Household heterogeneity and the price puzzle in the new Keynesian model

Daisuke Ida [*]

[*]Momoyama Gakuin University

September 9, 2022

Outline

Motivation

The objective of this paper is

to examine the role of household heterogeneity to explain and resolve the price puzzle without assuming the cost channel hypothesis.

- Does a contractionary monetary policy shock lead to a decline in inflation?
- Although the traditional monetary policy channel supports this view, the empirical studies using the VAR model observe the price puzzle.
- The price puzzle implies that a monetary tightening shock should generally cause an increase in inflation (Sims, 1992).
- Although the cost channel hypothesis is used to explain the price puzzle, both that hypothesis and the price puzzle may not be empirically supported since 1980s (Florio, 2018).
- How should we reconcile this inconsistent argument?

Motivation (Cont.)

- The objective of this paper is to theoretically show the occurrence of the price puzzle in the new Keynesian (NK) model without relying on the assumption of the cost channel.
- We show that whether monetary tightening shock causes a decline in inflation depends on household heterogeneities.
- Recently, the heterogeneities in households have been addressed in the NK model.
- The previous studies argued whether heterogeneities in households change the standard monetary transmission channel.

Motivation (Cont.)

- Specifically, we derive the condition to generate the price puzzle in two types of NK models that incorporate household heterogeneities.
- The first model is a so-called two-agent NK (TANK) model developed by Bilbiie (2008).
- The second model is an extension of the TANK model. Specifically, Bilbiie (2018) constructed the tractable heterogenous NK (THANK) model.
- We consider the price puzzle in these models. In particular, we check whether the results obtained in the TANK model carry over into the THANK model.

Main findings

1. In the TANK model, the price puzzle is more likely to occur as the share of liquidity constrained consumers increases. This result is carried over into the THANK model.

2. In this paper, we address the fact that the price puzzle can be explained theoretically without introducing the cost channel assumption.

3. Although in the TANK model the price puzzle occurs as a share of liquidity constrained consumers increases, such a share is not supported by empirical studies.

4. Thus, our results address an alternative interpretation of the price puzzle without considering the cost channel.

Related literature

1. Price puzzle: Empirical studies

2. Price puzzle: Theoretical studies

3. Household heterogeneity in the NK model

◯ Some remarks

- In the textbook NK model, like (Galí, 2015), a monetary contraction does not cause a price puzzle.

- An inclusion of the cost channel in the NK model helps to understand the theoretical explanation of the price puzzle.

- However, in contrast to this theoretical advantage, empirical studies does not necessarily the cost channel hypothesis.

The price puzzle: Empirical studies

- Barth III and Ramey (2001): supports cost channel
- Christiano *et al.* (2005): supports cost channel
- Castelnuovo (2007): Cost channel evidence?
- Rabanal (2007): does not support cost channel
- Florio (2018): almost no evidence for price puzzle after great inflation

At least since the 1980s, the price puzzle appears not to be supported.

The price puzzle: Theoretical studies based on NKM

- Ravenna and Walsh (2006): Cost channel and optimal policy
- Chowdhury *et al.* (2006): Cost channel and the price puzzle
- Ali and Anwar (2016): Cost channel in an open economy
- Qureshi and Ahmad (2021): Cost channel and trend inflation

A stronger cost channel easily causes the price puzzle.

However, as mentioned earlier, the cost channel hypothesis is not always consistent with the empirical studies. How do we reconcile this inconsistent argument? This paper focuses on the household heterogeneities.

Heterogeneities in the NKM

- TANK: Bilbiie (2008)
- Heterogenous NK (HANK): Kaplan *et al.* (2018)
- Tractable HANK (THANK): Bilbiie (2018)

How do heterogeneities in households affect monetary policy shock?

- Whether a monetary policy shock reduces the inflation rate depends strongly on the magnitude of household heterogeneity.
- In the TANK model, an increase in a liquidity constrained consumer dampens the expectations channel of monetary policy.
- In this case, a monetary contraction may cause inflation to rise rather than fall.

