A17)$$

Where MS_t is the markup shock.

For the basic linear NK model, it results in the 3 equations including the interest rate rule. If we linearize the firm optimal pricing behavior, we should have the Phillips curve. If we linearize the household optimal behavior, we should obtain the IS curve. However, for the more complicated model, it is convenient to non-linearly solve the model.

4. Price Dispersion

Defining Y_t^W as the aggregate factor inputs and using $N_t = \int_0^1 N_t(i) di$ yields the aggregate factor inputs:

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

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

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

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

$$Y_t^W = \left(\frac{P_t^0}{P_t}\right)^{-\zeta} Y_t = Y_t \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\zeta} di$$

Therefore, the equilibrium relation between aggregate demand and aggregate factor inputs is given by:

$$C_t + I_t + G_t = \left(\frac{P_t^*}{P_t}\right)^\zeta Y_t^W = \left(\frac{P_t^*}{P_t}\right)^\zeta (A_t N_t)^\alpha K_{t-1}^{1-\alpha} \quad (A18)$$

Notice that price stickiness causes an inefficiency through the price dispersion mechanism. The price dispersion is $\Delta_t = (P_t^*/P_t)^{-\zeta}$. We obtain

$$Y_t = \frac{(A_t N_t)^\alpha K_{t-1}^{1-\alpha}}{\Delta_t} \quad (A19)$$

Appendix II: The Non-linear Model Summary

The non-linear equilibrium conditions of the model take the following form:

$$U_t = \frac{((C_t - \chi C_{t-1})^{1-\varrho} (1 - N_t)^\varrho)^{1-\theta} - 1}{1 - \theta} \quad (B1)$$

$$U_{C,t} = (1 - \varrho)(C_t - \chi C_{t-1})^{(1-\varrho)(1-\theta)-1} (1 - N_t)^\varrho (1-\theta) \quad (B2)$$

$$U_{N,t} = -\varrho(C_t - \chi C_{t-1})^{(1-\varrho)(1-\theta)} (1 - N_t)^{\varrho(1-\theta)-1} \quad (B3)$$

$$\Lambda_{t,t+1} = \frac{\beta U_{C,t+1}}{U_{C,t}} \quad (B4)$$

$$1 = E_t[\Lambda_{t,t+1} R_t] \quad (B5)$$

$$R_t = \frac{R_{n,t-1}}{\pi_t} \quad (B6)$$

$$\frac{U_{N,t}}{U_{C,t}} = -W_t \quad (B7)$$

$$\Delta_t = \zeta \pi_t^\zeta \Delta_{t-1} + (1 - \zeta) \left(\frac{M_t}{M M_t}\right)^{-\zeta} \quad (B8)$$

$$Y_t = \frac{(A_t N_t)^\alpha K_{t-1}^{1-\alpha}}{\Delta_t} \quad (B9)$$

$$Y_t^W = (A_t N_t)^\alpha K_{t-1}^{1-\alpha} \quad (B10)$$

$$1 = q_t - q_t \phi \left(\frac{I_t}{I_{t-1}} \right) - q_t \frac{I_t}{I_{t-1}} \phi' \left(\frac{I_t}{I_{t-1}} \right) + E_t \beta \frac{\lambda_{t+1}}{\lambda_t} [q_{t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 \phi' \left(\frac{I_{t+1}}{I_t} \right)] \quad (B11)$$

$$1 = E_t [\Lambda_{t,t+1} R_{K,t}] \quad (B12)$$

$$\frac{P_t^W}{P_t} = \frac{W_t N_t}{\alpha \Delta_t Y_t} \quad (B13)$$

$$Y_t = C_t + G_t + I_t \quad (B14)$$

$$K_{t+1} = (1 - \delta) K_t + \left[1 - S \left(\frac{I_t}{I_{t-1}} \right) \right] I_t \quad (B15)$$

$$X_t = \frac{I_t}{I_{t-1}} \quad (B16)$$

$$S(X_t) = \phi_X(X_t - 1)^2 \quad (B17)$$

$$S'(X_t) = 2\phi_X(X_t - 1) \quad (B18)$$

$$G_t = T_t \quad (B19)$$

$$MM_t = Y_t + \omega E_t [\Lambda_{t,t+1} \pi_{t+1}^{\zeta-1} MM_{t+1}] \quad (B20)$$

