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Observed inflation-target adjustments in an estimated DSGE model for Indonesia: Do they matter for aggregate fluctuations?*

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Abstract

This paper investigates the role of observed official inflation-target adjustments in aggregate macroeconomic fluctuations in Indonesia, using an estimated Dynamic Stochastic General Equilibrium (DSGE) model. The paper finds that these adjustments or shocks play a non-trivial role in the fluctuations of inflation and nominal interest rate in Indonesia. Output fluctuations, however, are virtually unaffected. A counterfactual exercise shows that a gradual reduction in Bank Indonesia's inflation target may have not been optimal. The paper also provides additional insights on the contribution of various shocks in driving aggregate fluctuations in Indonesia. Technology and monetary-policy shocks are found to be the main driving factor for both output and inflation fluctuations. Movements in the nominal interest rate are mostly driven by preference and risk-premium shocks, with inflation-target shocks playing a larger role in the longer run. The inclusion of inflation-target shocks in the model is also shown to improve the model's fit and out-of-sample predictive performance.

JEL Classification: E12; E32; E58; E61; F41

Keywords: Inflation target, inflation-target adjustments or shocks, DSGE model for Indonesia, source of aggregate fluctuations, Bank Indonesia

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1 Introduction

Under an inflation-targeting framework, the central bank in general has the ability to choose the appropriate inflation rate to target. The US Federal Reserve aims for a 2% inflation target, the European Central Bank considers a rate below, but close to, 2% as being appropriate, while the Reserve Bank of Australia settles for a 2-3% target over the medium term. In most cases, the target inflation is chosen at the start of the formal implementation of the inflation targeting regime and kept the same thereafter. Bank Indonesia—the central bank of Indonesia—however, has chosen to follow a different strategy since it first started announcing its inflation target to the public back in late 2000. As shown in Figure 1, since 2000 Bank Indonesia (BI) has adjusted its official inflation target by a total of twelve times, with seven of them happened during the full-fledged inflation-targeting framework (ITF) period (2005.Q3 onward). These adjustments were made based on the state and condition of the economy at the time, and were likely part of a gradual disinflation process towards achieving a low and stable long-run inflation rate.[1] Along with the downward trajectory of the inflation target, both inflation and the nominal interest rate (or the BI rate) appear to trend downward as well.

This observation raises a question of whether the inflation-target adjustments made by BI play a role in driving aggregate economic fluctuations in Indonesia. And if they do, how much do these adjustments matter? How different would the paths of inflation, nominal interest rate, and output be if Bank Indonesia had followed a different adjustment strategy? I answer these questions within a Dynamic Stochastic General Equilibrium (DSGE) model, fitted to a number of key macroeconomic time series for Indonesia, including Bank Indonesia's official inflation target measures. The small open-economy model is estimated using Bayesian estimation techniques and modified to allow for a meaningful role for inflation-target adjustments. The use of an estimated DSGE model is essential, as it allows us to identify the shocks hitting the economy and to disentangle the effect of inflation-target adjustments or shocks on aggregate fluctuations from the contribution of other structural shocks. It also permits the investigation of alternative paths of inflation-target adjustments

[1] See Harmanta, Bathaluddin and Waluyo (2011) and Wimanda, Prasmoko and Oktiyanto (2011) for discussions on the characteristics of inflation and the disinflation process in Indonesia.

using counterfactual exercises.

I find that observed inflation-target adjustments play a non-trivial role in driving inflation and nominal interest rate fluctuations. The forecast error variance decompositions reveal that these shocks explain between 20-43% of fluctuations in the BI rate during the full-fledged ITF period, depending on the forecast horizons. For inflation, inflation-target shocks account for up to 12% of the fluctuations. These findings are confirmed by their respective historical shock decomposition. Movements in aggregate output (GDP per capita), however, are not meaningfully affected by the inflation-target shocks. The counterfactual exercises further corroborate these findings. Both the inflation rate and the BI rate would have been a full 2% higher in 2017.Q1 if BI had instead decided to maintain its inflation target at 6% per annum. On the other hand, if BI had alternatively chosen to lower the inflation target immediately to 4% per year—the actual target in 2017.Q1—in 2005.Q3, both rates would have been around 1% lower on average, with virtually no output loss. The latter finding provides some support to a fast disinflation process, over the gradualist approach.

Along with main findings described above, the paper also addresses the sources of aggregate macroeconomic fluctuations in Indonesia. Technology and monetary-policy shocks are found to be the main driving factor for both output and inflation fluctuations. Movements in the nominal interest rate are mostly driven by preference and risk-premium shocks, with inflation-target shocks playing a larger role in the longer run. These additional findings, within the context of being produced by an estimated DSGE model for Indonesia, are currently lacking in the literature, aside from Dutu (2016) who provides the historical shock decomposition of output growth. These findings thus provide additional insights and contributions to the understanding of the source of aggregate fluctuations in Indonesia.

1.1 Related literature and contribution

This paper contributes to two strands of literature. The first literature concern the incorporation of time-varying inflation targets into DSGE models, in both their estimated and calibrated variants. A non-exhaustive list of studies along this dimension includes Smets and Wouters (2003), Ireland (2007), Cogley, Primiceri and Sargent (2010), Fève, Matheron and Sahuc (2010), Del Negro and Eusepi (2011), Del Negro, Giannoni and Schorfheide (2015), Bhattarai, Lee and Park (2016), and Eo and Lie (2017, 2018). What is unique about this paper is its use of actual data on official inflation-target adjustments made by a central bank (i.e. Bank Indonesia) as part of the observables used in the (Bayesian) estimation procedure. In most existing studies in the literature, inflation target and its adjustments (if any) are treated as being unobserved. Even when they are treated as part of the observables, long-run inflation expectations data are usually used to proxy for the time-varying inflation targets (see e.g. Del Negro and Eusepi (2011) and Del Negro, Giannoni and Schorfheide (2015)). The use of observed inflation-target adjustments data allows for a precise identification of the inflation-target shocks, especially in terms of distinguishing them from the conventional monetary-policy shocks.

The paper also makes contribution to the literature on the DSGE modelling for Indonesia to understand various policy issues and their implications. Interests on this literature have been ramped up by Bank Indonesia's (and to some extent, the Ministry of Finance's) increasing need for a good-fitting and reliable DSGE model to be used for forecasting and policy simulations. Not surprisingly, there is a growing list of recent studies on calibrating and estimating DSGE models for Indonesia to analyze various issues: among others, Joseph, Dewandaru and Ari (2003), Joseph, Dewandaru and Gunadi (2003), Alamsyah (2004), Hutabarat (2010), Tjahjono and Waluyo (2010), Harmanta et al. (2013), Harmanta, Purwanto and Oktiyanto (2014), Dutu (2016), and Sahminan et al. (2017). Aside from Dutu (2016), none of the existing studies considers inflation-target adjustments — they simply assume that the inflation target is constant. None of them investigates the role of inflation-target adjustments in driving aggregate fluctuations. Dutu (2016) estimates a DSGE model for Indonesia with time-varying inflation targets, but the study is mostly interested in looking at the driving factor behind the slowdown in Indonesia's economic growth and it does not fit the model to the observed Bank Indonesia's official inflation target.

In addition to the above contribution, the paper also shows that the inclusion of inflation-target adjustments or shocks and their direct effects improves the model's fit and out-of-sample predictive performance. The marginal likelihood of this model is higher compared to the standard model without inflation-target adjustments. The inclusion of a money-holding friction into the model also turns out to be warranted. The model can thus be used as a standard model or as a starting point to develop DSGE models for Indonesia with useful additional features, such as financial frictions and macroprudential policies.

The rest of the paper is organized as follows. Section 2 presents the DSGE model to be estimated. Section 3 describes the data and priors and presents the posterior estimates. This section also provides the main analysis on the role of inflation-target adjustments in driving aggregate fluctuations. Section 4 performs counterfactual exercises and provides an extension. Section 5 concludes.

2 The estimated model

The model is a standard small open-economy (SOE) model along the lines of Gali and Monacelli (2005), Monacelli (2005), Lubik and Schorfheide (2007), Del Negro, Schorfheide et al. (2009), and Justiniano and Preston (2010). In particular, I closely follow the model specification in Justiniano and Preston (2010), but with two important extensions. The first extension involves the inclusion of potential adjustments in the central bank's inflation target. This time-varying target or trend inflation features in the monetary policy rule and is internalized into firms' pricing decision and hence, directly affects the aggregate price level. In the second extension, I assume that there is a money-holding friction due to a cash-in-advance (CIA) constraint.[2,3] This additional friction is motivated by the fact that Indonesia is still pretty much a cash-oriented society, despite recent efforts by various government entities to promote cashless transactions.[4] Records from Bank Indonesia (BI) show that in 2015 almost 90% of all transactions in Indonesia are cash transactions.[5]

With the exception of the time-varying inflation target, the model's features and assumptions are standard in the literature — hence, the detail and derivation of the non-linear model are relegated to an (online) Appendix. Here, I only describe the overall feature of the model, focusing on how the inflation-target adjustments are incorporated into the model. I

[2]See e.g. Lucas (1980) or Schmitt-Grohé and Uribe (2007) for the use of a CIA constraint to introduce a money-holding friction.

[3]Standard DSGE models, including those with small-open economy features, are usually *cashless* models, where money functions only as a unit of account.

[4]For example, in August 2014 Bank Indonesia launched "Gerakan National Non Tunai" (Task Force for Financial Inclusion and Electronification) to promote cashless transactions.

[5]See http://en.tempo.co/read/news/2015/04/24/056660543/

then proceed to describing the log-linearized model, used in the estimation.

2.1 The non-linear model

The model economy is a medium-scaled SOE DSGE model, consisting of a domestic (home) country and a foreign country or economy. The domestic economy consists of a representative household, a continuum of monopolistically-competitive firms producing differentiated varieties, a continuum of retail firms or importers, and a monetary policy authority. The size of the foreign economy (or the rest of the world) is considered much larger compared to the domestic economy that it is essentially a closed economy. Aggregate stochastic fluctuations are driven by 9 exogenous shocks: technology, preference, cost-push, monetary-policy, risk-premium, foreign-output, foreign-inflation, foreign interest-rate, and inflation-target shocks. The asset markets are incomplete.

Households maximize their lifetime utility subject to a standard flow budget constraint. In each period, they choose the optimum amount of consumption and labor effort and purchase domestic and foreign one-period nominal bonds. The aggregate consumption index is a composite of domestically- and foreign-produced goods, which are in turn a CES (constant elasticity of substitution) of intermediate-good varieties of each respective origin. Consumption purchase is subject to a CIA constraint,

$$M_t \geq \nu^h P_t C_t \ ,$$

where M_t, P_t, and C_t denote the amount of money holding, aggregate consumer price index (CPI) or level, and aggregate consumption, respectively. The parameter ν^h can be interpreted as the fraction of consumption purchased using money or cash. Households derive incomes from their labor effort and lump-sun government transfers and receive profits generated by domestic producers and importers. There is a degree of internal habit formation in the households' consumption decision. The intertemporal decision by households is subject to a preference shock.