Contribution of our paper to previous studies: The role of TANK

- Bilbiie (2008): Considering indeterminacy problem in the TANK
- Colciago (2011): Solving indeterminacy problem in the TANK
- Galí *et al.* (2007): Solving the fiscal policy puzzle
- Bilbiie (2018): Analyzing the forward guidance puzzle

As far as we know, none of studies try to study the role of the TANK model to explain the price puzzle.

Main message

- A simple household heterogeneous NK model helps to explain why the price puzzle is likely to emerge during the 1970s and to disappear since the 1980s without introducing the cost channel.
- Thus, instead of assuming the cost channel the TANK model helps to understand the mechanism why inflation increases in response to a monetary contraction through an inverted DIS logic.

Benchmark model: TANK

Model summary: Bilbiie (2008)

- Two types of hoseholds: Ricardian $(1 - \gamma)$ and liquidity constrained households (γ)
- Since Ricardian households can freely access the financial asset markets, they can consider an intertemporal optimal allocation of consumption.
- Since liquidity constrained households cannot do so, their current consumption is restricted to current disposable income.

Characteristics of the TANK

- The inverted slope of a dynamic IS (DIS) curve is possible. Thus, the output gap increases in response to an increase in the real interest rate
- This case is likely to occur as γ increases.

As shown in Bilbiie (2008), the TANK model is summarized as follows:

$$x_t = E_t x_{t+1} - \alpha(i_t - E_t \pi_{t+1}) \tag{1}$$

$$\pi_t = \beta E_t \pi_{t+1} + \lambda(1 + \varphi)x_t \tag{2}$$

where x_t, π_t, and i_t denote the output gap, the inflation rate, and the interest rate, respectively. Equations (1) and (2) represent DIS curve and the new Keynesian Phillips curve (NKPC), respectively. λ is the slope of the NKPC and φ denotes the inverse of Frish elasticity.

Slope of DIS

$$\alpha = \frac{1 - \gamma}{1 - \gamma(1 + \varphi)}$$

The paramter γ denotes a share of liquidity constrained households.

If $1 - \gamma(1 + \varphi) < 0$, the inverted DIS is possible.

Monetary policy rule is given as follows:

$$i_t = \phi_\pi \pi_t + e_t \qquad (3)$$

where ϕ_π denotes the inflation stabilization coefficient in the Taylor rule. e_t denotes an exogenous monetary policy shock, which follows AR(1) shock process given by $e_t = \rho e_{t-1} + \epsilon_t^e$ with $0 \le \rho < 1$, where ϵ_t^e is an independent and identically distributed (i.i.d.) shock with constant variance σ_e^2.

MSV solution

$$\pi_t = -\frac{\lambda(1-\gamma)(1+\varphi)}{(1-\rho)(1-\rho\beta)(1-\gamma(1+\varphi)) + (\phi_\pi-\rho)\lambda(1-\gamma)(1+\varphi)}e_t \qquad (4)$$

Since the numerator is never negative, the condition that the denominator takes a negative value is required to generate a price puzzle.

The threshold γ^* becomes

$$\gamma^* = \frac{\lambda(1+\eta)(\phi_\pi - \rho) + (1-\rho)(1-\rho\beta)}{[(1-\rho)(1-\rho\beta) + (\phi_\pi - \rho)\lambda](1+\varphi)}. \tag{5}$$

I summarize the following results based on the threshold γ^*.

Proposition 1: The price puzzle in the TANK

When $\gamma > \gamma^*$, monetary tightening leads to an increase in inflation

Proposition 2: Sensitivity of the threshold γ^*: The role of ϕ_π

An increase in ϕ_π raises the threshold of γ.

This proposition states that since the stronger response of the interest rate to inflation increases the threshold γ^*, such a stronger interest rate reaction can prevent the price puzzle.