$$M_t = \left(\frac{1}{1-1/\zeta} \right) Y_t \varphi_t MS_t + \omega E_t [\Lambda_{t,t+1} \pi_{t+1}^\zeta M_{t+1}] \quad (B21)$$

$$1 = \zeta \pi_t^{\zeta-1} + (1 - \zeta) \left(\frac{M_t}{MM_t} \right)^{1-\zeta} \quad (B22)$$

$$\varphi_t = \frac{P_t^W}{P_t} \quad (B23)$$

$$R_{t+1}^K = \frac{q_{t+1}(1 - \delta) + r_{t+1}^K}{q_t} \quad (B24)$$

$$\frac{P_t^*}{P_t} = \frac{M_t}{MM_t} \quad (B25)$$

$$\log \left(\frac{R_{n,t}}{R_n} \right) = \rho_r \log \left(\frac{R_{n,t-1}}{R_n} \right) + (1 - \rho_r) \alpha_\pi \log \left(\frac{\pi_t}{\pi} \right) + (1 - \rho_r) \alpha_y \log \left(\frac{Y_t}{Y} \right) \epsilon_{M,t} \quad (B26)$$

The exogenous shocks evolve according to

$$\log \left(\frac{A_t}{A} \right) = \rho_A \log \left(\frac{A_{t-1}}{A} \right) + \epsilon_{A,t} \quad (B27)$$

$$\log \left(\frac{G_t}{G} \right) = \rho_G \log \left(\frac{G_{t-1}}{G} \right) + \epsilon_{G,t} \quad (B28)$$

$$\log\left(\frac{MS_t}{MS}\right) = \rho_{MS} \log\left(\frac{MS_{t-1}}{MS}\right) + \epsilon_{MS,t} \quad (\text{B29})$$

This is 29 endogenous variables in 29 equations. The endogenous variables are $U_t, U_{C,t}, U_{N,t}, \Lambda_{t,t+1}, R_t, R_{n,t}, \pi_t, W_t, C_t, N_t, \Delta_t, Y_t, Y_t^W, R_{K,t}, \tau_t^K, \frac{P_t^W}{P_t}, I_t, G_t, K_t, X_t, S(X_t), S'(X_t), T_t, A_t, q_t, \varphi_t, M_t, MM_t$ and MS_t . The exogenous variables are $\epsilon_{M,t}, \epsilon_{A,t}, \epsilon_{G,t}$ and $\epsilon_{MS,t}$.

Appendix III: The Steady State Relationships

The steady state relationships are obtained from the equilibrium conditions by dropping the time subscript. The variables without the time t index denote the steady state counterpart of the dynamic variables.

$$\begin{aligned} N &= N_{SS} & A &= 1 & R &= 1/\beta \\ \frac{P^W}{P} &= 1 - \frac{1}{\zeta} & \frac{K}{Y} &= \frac{P^W(1-\alpha)}{P(R-1+\delta)} & \frac{I}{Y} &= \frac{P^W(1-\alpha)\delta}{P(R-1+\delta)} \\ \frac{C}{Y} &= 1 - \frac{I}{Y} - g_y & \varrho &= \frac{(1-N)}{\left[1 + N\left(\frac{\frac{C}{Y}(1-\chi)}{\frac{\alpha P^W}{P} - 1}\right)\right]} & \Delta &= 1 \\ Y^W &= AN\left(\frac{K}{Y^W}\right)^{\frac{1-\alpha}{\alpha}} & Y &= \frac{Y^W}{\Delta} & K &= \frac{K}{Y^W} Y^W \\ I &= \frac{I}{Y} Y & G &= g_y Y & W &= \alpha \frac{P^W}{P} \frac{Y^W}{N} \\ C &= \frac{C}{Y} Y & T &= G & \Lambda &= \beta \\ \frac{M}{MM} &= 1 & R^K &= R & R &= \frac{R_n}{\pi} \\ S &= 0 & S' &= 0 & q &= 1 \\ X &= 1 & \varphi &= \frac{P^W}{P} & \pi &= 1 \\ U &= \frac{((C - \chi C)^{1-\varrho}(1-N)^\varrho)^{1-\theta} - 1}{1-\theta} \\ U_C &= (1-\varrho)(C - \chi C)^{(1-\varrho)(1-\theta)-1}(1-N)^\varrho(1-\theta) \\ U_N &= -\varrho(C - \chi C)^{(1-\varrho)(1-\theta)}(1-N)^{\varrho(1-\theta)-1} \end{aligned}$$