Each monopolistically-competitive domestic producer produces a differentiated domestic variety $i \in [0, 1]$ using labor as the only input into production. The production function is subject to an aggregate technology shock. These producers satisfy both domestic and foreign demands for their products. Each domestic producer is a profit maximizer, but it faces an infrequent opportunity to optimally adjust its price à la Calvo (1983). At any given point in time in which producers are not allowed to adjust prices optimally, they simply index their prices to a mixture of the past producer-price inflation and *current* inflation target, with relative weights given by δ_H and $1-\delta_H$, respectively. An adjustment (or anticipated adjustment) in the inflation target by the central bank is thus internalized into domestic producers' (and importers') pricing decision. Note that the composite domestically-produced goods is a CES aggregation of these differentiated domestic varieties.

Importers purchase foreign varieties, $j \in [0,1]$, to be sold in the domestic market. The law of one price (LOP) is assumed to hold at the dock for each of these varieties. However, each importer has some monopoly power in the domestic market, and hence, charge a positive mark-up, i.e. there is a deviation from the LOP at the retail level. Similar to domestic producers, importers face an infrequent optimal price adjustment à la Calvo and face a similar price-indexation mechanism, but with a mixture of past import-price inflation and current inflation target, with relative weights given by δ_F and $1-\delta_F$, respectively. The composite foreign goods in the aggregate consumption index is a CES aggregation of these foreign varieties.

Monetary-policy rule and the evolution of inflation target The central bank conducts policy according to a Taylor-type rule,

$$\frac{i_t}{\bar{\imath}_t} = \left(\frac{i_{t-1}}{\bar{\imath}_{t-1}}\right)^{\rho_i} \left[\left(\frac{\Pi_t}{\overline{\overline{\Pi}}_t}\right)^{\psi_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\psi_y} \left(\frac{Y_t}{Y_{t-1}}\right)^{\psi_{\Delta y}} \left(\frac{\tilde{e}_t}{\tilde{e}_{t-1}}\right)^{\psi_e} \right]^{1-\rho_i} \exp(\tilde{\varepsilon}_{M,t}) \ , \tag{1}$$

where i_t is the nominal interest rate, Π_t is (gross) inflation, Y_t is output, and $\tilde{e}_t$ is the nominal exchange rate (home-currency price of foreign currency). $\tilde{\varepsilon}_{M,t} \sim i.i.d.\ N(0, \sigma_M^2)$ is the conventional monetary-policy shock. Hence, the central bank is assumed to adjust the nominal rate in response to the deviation of inflation from its target ($\overline{\Pi}_t$), deviation of output from the steady state ($\bar{Y}$), output growth, and nominal exchange-rate depreciation — the feedback coefficients are ψ_π, ψ_y, ψ_{Δ_y}, and ψ_e, respectively. There is a degree of interest-rate smoothing, reflected by the parameter $\rho_i \in [0, 1)$. As described in the appendix, the time-varying nature of inflation target imparts time variation in the (target) nominal interest rate in the medium run.

What is non-standard about (1) is the assumption that the inflation target is potentially time-varying and subject to adjustments. Specifically, it follows a first-order stationary autoregressive process (AR(1)),

$$\log(\overline{\Pi}_t) = (1 - \rho_{\overline{\pi}}) \log(\overline{\Pi}) + \rho_{\overline{\pi}} \log(\overline{\Pi}_{t-1}) + \tilde{\varepsilon}_{\overline{\pi},t} \ , \tag{2}$$

where $\rho_{\overline{\pi}} \in [0, 1)$, $\tilde{\varepsilon}_{\overline{\pi},t} \sim i.i.d.\ N(0, \sigma^2_{\pi^*})$ is the inflation-target (IT) shock and $\overline{\Pi}$ is the constant, long-run steady-state inflation target. This specification follows that in Smets and Wouters (2003), Cogley, Primiceri and Sargent (2010), Del Negro, Giannoni and Schorfheide (2015), Bhattarai, Lee and Park (2016), and Eo and Lie (2018), which assume a stationary, but highly persistent (near unit-root) process. In an estimated DSGE model for Indonesia, Dutu (2016) also assumes a stationary AR(1) process for the inflation target. An alternative specification is to assume a pure random walk process for the inflation target, as in Ireland (2007) and Fève, Matheron and Sahuc (2010), for example.[6] Past official inflation-target adjustments made by BI, however, are best characterized as non-permanent adjustments, as the official target is usually reviewed by BI and is subject to change every year. Harmanta, Bathaluddin and Waluyo (2011) describe that the yearly inflation target set by BI is meant to be a short-term target, intended as a part of a gradual disinflation process towards a low and stable long-run inflation rate and to enhance the credibility of BI in fighting and stabilizing inflation.

I note that the assumption in (2) that inflation-target adjustments are exogenous is a common approach in the literature and is meant to be a short cut. One can instead, rightfully, interpret these adjustments as being endogenous, e.g. as part of the central bank's learning process on the nature of inflation dynamics or as part of a longer-term, gradual disinflation process.[7] This paper is taking an agnostic view regarding the endogenous mechanism and

[6] Cogley and Sargent (2005) also assume that trend inflation follows a random walk process in their time-varying Bayesian VAR. See also Cogley and Sbordone (2008) and Lie and Yadav (2017) for a similar treatment.

[7] See e.g. Primiceri (2006) and Milani (2009) for the learning explanation.

leaves the issue for future research.

2.2 The linearized model

In the linearized version of the model described below, the notation $\hat{x}_t$ denotes the *log* deviation of any variable x_t from its steady state or trend, except for inflation and interest-rate variables, which are in *level* deviation from their respective steady-state values. Five nominal variables—CPI-inflation ($\hat{\pi}_t$), producer-price inflation ($\hat{\pi}_{H,t}$), import-price inflation ($\hat{\pi}_{F,t}$), the nominal exchange-rate growth or depreciation ($\hat{e}^c_t$), and the nominal interest rate ($\hat{\imath}_t$)—have potentially time-varying trends imparted by the time-varying inflation target. These five variables are therefore written in terms of deviations from the time-varying trends.[8]

The dynamics of consumption, $\hat{c}_t$, follows

$$\begin{aligned}(\hat{c}_t - h\hat{c}_{t-1}) &= E_t(\hat{c}_{t+1} - h\hat{c}_t) - \sigma^{-1}(1-h)(\hat{\imath}_t - E_t\hat{\pi}_{t+1}) \\ &\quad + \sigma^{-1}(1-h)(\hat{\varepsilon}_{g,t} - E_t\hat{\varepsilon}_{g,t+1}) - \kappa_0\sigma^{-1}(1-h)(\hat{\imath}_t - E_t\hat{\imath}_{t+1}) \ ,\end{aligned} \tag{3}$$

where h and σ are structural parameters denoting the habit formation and the inverse elasticity of intertemporal substitution, respectively. $\hat{\varepsilon}_{g,t}$ is the intertemporal preference shock, which follows a first-order autoregressive process $\hat{\varepsilon}_{g,t} = \rho_g\hat{\varepsilon}_{g,t-1} + \eta_{g,t}$, with $\eta_{g,t} \sim$ i.i.d. $N(0, \sigma_g^2)$. This otherwise-standard consumption Euler equation has an additional term involving current and expected future interest rates (the second term in the second line of (3)), due to the CIA constraint. Here, κ_0 is a reduced-form parameter that is a positive function of structural parameter ν^h; when $\nu^h = 0$, we obtain a standard consumption Euler equation under the cashless-purchase assumption.[9] Movements in the nominal interest rate thus have additional dynamic effects on consumption fluctuations when a money-holding friction is present.

The aggregate resource constraint in the domestic economy is given by

$$\hat{y}_t = (1-\alpha)\hat{c}_t + \alpha\eta(2-\alpha)\hat{S}_t + \alpha\eta\hat{\Psi}_{F,t} + \alpha\hat{y}^*_t \ . \tag{4}$$

[8] In the long run, however, these variables are constant since the inflation target is constant.

[9] That is, $\kappa_0 \equiv \nu^h\bar{R}^{-1}/\left(1+\nu^h(1-\bar{R}^{-1})\right)$, where $\bar{R}$ is the long-run steady-state gross nominal interest rate.

Here, output, $\hat{y}_t$, is absorbed by demands from the domestic households and the foreign economy. The former is equal to $(1-\alpha)\hat{c}_t$ where $1-\alpha$ represents the share of domestically-produced goods in the aggregate consumption basket, while the latter depends positively on the terms of trade (ratio of import prices to export prices), $\hat{S}_t$, foreign aggregate demand or output, $\hat{y}_t^*$, and the law of one price (LOP) gap, $\hat{\Psi}_{F,t}$, which represents the deviation of the law of one price for the import goods at the retail level.[10] The structural parameter η is the elasticity of substitution between domestic and imported goods.

Next, the evolutions of terms of trade and LOP gap are given by

$$\Delta \hat{S}_t = \hat{\pi}_{F,t} - \hat{\pi}_{H,t} \ , \tag{5}$$

$$\Delta \hat{\Psi}_{F,t} = \hat{e}_t^c + \hat{\pi}_t^* - \hat{\pi}_{F,t} \ , \tag{6}$$

where $\hat{\pi}_t^*$ denotes foreign inflation. Producer-price inflation is linked to CPI inflation through the relationship

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \alpha \left(\hat{S}_t - \hat{S}_{t-1} \right) \ . \tag{7}$$

Note that (5) and (7) imply

$$\hat{\pi}_t = (1-\alpha)\hat{\pi}_{H,t} + \alpha \hat{\pi}_{F,t} \ ,$$

that is CPI inflation is a weighted average between producer-price inflation import-price inflation, with each respective weight given by its respective share in the consumption basket. The real exchange rate, $\hat{q}_t$, is linked to the LOP gap and the terms of trade through the following relationship:

$$\hat{q}_t = \hat{\Psi}_{F,t} + (1-\alpha)\hat{S}_t. \tag{8}$$

Log-linearizations of the aggregate producer-price and the optimal price equations lead to a standard Phillips-curve equation for producer-price inflation,

$$\begin{aligned} \hat{\pi}_{H,t} - \delta_H \left(\hat{\pi}_{H,t-1} - \hat{g}_t^{\overline{\pi}} \right) \quad = \quad & \beta E_t \left[\hat{\pi}_{H,t+1} - \delta_H \left(\hat{\pi}_{H,t} - \hat{g}_{t+1}^{\overline{\pi}} \right) \right] \\ & + \frac{(1-\theta_H)(1-\theta_H \beta)}{\theta_H} \widehat{mc}_t \ , \end{aligned} \tag{9}$$

[10] More formally, $\hat{\Psi}_{F,t}$ is the ratio of aggregate domestic-currency price of import goods at the dock and its aggregate price at the retail level.