Proposition 3: Sensitivity of the threshold γ^*: The role of ρ

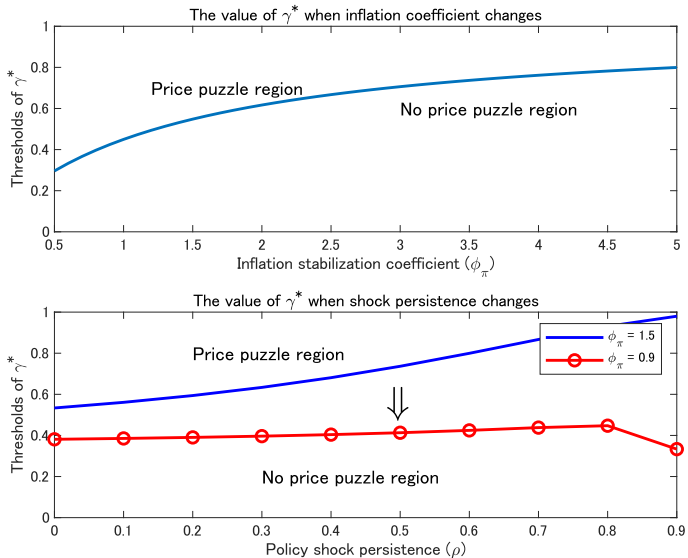If $\lambda\mathcal{A} + (1+2\rho\beta)\mathcal{B} < \beta\mathcal{B}$, an increase in ρ raises the threshold of γ, where

$$\mathcal{A} = (1-\rho)(1-\rho\beta)(2+\varphi) + 2\lambda(1+\varphi)(\phi_\pi - \rho) > 0$$
$$\mathcal{B} = (1-\rho)(1-\rho\beta)(1+(1+\varphi)^2) + 2\lambda(1+\varphi)(\phi_\pi - \rho) > 0$$

$\Diamond$ Implication from Propositions 1 - 3

- The occurrence of the price puzzle is possible even if the cost channel is absent.

- The central bank steadily prevents the occurrence of the price puzzle if stronger monetary tightening is introduced through a rise in ϕ_π.

Figure 1: Threshold of γ

◯ Interpretation: The value of ϕ_π

- If ϕ_π is less than unity, the price puzzle is likely to occur because of a decline in the threshold γ^*.

- The case of both a smaller value of ϕ_π and a larger value of γ can help the inflation dynamics during great inflation.

- This result is consistent with the discussion in Bilbiie (2008).

◯ Interpretation: The value of ρ

- A larger value of shock persistent can help to avoid the price puzzle because it increases the threshold γ^*.

- In other words, if the persistence of policy shocks is sufficiently large, the price puzzle can be mitigated along with the satisfaction of the Taylor principle.

- However, if the Taylor principle fails, the price puzzle is likely to occur regardless of the degree of policy shock persistence.
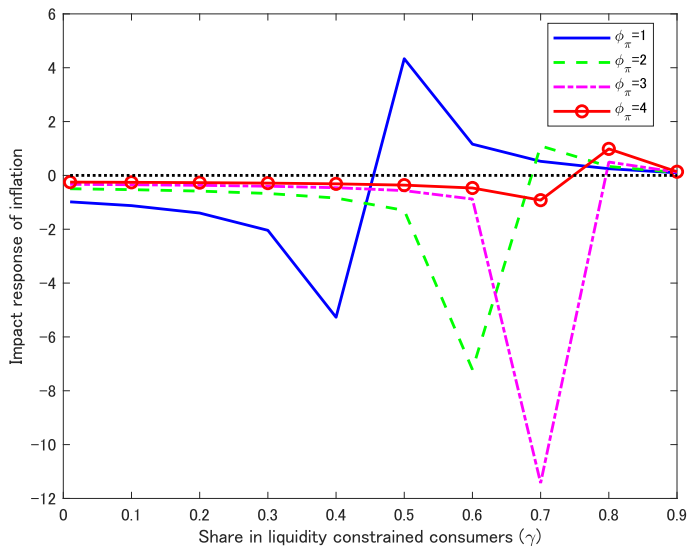
Figure 2: Impact response of inflation to policy shock: Change in ϕ_π

○ Implication from Figure 2

- Figure 2 shows the impact response of the inflation rate to a contractionary monetary policy shock.
- A smaller value of ϕ_π causes the price puzzle when γ takes a value above approximately 0.5.
- However, an increase in ϕ_π prevents the initial increase in the inflation rate unless the parameter γ extremely larger values.
- This extremely larger value is not supported by the empirical studies (Almgren *et al.*, 2019; Kaplan *et al.*, 2014).

Therefore, we can say that within the parameter ranges of γ supported by previous studies, the central bank prevents the price puzzle if they react aggressively to an increase in the inflation rate.

$\diamondsuit$ Economic intuition for Figure 2

- Why does a larger value of γ require to generate the price puzzle?
- A larger value of γ dampens the expectations channel of monetary policy through a change in the real interest rate.
- This also implies that the impact of monetary tightening on current inflation and the output gap becomes larger.
- Since a larger value of γ induces an inverted DIS curve, an increase in the real interest rate caused by a monetary contraction raises the output gap.
- A rise in the output gap results in an increase in inflation through the Phillips curve.
- Once γ approaches unity, however, the effect of monetary tightening on inflation disappears because the slope of the DIS becomes zero.
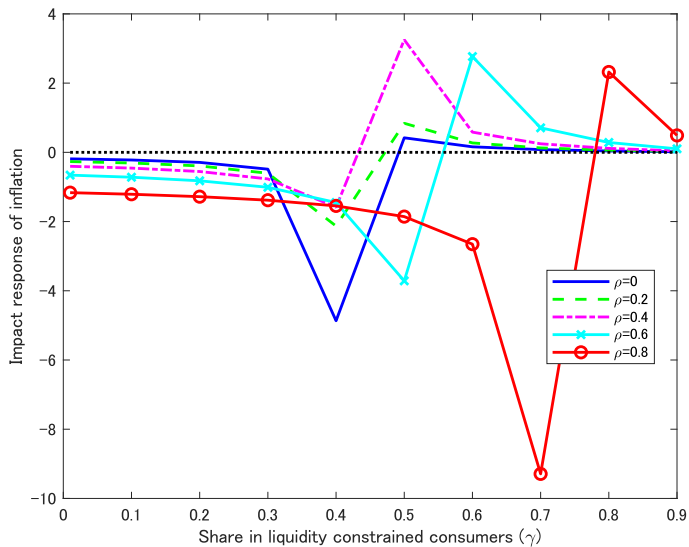
Figure 3: Impact response of inflation to policy shock: Change in ρ

◯ Implication from Figure 3

- Figure 3 illustrates the impact response of the inflation rate to a contractionary monetary policy shock when shock persistency ρ changes.
- A smaller value of ρ causes the price puzzle when γ takes a value above 0.5.
- As long as the value of ρ is less than 0.5, the central bank cannot prevent the price puzzle when γ is above 0.5.
- However, as the parameter ρ predominately takes a larger value, the price puzzle disappears unless the parameter γ extremely larger value.

Therefore, given the value of ϕ_π, the central bank can also prevent the price puzzle if the stronger persistence of monetary tightening shock is introduced.

◇ Economic intuition for Figure 3

- Given that the Taylor principle holds (i.e., $\phi_\pi = 1.5$), larger shock persistence should reinforce the effect of a monetary contraction on inflation.

- However, since the expectations channel of monetary policy is counteracted by an increase in γ, a weaker policy shock persistence does not prevent an increase in the inflation rate due to the inverted DIS.

- Therefore, to compensate lack of a monetary contraction, larger shock persistence is required to solve the price puzzle.