where $\hat{g}_t^{\overline{\pi}} \equiv \log(\overline{\Pi}_t) - \log(\overline{\Pi}_{t-1})$ is the growth rate of trend or target inflation. β is the subjective discount factor and θ_H is the Calvo probability of optimal price reset. The dynamics of real marginal cost, $\widehat{mc}_t$, is given by

$$\begin{aligned} \widehat{mc}_t &= \varphi\hat{y}_t - (1+\varphi)\hat{\varepsilon}_{a,t} + \alpha\hat{S}_t + \sigma(1-h)^{-1}(\hat{c}_t - h\hat{c}_{t-1}) \\ &\quad +\kappa_0\hat{\imath}_t \ , \end{aligned} \tag{10}$$

where φ is the inverse Frisch labor supply elasticity and $\hat{\varepsilon}_{a,t}$ is the technology shock, assumed to follow $\hat{\varepsilon}_{a,t} = \rho_a\hat{\varepsilon}_{a,t-1} + \eta_{a,t}$, with $\eta_{a,t} \sim$ i.i.d. $N(0, \sigma_a^2)$. Notice that the money-holding friction makes the real marginal cost to be directly affected by movements in the nominal interest rate. Here, all else equal, a higher opportunity cost of holding money (a higher nominal interest rate) leads to an increase in the real marginal cost through a reduction in the labor supply. Similar to producer-price inflation, log-linearizations of the optimal price and aggregate import-price equations lead to a Phillips curve equation for import-price inflation,

$$\begin{aligned} \hat{\pi}_{F,t} - \delta_F\left(\hat{\pi}_{F,t-1} - \hat{g}_t^{\overline{\pi}}\right) &= \beta E_t\left[\hat{\pi}_{F,t+1} - \delta_F\left(\hat{\pi}_{F,t} - \hat{g}_{t+1}^{\overline{\pi}}\right)\right] \\ &\quad +\frac{(1-\theta_F)(1-\theta_F\beta)}{\theta_F}\widehat{\Psi}_{F,t} \\ &\quad +\hat{\varepsilon}_{cp,t} \ , \end{aligned} \tag{11}$$

where the LOP gap becomes the relevant marginal-cost measure. θ_F is the probability of optimal price reset in the import sector and $\hat{\varepsilon}_{cp,t}$ is the import cost-push shock, assumed to follow $\hat{\varepsilon}_{cp,t} = \rho_{cp}\hat{\varepsilon}_{cp,t-1} + \eta_{cp,t}$, with $\eta_{cp,t} \sim$ i.i.d. $N(0, \sigma_{cp}^2)$.

The equilibrium in the foreign exchange or asset market is given by the interest-parity condition,

$$(\hat{\imath}_t - E_t\hat{\pi}_{t+1}) - \left(\hat{\imath}_t^* - E_t\hat{\pi}_{t+1}^*\right) = E_t\Delta\hat{q}_{t+1} - \chi\hat{a}_t - \chi E_t\tilde{\phi}_{t+1} \ , \tag{12}$$

where $\hat{\imath}_t^*$ and $\hat{a}_t$ denote the foreign nominal interest rate and net foreign asset position (as a fraction of steady-state output), respectively. The relative risk-premium shock, $\tilde{\phi}_t$, evolves according to $\tilde{\phi}_t = \rho_\phi\tilde{\phi}_{t-1} + \eta_{\phi,t}$, with $\eta_{\phi,t} \sim$ i.i.d. $N(0, \sigma_\phi^2)$ and χ is a parameter governing the impact of the shock on the relative holding of foreign asset. The equation describing the net foreign asset position is given by

$$\begin{aligned}\hat{c}_t + \hat{a}_t &= \beta^{-1}\hat{a}_{t-1} - \alpha\left(\hat{S}_t + \widehat{\Psi}_{F,t}\right) + \hat{y}_t \\ &\quad -\nu^h\left(\hat{c}_t - \hat{c}_{t-1}\right) - \nu^h\hat{\pi}_t \ .\end{aligned} \tag{13}$$

The model is closed with the monetary-policy rule,

$$\hat{\imath}_t = \rho_i\hat{\imath}_{t-1} + (1-\rho_i)\left[\psi_\pi\hat{\pi}_t + \psi_y\hat{y}_t + \psi_{\Delta_y}\Delta\hat{y}_t + \psi_e\hat{e}^c_t\right] + \tilde{\varepsilon}_{M,t} \ , \tag{14}$$

where $\tilde{\varepsilon}_{M,t} \sim$ i.i.d. $N(0,\sigma^2_M)$ is the unanticipated monetary-policy shock. Following (2), the inflation target—in terms of level deviation from the constant long-run target, $\widehat{\overline{\pi}}_t \equiv \overline{\pi}_t - \overline{\pi}$—evolves according to

$$\widehat{\overline{\pi}}_t = \rho_{\overline{\pi}}\widehat{\overline{\pi}}_{t-1} + \tilde{\varepsilon}_{\overline{\pi},t} \ . \tag{15}$$

Finally, in terms of the foreign economy, following Justiniano and Preston (2010) I assume that the paths of the three foreign variables—$\hat{\pi}^*_t$, $\hat{y}^*_t$, and $\hat{\imath}^*_t$—are exogenously given by a vector autoregression of order two (VAR(2)).

The linear rational-expectations equilibrium Together with the processes for the exogenous variables and foreign-economy variables and the inflation-target process in (15), equations (3) to (14) determine a linear rational-expectations equilibrium in 12 endogenous variables: $\hat{c}_t$, $\hat{\imath}_t$, $\hat{\pi}_t$, $\hat{y}_t$, $\hat{S}_t$, $\hat{\Psi}_{F,t}$, $\hat{\pi}_{H,t}$, $\hat{\pi}_{F,t}$, $\hat{q}_t$, $\widehat{mc}_t$, $\hat{e}^c_t$, and $\hat{a}_t$, driven by 9 exogenous shocks: $\eta_{a,t}$, $\eta_{g,t}$, $\eta_{cp,t}$, $\eta_{\phi,t}$, $\tilde{\varepsilon}_{M,t}$, $\tilde{\varepsilon}_{\overline{\pi},t}$, and three foreign shocks affecting $\hat{\pi}^*_t$, $\hat{y}^*_t$, and $\hat{\imath}^*_t$.

3 Parameter estimates and empirical results

3.1 Data and prior distribution

I estimate the linearized model described above using likelihood-based Bayesian methods to fit nine quarterly time-series or observables.[11] Six observables involve the Indonesian (domestic) time-series: headline CPI inflation (% per year), gross-domestic product (GDP) per capita (in log deviation from the linear trend), BI rate (% per year), real exchange rate (in log difference), terms of trade (in log difference), and the official Bank Indonesia's headline CPI-inflation target (% per year). Three observables involve the foreign economy, proxied by US data series: headline CPI inflation, GDP per capita, and the federal funds rate.[12] Indonesian inflation, interest-rate, terms of trade, and inflation-target data are from time-series published by Bank Indonesia, while GDP per capita data are from the IMF's International Financial Statistics (IFS) database.[13] The three US time-series are sourced from the Federal Reserve Economic Data (FRED) database, while the (model-consistent) real exchange rate data are constructed using the nominal exchange rate data from the IFS database, Indonesian CPI series from Bank Indonesia, and US CPI series from the FRED database. The corresponding measurement equations are given in the appendix.

The model is estimated over the 2005.Q3–2017.Q1 sample period, where the start of the sample period corresponds to the beginning of the implementation of a full-fledged inflation-targeting framework (ITF) by Bank Indonesia. Although Bank Indonesia has started announcing the target inflation to the public since late 2000, the full and formal implementation of inflation targeting as the official policy framework only started in July 2005 under the Central Bank Act No.4 2004. See Harmanta (2009) and Wimanda (2009) for discussions on the implementation history of Bank Indonesia's ITF.

Table 1 presents information about the prior distribution of the structural parameters to be estimated, along with their definitions. Most of the priors are standard in the literature. The three elasticity parameters (σ, φ, η) are assumed to follow Gamma distributions, with

[11] Eight observables, minus the headline CPI-inflation target, mirror those used in Justiniano and Preston (2010) for the Australian, Canadian, and New Zealand economies.

[12] Future research should consider using trade-weighted data, whenever available, to represent the foreign economy.

[13] The terms of trade data are constructed based on the published import and export price-index data.

the prior means set to the corresponding posterior mean estimates in Harmanta et al. (2013). The habit parameter h follows a Beta distribution with mean 0.5—the mid value of its interval $[0, 1]$—and standard deviation 0.25. The prior mean of the money-holding parameter, ν^h, is set to the posterior mean estimate in Zam (2017) for the same sample period. Both indexation parameters (δ_H and δ_F) and Calvo parameters (θ_H and θ_F) are assumed to follow Beta distributions, each with mean 0.5 (the middle value of their possible range).[14] On the Taylor-rule feedback parameters, ψ_π and ψ_y are assumed to follow Gamma distributions with mean 1.90 and 0.25, respectively — these numbers are equal to their corresponding posterior mean estimates in Harmanta, Purwanto and Oktiyanto (2014). The two other feedback parameters (ψ_{Δ_y}, ψ_e) also follow Gamma distributions with mean 0.25 and standard deviation 0.13. The four autoregressive coefficients and the standard errors of the exogenous shocks are assumed to follow Beta and Inverse-Gamma distributions, respectively — except for the standard error of the inflation-target shock, their means and standard deviations follow those in Justiniano and Preston (2010). For the standard error of the inflation-target shock, I assume a mean of 0.20, which is equal to the standard error of actual, historical inflation-target adjustments from 2000 up to 2017 (see Panel B in Figure 1). Since inflation target is assumed to follow an exogenous AR(1) process and the actual data series are used as part of the observables in the estimation, the choice of prior mean is largely immaterial, i.e. its posterior mean should be roughly equal to the standard error in the relevant sample.

Six parameters in the estimation procedure are calibrated, largely for identification purpose. β, the subjective discount factor, is set to 0.99. The calibrated value of the risk-premium parameter χ is as in Justiniano and Preston (2010). The openness parameter, α, is set equal to the actual average share of imports as a fraction of GDP from 2005 to 2017 (around 20%). The smoothing parameter in the Taylor rule is set to $\rho_i = 0.75$, which is consistent with the posterior mean in Harmanta, Purwanto and Oktiyanto (2014) and close to that in Dutu (2016) (0.8). Following Cogley, Primiceri and Sargent (2010) and Bhattarai, Lee and Park (2016), the AR(1) persistence parameter of the inflation-target process $\rho_{\overline{\pi}}$ is calibrated to 0.995.[15] Finally, the long-run steady-state inflation is set to 4% per year,

[14] The means for the Calvo parameters are consistent with those in Sahminan et al. (2017)

[15] I have tried estimating $\rho_{\overline{\pi}}$ instead. It turns out the posterior mean estimate is very close to this calibrated value (0.995) — result is available upon request. Dutu (2016) also calibrates a very high value of $\rho_{\overline{\pi}}$ (0.975).

consistent with Bank Indonesia's official headline-CPI inflation target as of 2017.Q1.