- Unfortunately, due to the inverted DIS, extremely large shock persistence again induces the price puzzle if a share in liquidity constrained consumers is predominately large.
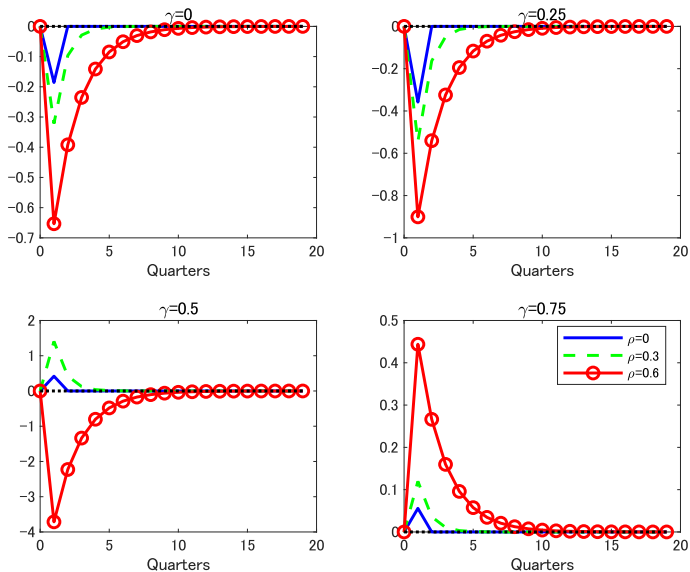
Figure 4: Impulse response of inflation to policy shock: Change in ρ

Interpretation of Figure 4

- Figure 4 illustrates the impulse response of the inflation rate to a contractionary monetary policy shock when shock persistency ρ changes.
- No price puzzle occurs in the standard NKM case ($\gamma = 0$)
- Even if a share in the liquidity constrained households is considered, the price puzzle does not occur if γ takes a smaller value.
- However, when $\gamma = 0.5$, the price puzzle occurs if ρ takes a value above 0.6.
- When $\gamma = 0.75$, the central bank cannot prevent the puzzle even in the case of $\rho = 0.6$.

Therefore, this paper concludes that the occurrence of price puzzle cannot be justified within plausible parameter ranges for γ.

Discussion

- Indeed, Bilbiie (2008) asserted that when the central bank failed to satisfy the Taylor principle, a sizable share of liquidity constrained households caused a high inflation during the 1970s.

- Clarida *et al.* (2000) also pointed out that the Federal Reserve Board (FRB) followed the central bank's reaction function that did not satisfy the Taylor principle.

- Several empirical studies have argued that the price puzzle disappears if we estimate the VAR model using a sample period starting in the 1980s, and the cost channel evidence has not been supported by any empirical studies since the 1980s.

Discussion (Cont.)

- Kaplan *et al.* (2014) pointed out that for the United States, Canada, Australia, the United Kingdom, Germany, France, Italy, and Spain, the share of households that face liquidity constraints is between 20% and 35%. Almgren *et al.* (2019) reported that the fraction of households that face liquidity constraints ranges from 10% in Malta to almost 65% in Latvia.

- Therefore, a value of γ that exceeds 0.5 appears not to be supported by the empirical analyses that estimate the share of liquidity-constrained consumers.

We can say that the emergence of the price puzzle that occurs with a greater value of γ is inconsistent with these previous empirical studies.

Alternative model: THANK

Model summary: Bilbiie (2018)

- Households participate infrequently in financial markets and freely adjust their portfolio when they do.

- When they do not, they receive only the payoff from previously accumulated bonds.

- There coexists saver (S) for participants and hand-to-mouth (H) for non-participants.

- The exogenous change of state follows a Markov chain: the probability to stay type S and H is respectively s and h, with transition probabilities $1 - s$ and $1 - h$.

- Firms face a monopolistically competitive environment and is subject to Calvo pricing.

See for Bilbiie (2018) and Bilbiie (2020) for a detailed model description about the THANK model.

Under THANK model, the DIS is now modified as follows:

$$x_t = \delta E_t x_{t+1} - \frac{1-\gamma}{1-\gamma\chi}(i_t - E_t\pi_{t+1}) \qquad (6)$$

where

$$\delta = 1 + (\chi - 1)\frac{1-s}{1-\gamma\chi}$$
$$\gamma = \frac{1-s}{2-s-h},$$
$$\chi = 1 + \varphi\left(1 - \frac{\tau_D}{\gamma}\right)$$

and τ_D denotes tax firm's profits, which is used as a fiscal policy tool for an endogenous redistribution scheme.

Characteristics of THANK: Some remarks (1)

- Although the direct effect of interest rates is measured by $1 - \gamma$, the indirect effect is increasing with γ at rate χ.
- with $\chi > 1$ the latter dominates, delivering amplification relative to RANK (dampening, for $\chi < 1$).
- $\gamma \chi$ is thus akin to an aggregate marginal propensity to consumption

Characteristics of THANK: Some remarks (2)

- The DIS is discounted when $\chi < 1$ or compounding when $\chi > 1$
- The slope of the DIS is more complicated than that in the TANK
- The shape of the NKPC remains unchanged

Special case of THANK: How does THANK relate to TANK?

When $s = h = 1$ and γ fixed at its initial free-parameter value

Following Bilbiie (2018), we regard the parameter γ as a share of liquidity constrained households to be consistent with the TANK model.

MSV solution

$$\pi_t = -\frac{\lambda(1-\gamma)(1+\varphi)}{(1-\gamma\chi)(1-\rho\delta)(1-\rho\beta) + (\phi_\pi - \rho)\lambda(1-\gamma)(1+\varphi)} e_t \quad (7)$$

Since the numerator is never negative, the condition that the denominator takes a negative value is required to generate a price puzzle. Thus, we have

Proposition 4: Price puzzle in the THANK model

If $(\gamma\chi - 1)(1-\rho\delta)(1-\rho\beta) > (\phi_\pi - \rho)\lambda(1-\gamma)(1+\varphi)$, the price puzzle occurs in the THANK model.

Unfortunately, we cannot analytically derive the threshold of γ in the THANK model. Therefore, in the following explanation, we numerically consider the occurrence of the price puzzle in the THANK model.
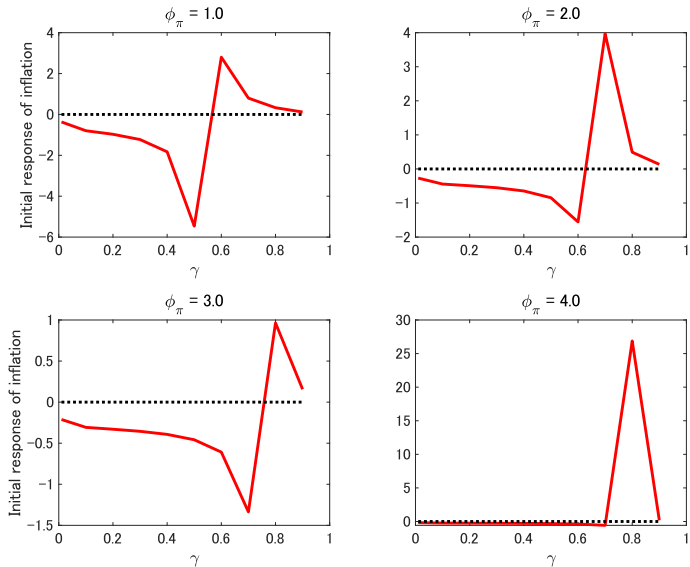
Figure 5: Impact response of inflation to policy shock: THANK model

○ Interpretation of Figure 5

- Figure 5 plots the impact response of inflation to a monetary tightening shock for the THANK model.
- Like the TANK model, the price puzzle is also observed in the TANK model with a larger value of γ.
- However, the threshold for γ is greater for the THANK model than for the TANK model when $\phi_\pi = 1.0$.
- In contrast to the TANK model, it appears that the THANK model shows a larger increase in inflation after a monetary contraction than the TANK model.
- In particular, the severe price puzzle emerges in the THANK model when $\phi_\pi = 4.0$.