3.2 Posterior estimates of the parameters

Table 2 reports the mean, along with the [5,95]% probability bands, of the posterior distribution of the parameters obtained by the Metropolis-Hastings algorithm.[16]

The inverse elasticity of intertemporal substitution is estimated to be 0.53, which is lower than the mean estimates (around 2) in Harmanta et al. (2013) and Harmanta, Purwanto and Oktiyanto (2014).[17] That the elasticity ($1/\sigma$) is above unity accords well with the estimate in Justiniano and Preston (2010) for the Canadian economy. The habit parameter is estimated to be quite low at 0.03 and with zero in its 95% probability interval. Habit formation is thus not important to match the persistence of output and consumption in Indonesia over the estimated sample period, in contrast to the high estimate of h (around 0.9) in Dutu (2016). This discrepancy possibly stems from the much-higher estimates of persistence parameters of the preference shock (0.9) and the risk-premium shock (0.97), which affect the intertemporal margin of consumption, in Table 2. The near-zero estimate of h, however, is consistent with the estimate in Zam (2017) over the same sample period. The data do not appear to be informative on the labor supply elasticity parameter, φ, as the posterior mean is about the same as the prior mean. The posterior mean of the money-holding parameter ν^h is 0.38, which is about the same as the mean estimate in Zam (2017). Money and money-holding friction thus still play an important role in the Indonesian economy.

Turning to the two past-indexation parameters, it is notable that despite the positive estimates—0.29 for domestic firms and 0.21 for importers—the 95% probability intervals in both estimates include zero. Hence, one cannot statistically reject the hypothesis that once inflation target is incorporated into the indexation mechanism, there is no need for the backward-looking inflation to match the persistence of both inflation series (producer-price inflation and import-price inflation). This result is largely consistent with the corresponding

[16] The Metropolis-Hastings algorithm is conducted with 5 MCMC chains of 100,000 draws each. The target acceptance rate is between 23.4%–30% and the first 40% of the draws in each chain are discarded as initial burn-in.

[17] Harmanta et al. (2013) and Harmanta, Purwanto and Oktiyanto (2014), however, perform the estimation using a different sample period, from 2001 to 2012.

estimates in Dutu (2016) using Indonesian data and in Eo and Lie (2018) using US data.[18] Without the indexation to inflation target and the time-varying inflation target assumption, the estimates of δ_H and δ_F tend to be much higher (see e.g. Hermawan and Munro (2008) and Harmanta, Purwanto and Oktiyanto (2014)).[19] This finding also accords well with the finding for the US Phillips curve in Cogley and Sbordone (2008): once time-varying trend inflation is assumed in the model and in the estimation procedure, the past-indexation parameter tends to zero.

The mean estimate of the domestic firms' Calvo parameter is 0.59, which is in between the mean estimate in Harmanta, Purwanto and Oktiyanto (2014) (0.50) and in Dutu (2016) (0.65). For importers, the Calvo parameter is estimated to be 0.41. This lower number for the import sector than in the domestic sector is consistent with the finding in Hermawan and Munro (2008). On the Taylor-rule parameters, ψ_π is estimated to be 1.6, which is about the same as the estimate in Dutu (2016). The much-higher estimate of ψ_{Δ_y} compare to ψ_y implies that Bank Indonesia reacts more to the fluctuations in the growth of output than the level of output — Justiniano and Preston (2010) report the same finding for central banks in Australia, Canada, and New Zealand. Regarding the exogenous-shock processes, the technology shock is estimated to be somewhat persistent, while preference, import cost-push, and risk-premium shocks are found to be very persistent — for these three shocks, the persistence parameter is 0.9 or higher. The import cost-push shock has the highest mean standard error, followed by technology shock and monetary-policy shock, respectively.

On the inflation-target shock process, the posterior mean standard error is estimated to be 0.12, which is roughly the same as the standard deviation of observed Bank Indonesia's inflation-target adjustments over the estimated sample period. Figure 2 shows that the estimated inflation-target shocks over the sample period largely match the actual shocks or adjustments in BI's headline-CPI inflation target. Small discrepancies in the two series occur because of the model assumption that inflation target follows a stationary (but highly persistent) process. Hence, in the quarters where there is no actual adjustment in the target,

[18] For example, the posterior mean of the indexation parameter for domestic prices in Dutu (2016) is 0.1264 with standard deviation 0.0638, which includes zero in its 95% probability bands.

[19] Using a partial-information GMM estimator over the 1980-2008 period, Wimanda, Turner and Hall (2011) also find that the backward-looking inflation component in the Phillips curve for Indonesia is more dominant than the forward-looking component.

the estimated model records small positive shocks to compensate for the autoregressive decline.

3.3 Implication of inflation-target adjustments on aggregate fluctuations

This section assesses the implication of Bank Indonesia's inflation-target adjustments on aggregate fluctuations, based on the estimated model. The focus in on three key aggregate macroeconomic variables: CPI inflation, output (GDP per capita), and the nominal interest rate (BI rate).

3.3.1 Forecast-error variance decomposition

Table 3 reports the mean forecast error variance decomposition of the three key variables at various horizons. Fluctuations in inflation at all considered horizons are dominated by technology and monetary-policy shocks. For example, these two shocks together account for more than 80% of inflation fluctuations in the short run (up to four quarters) and around 72% in the longer run at ten-year horizon. Import cost-push shocks also play a supporting role in driving inflation fluctuations (accounting for more than 8% of the forecast error variance at all horizons), while preference, risk-premium, and foreign shocks all play only a minor role. In terms of inflation-target shocks, it seems that they play a minor role in driving the short-run movements in inflation: up to one-year horizon, they explain less than 2% of the forecast error variance of inflation. In the longer run, inflation-target shocks explain a larger fraction of inflation variation, e.g. close to 12% at the ten-year horizon.

While this result may seem indicative of a relatively small role of inflation-target shocks for inflation fluctuations, it is important to note that there are only seven occurrences of inflation-target adjustments (shocks) in the estimated sample period, which is a much smaller frequency compared to the other shocks.[20] Viewed from this perspective, the contribution of inflation-target shocks to inflation movements is not insignificant, especially in the medium

[20] Compared to the finding here, Ireland (2007) and Fève, Matheron and Sahuc (2010) find somewhat larger contributions of inflation-target shocks to inflation movements for the US economy. Their estimates, however, are based on a much longer sample period where movements in the (unobserved) inflation target are frequent.

to long run. The historical shock decomposition of inflation, presented in the next section, also reveals a non-trivial role of inflation-target shocks for the fluctuations of inflation. Another notable observation is in regard to the relatively small role of inflation-target shocks in explaining low-frequency movements in inflation, especially when compared to the results for the US economy in Ireland (2007) and Fève, Matheron and Sahuc (2010). In these two studies, low-frequency movements of inflation are almost wholly explained by the (unobserved) inflation-target shocks. This perhaps is an indication that credibility may still be an issue in Bank Indonesia's inflation-targeting framework.

Inflation-target shocks play a much more important role in driving fluctuations in the nominal interest rate. Even at the short-run horizon, inflation-target adjustments account for almost 20% of the nominal interest rate's forecast error variance. The bulk of the short-run movements in the nominal rate, however, are due to preference and risk-premium shocks. Ireland (2007) also finds that in the short run, preference shocks are the dominant source of fluctuations in the US federal funds rate. The role of inflation-target shocks are even more significant at longer horizons: for example, these shocks alone explain almost half of the movements in the nominal interest rate at ten-year (40-quarter) horizon. At this ten-year horizon, inflation-target and risk-premium shocks together account for almost 75% of nominal interest rate fluctuations. The other four types of shocks—technology, import cost-push, monetary-policy, and foreign—only account for a small fraction of the forecast error of the nominal rate at all horizons. The small role of the unanticipated monetary policy shocks in driving nominal interest-rate movements implies that Bank Indonesia changed the BI rate largely in response to other shocks, e.g. when an official inflation-target adjustment took place.

In terms of output fluctuations, inflation-target shocks appear to play a negligible role at all considered forecast horizons. This result is consistent with the findings for the US economy in both Ireland (2007) and Fève, Matheron and Sahuc (2010) for the same inflation-target process.[21] Technology shocks are the dominant source of output fluctuations, more so at longer horizons. Monetary-policy shocks also account for a significant fraction of the

[21] Fève, Matheron and Sahuc (2010), however, find a non-negligible role on output movements when the inflation-target adjustments (shocks) are gradual.

movements in output, especially in the short run. Preference, risk-premium, import cost-push, and foreign shocks do not appear to play a major role in output fluctuations both in the short run and in the medium run.

3.3.2 Historical shock decomposition

To assess the historical contribution of inflation-target shocks to inflation fluctuations, Figure 3 shows the historical decomposition of inflation. Though not the dominant the factor, inflation-target shocks still play an important role in driving movements in inflation, especially in and immediately following an adjustment period. To see this, recall the following historical timing and size of Bank Indonesia's seven inflation-target adjustments over the sample period:

Timing (quarter):	2006.Q1	2007.Q1	2008.Q1	2009.Q1	2010.Q1	2012.Q1	2015.Q1
Size (% p.a.):	+2%	−2%	−1%	−0.5%	+0.5%	−0.5%	−0.5%

When the target was increased by 2% per annum in 2006.Q1, the decomposition shows that inflation-target shocks' contribution to inflation is around 2.5% per annum. This is quite a sizeable contribution, given that actual CPI-inflation was 7.8% per annum in 2006.Q1. The contribution size is relatively unchanged over the next three quarter, until Bank Indonesia decided to decrease the inflation target by 2% in 2007.Q1, at which point the contribution of inflation-target shocks to inflation decreases to around 1.03% per annum. The contribution starts to turn negative when Bank Indonesia decided to further decrease the target twice in 2008.Q1 and 2009.Q1. In 2009.Q1, the contribution size is around −0.42% per annum. After a brief interjection in 2010.Q1 where the target was increased, Bank Indonesia continued the downward trajectory in the official inflation target: it was cut by 0.5% per annum in 2012.Q1 and then in 2015.Q1. During the most recent cut in 2015.Q1, inflation-target shocks contribute −0.4% per annum to inflation (the CPI inflation rate was around −1.8% per annum in 2015.Q1).

Figure 3 also shows that technology and monetary-policy shocks (and preference shocks, to some extent) are the main driving factor in the historical movements of inflation in Indonesia over the sample period. This finding is in accord with the forecast error variance decomposition of inflation reported in Table 3. Another notable observation from Figure 3 is regarding the estimated source of the huge spike in CPI inflation in 2005.Q4, which was essentially caused by the Indonesian government's huge reduction in the fuel price subsidy. Since the model lacks a mechanism to explain changes in the fuel price subsidy, the decomposition attributes the inflation spike mainly to a combination of (negative) technology shocks and (negative) monetary-policy shocks.

Turning to the historical decomposition of the nominal interest (BI) rate, Figure 4 shows that preference and risk-premium shocks are the dominant source of historical movements in the BI rate, confirming the forecast error variance result in Table 3. Inflation-target shocks, however, have a non-trivial contribution, especially in the early part of the sample from 2005-2006 when the target was increased by 2% per annum. Towards the end of the sample from mid-2014 to 2017.Q1, inflation-target shocks play a major supporting role in the downward trajectory of the BI rate. In terms of the long-run (or medium-run) declining trend in the BI rate (see Panel C in Figure 1), (positive) risk-premium shocks play a major role from the beginning of the sample up to 2013, while (negative) preference shocks provide the main driving factor towards the end of the sample.[22]

Figure 5 shows that historical output movements are primarily driven by technology and monetary-policy shocks. Technology shocks contribute negatively to output movements in the beginning of the sample period, but the contribution turns positive from 2009 onward. The finding that technology (or multi-factor productivity) shocks play a dominant role in historical output movements in Indonesia during this period is consistent with the finding in Dutu (2016). Import cost-push shocks have a largely negative contribution to output, especially from 2009 onward. Confirming the previous result from Table 3, inflation-target shocks have a negligible role on output.

3.3.3 Impulse response to an inflation-target shock

How do inflation-target shocks affect the dynamics of the three key aggregate macroeconomic variables? Figure 6 plots the impulse responses to a one standard deviation inflation-target

[22] In the model, a positive risk-premium shock or a negative preference shock leads to a decline in the nominal interest rate.

shock. Focusing on the mean responses (solid lines), a one standard-deviation (0.12% per-annum) increase in the inflation target raises inflation by more than 0.4% on impact. Inflation rises because of higher expected inflation, caused by the persistently-higher inflation target — in fact, inflation and expected inflation remain elevated well about their initial rates even after 10 quarter. In order to raise the inflation target, the central bank needs to contemporaneously raise the nominal interest rate by about 0.5% per annum. Similar to inflation, the nominal rate remains persistently elevated for a considerable number of quarters. Despite a higher nominal rate, higher expected inflation leads to periods of lower real interest rate, causing a mild output stimulation. The mild and short-lived positive output responses are congruent with the above finding that inflation-target shocks play a negligible role on output fluctuations. The nominal exchange rate is virtually unaffected by the shock.

The impulse-response figure shows that an increase in the inflation target necessitates raising the nominal interest rate on impact. Hence, the estimated model exhibits a so-called Neo-Fisherian property — see e.g. Garín, Lester and Sims (2018) for a discussion on this property. Based on a DSGE model fitted to US data, Eo and Lie (2018) find that the US economy also exhibits Neo-Fisherianism. Related to this point, I note that raising (dropping) the inflation target is not equivalent to a conventional expansionary (contractionary) monetary-policy shock. This is because in order to expand output and raise inflation, a conventional monetary-policy shock necessitates a decrease in the nominal interest rate, as shown in Figure 7.

3.3.4 Model fit and comparison

I now assess whether incorporating inflation-target adjustments into the model leads to an improvement in the model's fit and out-of-sample predictive performance. The estimated model above is compared to an alternative, standard model without inflation-target adjustments. In this alternative model specification, the indexation mechanisms in the domestic and import sectors are based on a weighted average of past inflation in the respective sector and the *constant*, long-run inflation target, set at 4% per annum (the latest BI's official headline CPI inflation target). The Taylor rule is also modified: the central bank is now assumed to response to the deviation of inflation from the constant inflation target. Overall, the posterior estimates of the structural parameters in this alternative model specification (not shown) are not that different compared to those in Table 2.[23]

Table 4 reports the marginal likelihoods, which can be interpreted as a measure of the model's fit and out-of-sample predictive performance, of the two model specifications.[24] The model with inflation-target adjustments is found to have a higher marginal likelihood: -863.11 versus -875.25 for the model without inflation-target adjustments. The posterior probability is almost 1, indicating an overwhelming preference towards the model with inflation-target adjustments.

4 Counterfactual exercises and extension

4.1 Counterfactuals

As another assessment on the role of inflation-target adjustments on aggregate fluctuations, I perform two counterfactual exercises involving the paths of inflation target, CPI inflation, and BI rate. In each of these exercises, starting the with the actual data values in 2005.Q2 and using the posterior mean estimates for the structural parameters, I feed the model with a counterfactual inflation-target path and the estimated smoothed paths for the remaining eight shocks. These exercises shed light on how the paths of inflation and BI rate would have been different from 2005.Q3-2017.Q1 if Bank Indonesia had followed a different inflation-target adjustment strategy. The counterfactual output path is not shown as it is barely affected by the alternative inflation-target paths.

4.1.1 No adjustment in the inflation target

The first counterfactual exercise supposes that Bank Indonesia did not adjust its inflation target further after 2005.Q2 and it stayed at 6% per annum onward. Figure 8 shows the resulting counterfactual paths in comparison to the actual paths.[25] Without further target

[23] Results are available upon request.

[24] Both model specifications use the same 9 observables in the estimation procedure.

[25] Since the model is simulated with smoothed shocks and CPI inflation, nominal interest rate, and inflation-target data are used as part of the observables in the estimation procedure, the estimated paths of the three series are identical to their actual paths.

adjustments, inflation would have been higher by about 1% per annum on average from 2005.Q3 to 2017.Q1, which is quite a significant difference. Furthermore, inflation would have been a full 2% higher in 2017.Q1. There is a short period of time in 2006 where the counterfactual inflation paths were below the actual paths — this is a direct effect of Bank Indonesia's decision to increase the official inflation target by a full 2% per year in 2006.Q1. Starting from 2007.Q2 to the end of the sample in 2017.Q1, the counterfactual paths are always above the actual paths of inflation, with an average difference of 1.4% per annum.

Similar to inflation, the nominal interest (BI) rate would have been higher overall. The rate would have been higher by 2% per annum in 2017.Q1 and the average difference over the 2005.Q3-2017.Q1 period is about 1%. There is a corresponding short period of time where the counterfactual paths were below the actual paths. Similarly, from 2008.Q1 onward, the counterfactual BI rates are always higher than the actual rates by 1.5% per annum on average. Interestingly, the average difference between the counterfactual and actual nominal interest rates is roughly the same as the average difference in the inflation rates. This is, however, a direct consequence of the previous finding that inflation-target shocks do not materially affect real variables, e.g. output and the real interest rate. Here, an increase in expected inflation caused by a higher inflation target is matched by an almost similar increase in the nominal interest rate.[26]

4.1.2 An immediate one-time adjustment in the inflation target

In the second counterfactual exercise, I assume that Bank Indonesia decided to conduct an immediate, one-time adjustment in the inflation target in 2005.Q3 from 6% per annum to 4% per annum. This new 4% target, which coincides with the latest actual Bank Indonesia's inflation target, is maintained until the end of the sample in 2017.Q1.

As shown in Figure 9, the counterfactual paths of both inflation and the BI rates are almost always below their respective actual paths. Both the inflation and the BI rates would have been lower by an average of 1% per annum over the entire 2005.Q3-2017.Q1 period. In the two years following the counterfactual cut to the inflation target (2005.Q4-2007.Q4)—the periods where the inflation-target adjustment would likely have the biggest impact—both

[26] Recall the Fisher equation, $r_t = i_t - E_t\pi_{t+1}$, where r_t is the real interest rate.

rates would have been lower by around 3% per annum on average. Starting from 2015.Q1 onward, there is virtually no difference between their counterfactual and actual paths.

The finding of this second counterfactual exercise implies that immediate disinflation, conducted through an immediate one-time reduction in the official inflation target, would have been a better policy choice than a gradual disinflation policy. Bank Indonesia would have achieved lower inflation and BI rates on average, without any meaningful output loss.[27] Lower inflation would have led to lower relative-price distortions and reduced uncertainties for consumers and businesses. A lower average BI rate would have lowered the rates on business and consumer loans, resulting in higher aggregate consumption and investment, which in turn would have led to higher economic growth.

4.2 Extension

In this extension, I reestimate the model over a longer sample period, from 2002.Q1 to 2017.Q1. The purpose is twofold: the first is to ensure that the above findings are robust and the second is to investigate whether the role of inflation-target adjustments in aggregate fluctuations is enhanced, given the higher frequency and size of the adjustments in this longer sample period (see Panel B in Figure 1).

Table 5 reports the posterior estimates — the same Bayesian estimation procedure and the same priors as in Table 1 are used to obtain these estimates. Overall, the posterior mean estimates are relatively stable and unchanged compared to the corresponding mean estimates in Table 2 for the full-fledged ITF period. Several differences are worth mentioning. First, the money-holding parameter, ν^h, is now estimated to be slightly higher at 0.42 (versus 0.38). Second, all four Taylor-rule feedback parameters have somewhat lower means compared to those in Table 2. Third, as expected, the mean standard error of the inflation-target shock is larger over the longer sample period. Table 4 shows that the model with inflation-target adjustments and indexation is still statistically preferred to the standard model without adjustments.

[27] Several empirical studies find that an immediate disinflation policy may have been a better policy than a gradualist approach, in a sense that it results in a lower output loss, see e.g. Ball (1994) and Boschen and Weise (2001). See Joseph, Dewandaru and Gunadi (2003) for an analysis and discussion of alternative disinflation strategies in the context of the Indonesian economy.

Finally, Table 6 reports the corresponding forecast error variance decompositions of inflation, output, and the nominal interest rate. The same general conclusions as previously can be drawn from the table. For example, it is still the case that technology and monetary-policy shocks are the main driver of inflation fluctuations at all considered horizons. The higher frequency and size of inflation-target adjustments over this longer sample period lead to enhanced roles of inflation-target shocks in driving fluctuations in inflation and the nominal interest rate. For example, inflation-target adjustments now explain 9% and 25% of movements in inflation at around two-year horizon and ten-year horizon, respectively. Output fluctuations remain largely unaffected by the inflation-target shocks.

5 Conclusion

This paper investigates the role of observed official inflation-target adjustments in aggregate macroeconomic fluctuations, using an estimated Dynamic Stochastic General Equilibrium (DSGE) model for Indonesia. The paper finds that these adjustments or shocks play a non-trivial role in the fluctuations of inflation and nominal interest rate in Indonesia. Output fluctuations, however, are virtually unaffected. A counterfactual exercise shows that a gradual reduction in Bank Indonesia's inflation target may have not been optimal. The paper also provides additional insights on the contribution of various shocks in driving aggregate fluctuations in Indonesia.

The inclusion of inflation-target shocks in the model is also shown to improve the model's fit and out-of-sample predictive performance. To this extent, the paper makes a contribution to the DSGE modelling for Indonesia and the developed model can be used as a standard model or as a starting point to develop DSGE models for Indonesia with useful additional features, such as financial frictions and macroprudential policies.