Summing up, the response of inflation to a monetary contraction is much smaller in the THANK model than in the TANK model when ϕ_π is less than 4.0.
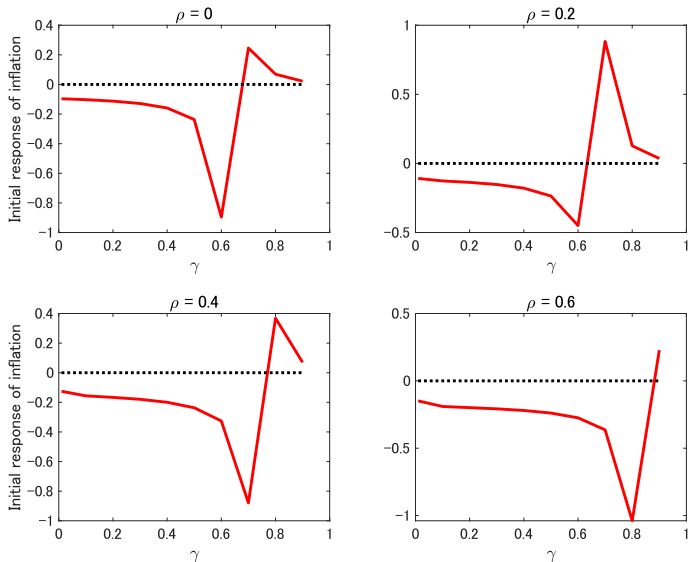
Figure 6: Impact response of inflation to policy shock in the THANK model: $\phi_\pi = 1.5$

◯ Interpretation of Figure 6

- Figure 6 illustrates the impact response of inflation to a monetary tightening shock for the case of the THANK model under several parameterization of shock persistence ρ.

- Like the TANK model, the price puzzle is also observed in the THANK model with a larger value of γ.

- However, unlike the case for a change in ϕ_π, the threshold for γ seems to be greater for the THANK model than for the TANK model regardless of the degree of policy shock persistence.

- In contrast to the TANK model, the THANK model shows a smaller increase in inflation after a monetary contraction than the TANK model when the parameter ρ changes.

Finally, we illustrate the impulse response of inflation to a contractionary policy shock in the THANK model.
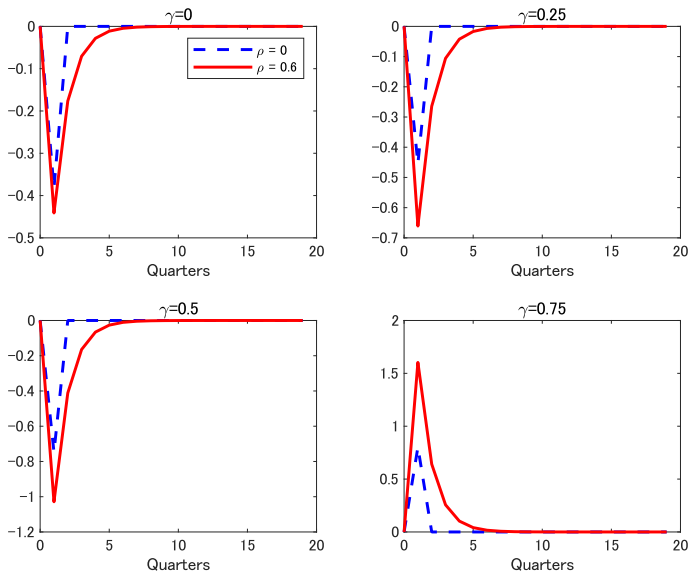
Figure 7: Impulse response of inflation to policy shock in the THANK model

○ Interpretation of Figure 7

- The price puzzle disappears as long as the parameter γ is less than 0.5.