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6 Tables and Figures

Table 1: Description of structural parameters and prior distributions

Description	Parameter	Range	Prior distr.	Prior mean	Prior std.
Inv. elas. of intertemporal substitution	σ	$\mathbb{R}^+$	*Gamma*	2.13	0.40
Habit formation	h	[0,1]	*Beta*	0.50	0.25
Inverse Frisch elas. of labor supply	φ	$\mathbb{R}^+$	*Gamma*	2.00	0.25
Elas. of subs. domestic and imported goods	η	$\mathbb{R}^+$	*Gamma*	2.59	0.75
Frac. of consumption held in money	ν^h	[0,1]	*Beta*	0.36	0.20
Index. to past inflation, domestic firms	δ_H	[0,1]	*Beta*	0.50	0.25
Index. to past inflation, importers	δ_F	[0,1]	*Beta*	0.50	0.25
Prob. of optimal price reset, domestic firms	θ_H	[0,1]	*Beta*	0.50	0.10
Prob. of optimal price reset, importers	θ_F	[0,1]	*Beta*	0.50	0.10
Taylor rule, inflation	ψ_π	$\mathbb{R}$	*Gamma*	1.90	0.30
Taylor rule, output	ψ_y	$\mathbb{R}$	*Gamma*	0.25	0.13
Taylor rule, output growth	ψ_{Δ_y}	$\mathbb{R}$	*Gamma*	0.25	0.13
Taylor rule, nominal exchange rate	ψ_e	$\mathbb{R}$	*Gamma*	0.25	0.13
Autoregr. technology shock	ρ_a	[0,0.99]	*Beta*	0.80	0.10
Autoregr. preference shock	ρ_g	[0,0.99]	*Beta*	0.80	0.10
Autoregr. cost-push shock	ρ_{cp}	[0,0.99]	*Beta*	0.50	0.25
Autoregr. risk-premium shock	ρ_ϕ	[0,0.99]	*Beta*	0.80	0.10
Std. technology shock	σ_a	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. preference shock	σ_g	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. mark-up shock	σ_{cp}	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. MP shock	σ_M	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. risk-premium shock	σ_ϕ	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. foreign output shock	σ_{y^*}	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. foreign inflation shock	σ_{π^*}	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. foreign interest-rate shock	σ_{i^*}	$\mathbb{R}^+$	*InvGamma*	0.50	inf.
Std. inflation-target shock	$\sigma_{\bar{\pi}^*}$	$\mathbb{R}^+$	*InvGamma*	0.20	inf.

Notes: *(1)* Calibrated parameters: $\beta = 0.99$, $\alpha = 0.20$, $\chi = 0.01$, $\rho_i = 0.75$, $\rho_{\bar{\pi}_*} = 0.995$, and $400\bar{\pi} = 400(\bar{\Pi} - 1) = 4$ (consistent with Bank Indonesia's official headline-CPI inflation target of 4% per annum in 2017.Q1); *(2)* the three foreign variables (output, inflation, and nominal interest rate) are assumed to follow a VAR(2), with identical priors as in Justiniano and Preston (2010).

Table 2: Posterior estimates

Description	Parameter	Posterior mean	95% prob. interval
Inv. elas. of intertemporal substitution	σ	0.53	[0.47, 0.63]
Habit formation	h	0.03	[0.00, 0.06]
Inverse Frisch elas. of labor supply	φ	2.02	[1.57, 2.50]
Elas. of subs. domestic and imported goods	η	1.27	[0.76, 1.82]
Frac. of consumption held in money	ν^h	0.38	[0.03, 0.76]
Index. to past inflation, domestic firms	δ_H	0.29	[0.00, 0.66]
Index. to past inflation, importers	δ_F	0.21	[0.00, 0.50]
Prob. of optimal price reset, domestic firms	θ_H	0.59	[0.47, 0.71]
Prob. of optimal price reset, importers	θ_F	0.41	[0.26, 0.56]
Taylor rule, inflation	ψ_π	1.60	[1.27, 1.95]
Taylor rule, output	ψ_y	0.12	[0.03, 0.21]
Taylor rule, output growth	ψ_{Δ_y}	0.91	[0.46, 1.33]
Taylor rule, nominal exchange rate	ψ_e	0.33	[0.15, 0.53]
Autoregr. technology shock	ρ_a	0.59	[0.42, 0.77]
Autoregr. preference shock	ρ_g	0.90	[0.79, 0.98]
Autoregr. import cost-push shock	ρ_{cp}	0.93	[0.84, 0.99]
Autoregr. risk-premium shock	ρ_ϕ	0.97	[0.94, 0.99]
Std. technology shock	σ_a	2.81	[1.84, 3.89]
Std. preference shock	σ_g	0.39	[0.21, 0.65]
Std. cosh-push shock	σ_{cp}	6.13	[2.59, 11.09]
Std. MP shock	σ_M	0.78	[0.49, 1.08]
Std. risk-premium shock	σ_ϕ	0.35	[0.22, 0.49]
Std. foreign output shock	σ_{y^*}	0.62	[0.50, 0.75]
Std. foreign inflation shock	σ_{π^*}	0.66	[0.53, 0.82]
Std. foreign interest-rate shock	σ_{i^*}	0.11	[0.09, 0.13]
Std. inflation-target shock	$\sigma_{\bar{\pi}^*}$	0.12	[0.09, 0.14]

Notes: *(1)* Sample period: 2005.Q3-2017.Q1 (full-fledged IT period); *(2)* the posterior distribution is obtained using the Metropolis-Hastings algorithm with 5 MCMC chains of 100,000 draws each — the target acceptance rate is between 23.4%–30% and the first 40% of the draws in each chain are discarded as initial burn-in.

Table 3: Forecast error variance decompositions

Horizon (quarters ahead)	Preference	Risk-premium	Technology	Import cost-push	Monetary policy	Foreign shocks	Inflation target
Inflation							
1	2.91	0.41	39.53	10.01	46.34	0.36	0.44
2	3.43	0.45	35.66	10.1	49.03	0.47	0.86
4	3.56	0.90	36.17	9.72	47.45	0.54	1.67
10	3.61	2.29	35.43	9.24	44.91	0.67	3.85
20	3.68	3.07	33.79	8.88	42.81	0.79	6.98
40	3.67	3.16	31.73	8.43	40.21	0.90	11.89
Nominal int. rate							
1	37.87	30.95	5.95	0.49	1.32	3.81	19.61
2	33.79	35.97	4.07	2.39	0.75	3.53	19.50
4	29.07	40.37	2.60	4.42	0.42	3.21	19.91
10	25.30	41.78	1.41	4.00	0.25	2.90	24.36
20	22.98	37.95	0.99	3.03	0.19	2.80	32.07
40	19.90	30.47	0.74	2.75	0.15	2.68	43.32
Output							
1	2.66	4.56	52.14	0.70	39.43	0.50	0.01
2	1.64	2.95	69.17	1.40	24.51	0.34	0.01
4	1.23	2.38	75.69	2.27	18.16	0.26	0.00
10	1.18	2.56	75.36	3.82	16.80	0.27	0.00
20	1.18	2.62	74.34	5.05	16.54	0.28	0.00
40	1.18	2.65	73.67	5.84	16.38	0.28	0.00

Notes: *(1)* Entries above are the posterior *mean* forecast error variance decompositions, in percentages (rounded to two decimal points); *(2)* foreign shocks include foreign-output, foreign-inflation, and foreign interest-rate shocks; *(3)* estimation sample period: 2005.Q3-2017.Q1.

Table 4: Comparison of the marginal likelihood of alternative models

DSGE Model	Marginal Likelihood	Posterior probability
Sample period: 2005.Q3-2017.Q1		
Model with IT adjustments	-863.11	0.999995
Model without IT adjustments	-875.25	5×10^{-6}
Sample period: 2002.Q1-2017.Q1		
Model with IT adjustments	-1134.1	0.94
Model without IT adjustments	-1136.8	0.06

Notes: *(1)* Log marginal likelihoods are computed based on the Laplace approximation — similar results are obtained under the modified harmonic mean approximation (Geweke (1999)); *(2)* the posterior odds ratio (probability) is computed with a uniform prior on both models.

Table 5: Posterior estimates — sample period: 2002.Q1–2017.Q1

Description	Parameter	Posterior mean	95% prob. interval
Inv. elas. of intertemporal substitution	σ	0.52	[0.47, 0.61]
Habit formation	h	0.02	[0.00, 0.05]
Inverse Frisch elas. of labor supply	φ	2.08	[1.61, 2.56]
Elas. of subs. domestic and imported goods	η	1.24	[0.80, 1.72]
Frac. of consumption held in money	ν^h	0.42	[0.05, 0.78]
Index. to past inflation, domestic firms	δ_H	0.26	[0.00, 0.63]
Index. to past inflation, importers	δ_F	0.17	[0.00, 0.42]
Prob. of optimal price reset, domestic firms	θ_H	0.58	[0.46, 0.70]
Prob. of optimal price reset, importers	θ_F	0.39	[0.24, 0.52]
Taylor rule, inflation	ψ_π	1.56	[1.23, 1.89]
Taylor rule, output	ψ_y	0.08	[0.02, 0.16]
Taylor rule, output growth	ψ_{Δ_y}	0.73	[0.40, 1.08]
Taylor rule, nominal exchange rate	ψ_e	0.24	[0.10, 0.40]
Autoregr. technology shock	ρ_a	0.55	[0.38, 0.72]
Autoregr. preference shock	ρ_g	0.89	[0.79, 0.98]
Autoregr. import cost-push shock	ρ_{cp}	0.95	[0.90, 0.99]
Autoregr. risk-premium shock	ρ_ϕ	0.97	[0.93, 0.99]
Std. technology shock	σ_a	2.88	[2.01, 3.97]
Std. preference shock	σ_g	0.45	[0.24, 0.68]
Std. cosh-push shock	σ_{cp}	6.56	[2.98, 11.41]
Std. MP shock	σ_M	0.67	[0.46, 0.91]
Std. risk-premium shock	σ_ϕ	0.35	[0.22, 0.48]
Std. foreign output shock	σ_{y^*}	0.59	[0.49, 0.71]
Std. foreign inflation shock	σ_{π^*}	0.62	[0.51, 0.74]
Std. foreign interest-rate shock	σ_{i^*}	0.10	[0.08, 0.12]
Std. inflation-target shock	$\sigma_{\bar{\pi}^*}$	0.15	[0.13, 0.18]

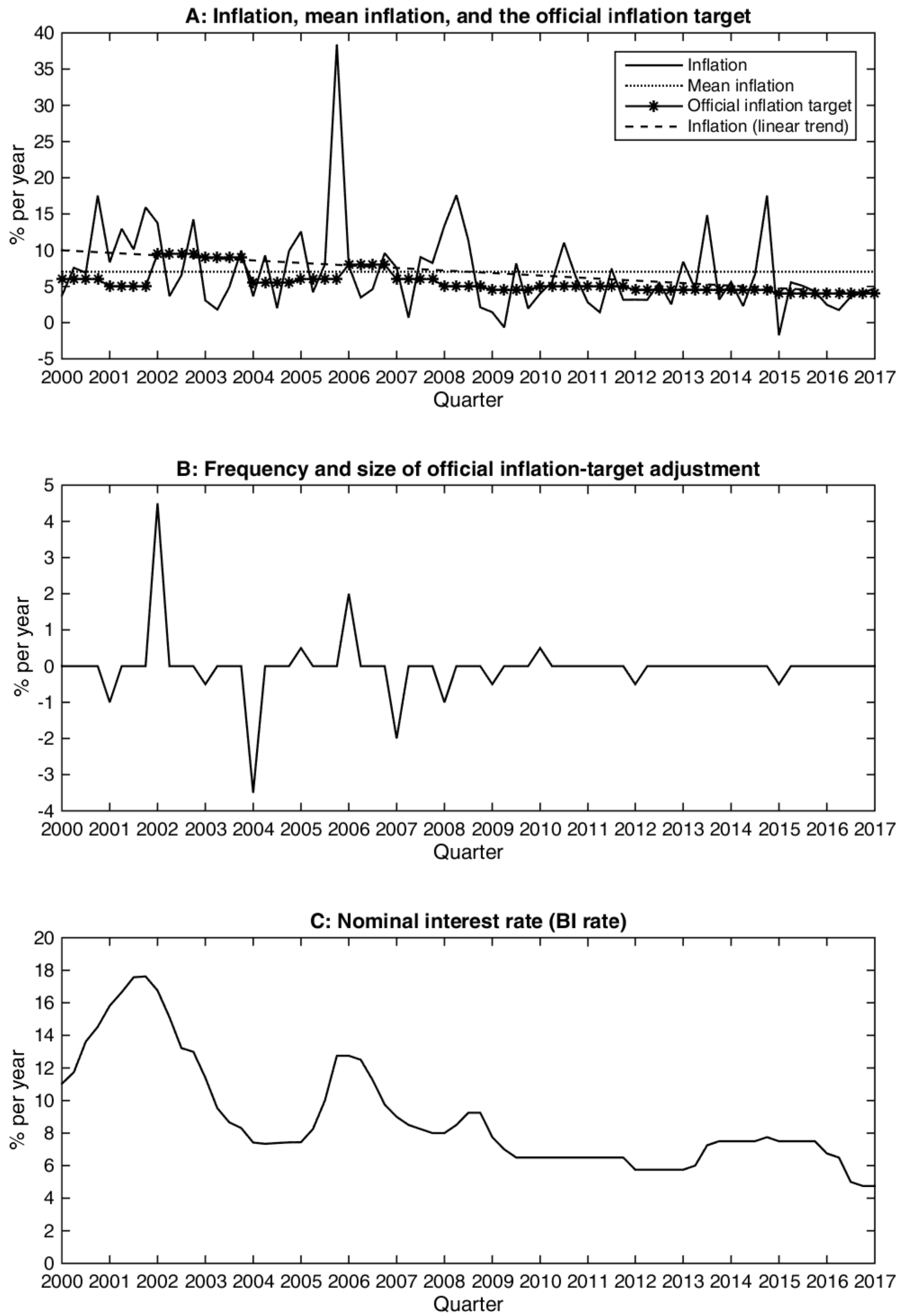
Notes: *(1)* Sample period: 2002.Q1-2017.Q1; *(2)* the posterior distribution is obtained using the Metropolis-Hastings algorithm with 5 MCMC chains of 100,000 draws each — the target acceptance rate is between 23.4%–30% and the first 40% of the draws in each chain are discarded as initial burn-in.

Table 6: Forecast error variance decompositions — sample period: 2002.Q1-2017.Q1

Horizon (quarters ahead)	Preference	Risk-premium	Technology	Import cost-push	Monetary policy	Foreign shocks	Inflation target
Inflation							
1	7.00	0.62	37.77	10.63	42.61	0.27	1.09
2	8.01	0.78	33.78	10.72	44.20	0.38	2.13
4	8.01	1.39	34.32	10.12	41.66	0.44	4.06
10	7.82	2.73	32.27	9.33	38.27	0.53	9.05
20	7.50	3.26	29.45	8.56	34.93	0.62	15.68
40	6.87	3.07	25.94	7.64	30.78	0.68	25.03
Nominal int. rate							
1	41.80	23.83	4.05	0.29	1.64	1.95	26.44
2	39.07	26.70	3.24	1.38	0.87	1.78	26.95
4	35.25	29.16	2.14	2.61	0.48	1.58	28.79
10	29.77	28.95	1.16	2.56	0.27	1.39	35.91
20	24.92	24.87	0.78	1.89	0.19	1.31	46.04
40	19.52	18.50	0.55	1.63	0.14	1.21	58.45
Output							
1	4.75	2.67	63.05	0.97	28.22	0.33	0.02
2	3.00	1.79	75.08	1.94	17.95	0.23	0.01
4	2.45	1.58	78.12	3.35	14.29	0.20	0.01
10	2.38	1.75	76.12	6.11	13.43	0.21	0.01
20	2.33	1.76	74.19	8.43	13.05	0.21	0.01
40	2.29	1.79	72.80	10.11	12.78	0.21	0.01

Notes: *(1)* Entries above are the posterior *mean* forecast error variance decompositions, in percentages (rounded to two decimal points); *(2)* foreign shocks include foreign-output, foreign-inflation, and foreign interest-rate shocks; *(3)* estimation sample period: 2002.Q1-2017.Q1.

Figure 1: Actual inflation, official inflation target, and the BI rate



Notes: *(1)* Inflation data are headline consumer-price index (CPI) inflation — source: Bank Indonesia; *(2)* official inflation target is based on Bank Indonesia's published official headline-CPI inflation target; *(3)* prior to 2005.Q3, rates on 1-month SBI (Bank Indonesia Certificates) are used in place of BI (Bank Indonesia) rates; *(4)* mean inflation and the linear inflation trend are calculated over the 2000.Q1-2017.Q1 sample period.

Figure 2: Observed versus estimated inflation-target shocks (2005.Q3-2017.Q1)

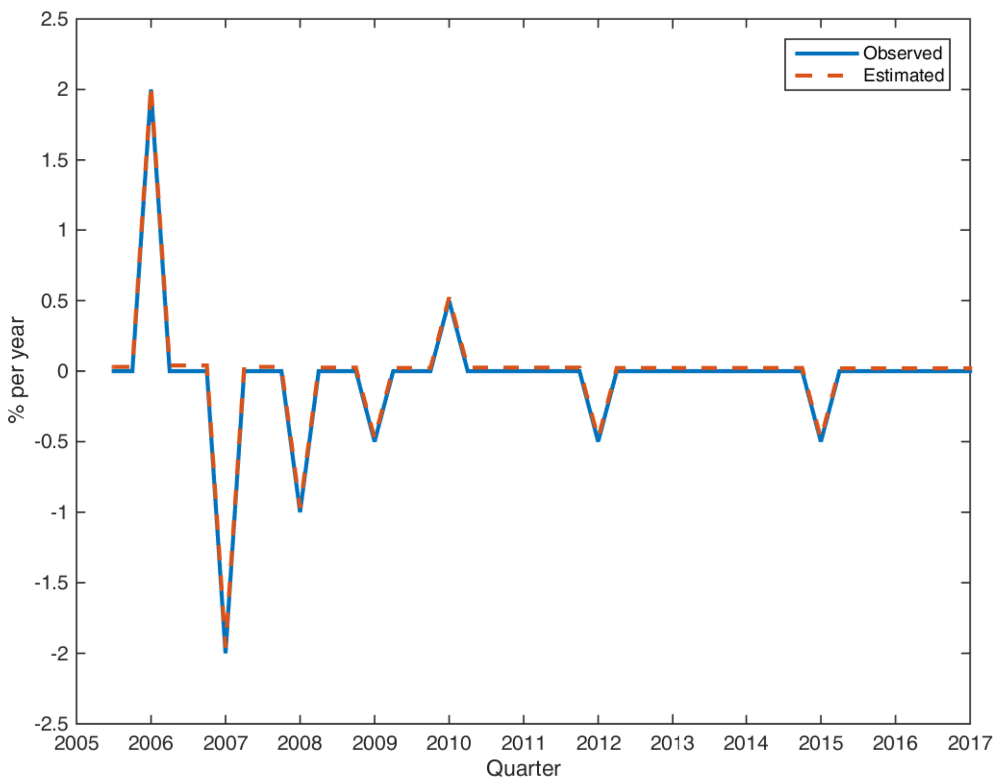
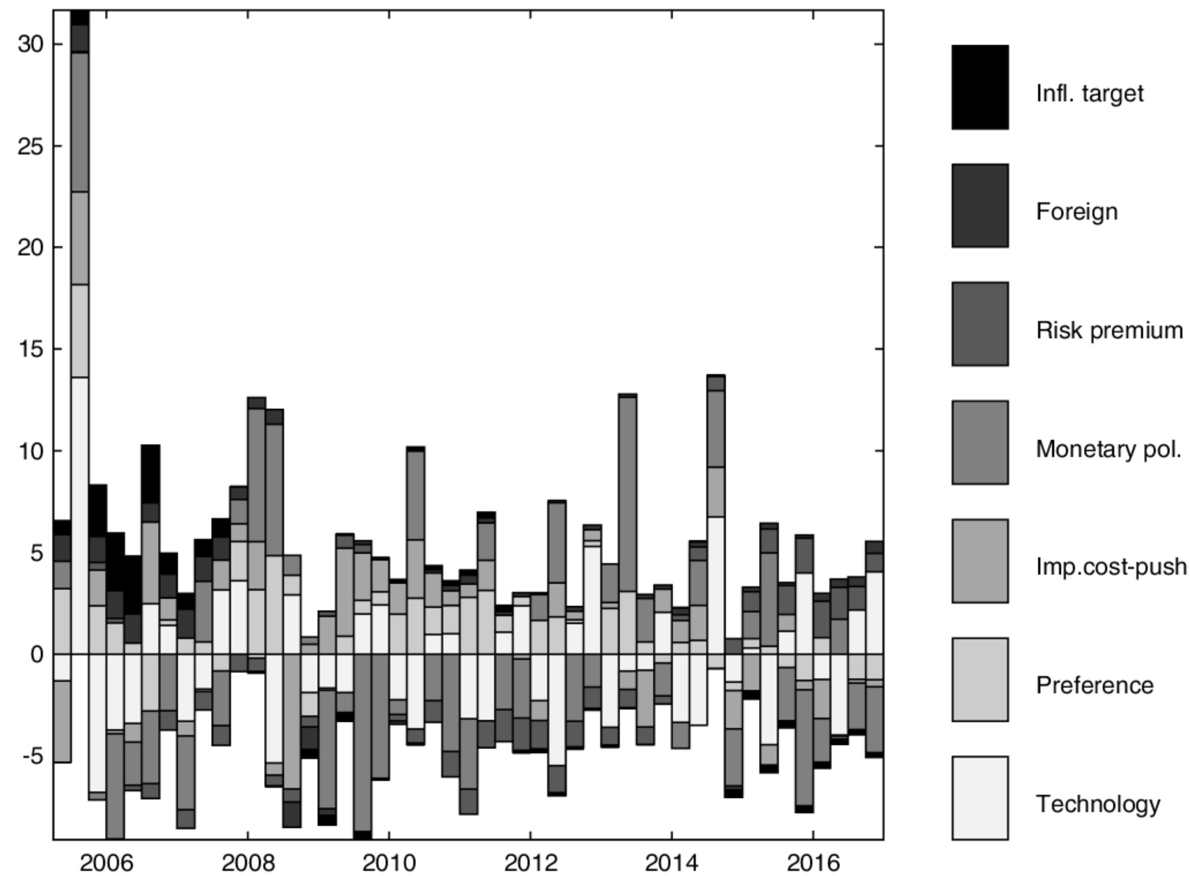
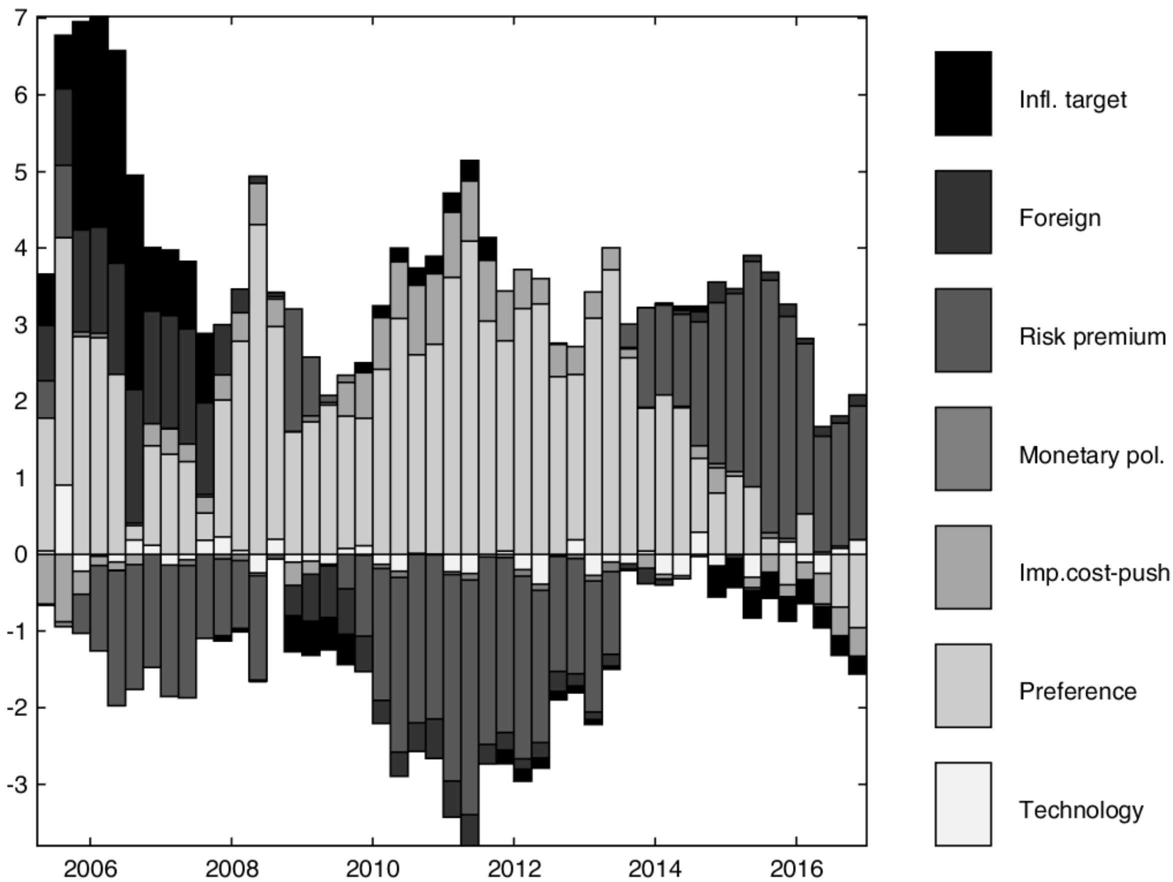