- Regardless of whether we introduce the presence of policy shock persistence, the response of inflation becomes positive when $\gamma = 0.75$.

◇ Main message

- The condition that the price puzzle occurs in the TANK model carries over into the THANK model.

- The threshold of γ appears to be larger in the case of the THANK model than that of the TANK model.

- Thus, the main findings from the previous section are robust to an alternative specification of the TANK model.

Conclusions

1. In this paper, we address the fact that the price puzzle can be explained theoretically without introducing the cost channel assumption.

2. To do so, we consider the effect of a contractionary policy shock on inflation in both TANK and THANK models.

3. In the TANK model, the price puzzle is more likely to occur as the share of liquidity constrained consumers increases. This result is carried over into the THANK model.

4. Thus, our results address an alternative explanation of the price puzzle without considering the cost channel.

References I

ALI, S. Z. and ANWAR, S. (2016). Can exchange rate pass-through explain the price puzzle? *Economics Letters*, **145**, 56–59.

ALMGREN, M., GALLEGOS, J. E., KRAMER, J. and LIMA, R. (2019). Monetary policy and liquidity constraints: Evidence from the euro area. *Available at SSRN 3422687*.

BARTH III, M. J. and RAMEY, V. A. (2001). The cost channel of monetary transmission. *NBER macroeconomics annual*, **16**, 199–240.

BILBIIE, F. O. (2008). Limited asset market participation, monetary policy and (inverted) aggregate demand logic. *Journal of Economic Theory*, **140**, 162–196.

— (2018). Monetary policy and heterogeneity: An analytical framework. *Available at SSRN 3106805*.

— (2020). The new keynesian cross. *Journal of Monetary Economics*, **114**, 90–108.

CASTELNUOVO, E. (2007). Cost channel and the price puzzle: The role of interest rate smoothing. *Unpublished manuscript, University of Padua*.

CHOWDHURY, I., HOFFMANN, M. and SCHABERT, A. (2006). Inflation dynamics and the cost channel of monetary transmission. *European Economic Review*, **50** (4), 995–1016.

CHRISTIANO, L. J., EICHENBAUM, M. and EVANS, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of political Economy*, **113** (1), 1–45.

CLARIDA, R., GALI, J. and GERTLER, M. (2000). Monetary policy rules and macroeconomic stability: evidence and some theory. *The Quarterly journal of economics*, **115** (1), 147–180.

References II

COLCIAGO, A. (2011). Rule-of-thumb consumers meet sticky wages. *Journal of money, credit and banking*, **43** (2-3), 325–353.

FLORIO, A. (2018). Nominal anchors and the price puzzle. *Journal of Macroeconomics*, **58**, 224–237.

GALÍ, J. (2015). *Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications*. Princeton University Press.

GALÍ, J., LÓPEZ-SALIDO, D. J. and JAVIER, V. (2007). Understanding effects of government spendig on consumption. *Journal of European Economic Association*, **5** (1), 227–270.

KAPLAN, G., MOLL, B. and VIOLANTE, G. L. (2018). Monetary policy according to hank. *American Economic Review*, **108** (3), 697–743.

—, VIOLANTE, G. L. and WEIDNER, J. (2014). *The wealthy hand-to-mouth*. Tech. rep., National Bureau of Economic Research.

QURESHI, I. A. and AHMAD, G. (2021). The cost-channel of monetary transmission under positive trend inflation. *Economics Letters*, **201**, 109802.

RABANAL, P. (2007). Does inflation increase after a monetary policy tightening? answers based on an estimated dsge model. *Journal of Economic Dynamics and control*, **31** (3), 906–937.

RAVENNA, F. and WALSH, C. E. (2006). Optimal monetary policy with the cost channel. *Journal of Monetary Economics*, **53** (2), 199–216.

SIMS, C. A. (1992). Interpreting the macroeconomic time series facts: The effects of monetary policy. *European economic review*, **36** (5), 975–1000.