Figure 3: Historical decomposition of inflation — 2005.Q3–2017.Q1



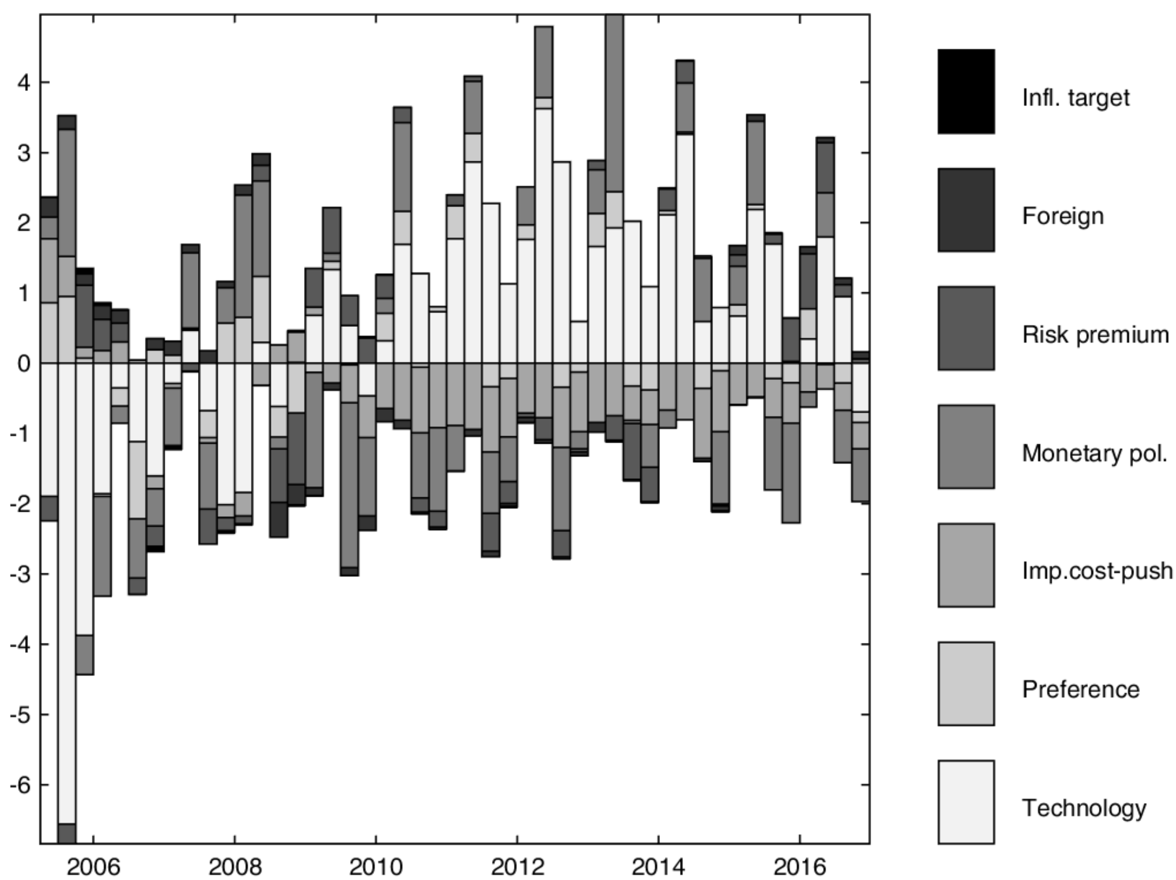
Notes: *(1)* Foreign shocks include foreign-output, foreign-inflation, and foreign interest-rate shocks; *(2)* the contribution units are in % per year.

Figure 4: Historical decomposition of nominal interest rate — 2005.Q3–2017.Q1



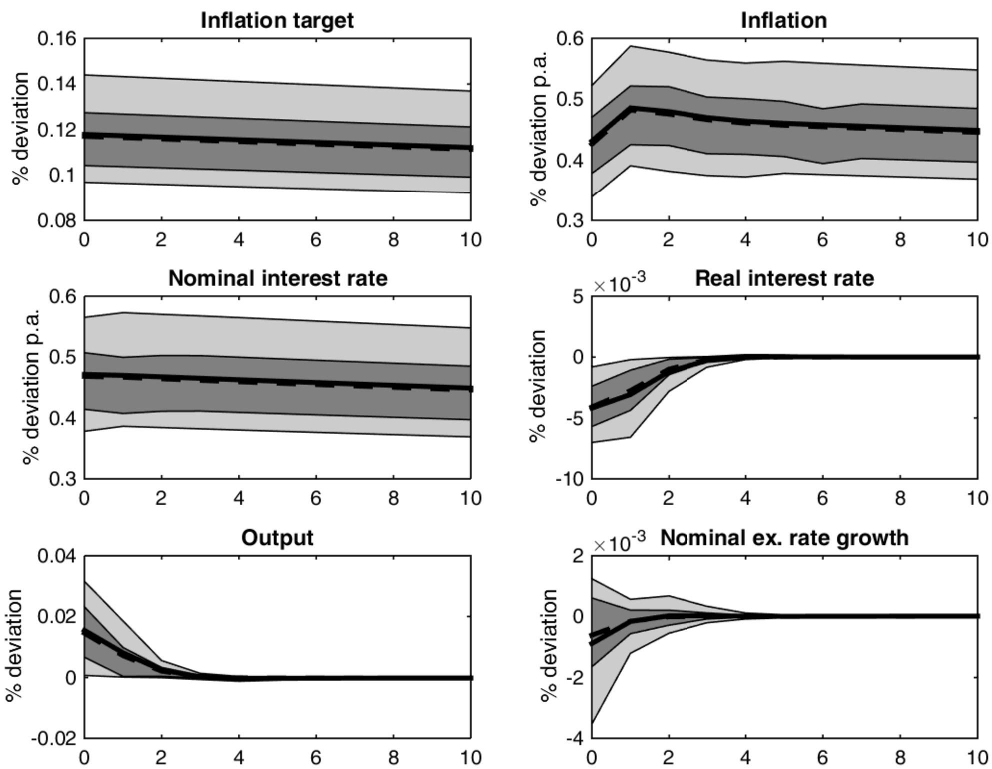
Notes: *(1)* Foreign shocks include foreign-output, foreign-inflation, and foreign interest-rate shocks; *(2)* the contribution units are in % per year.

Figure 5: Historical decomposition of output (GDP) — 2005.Q3–2017.Q1



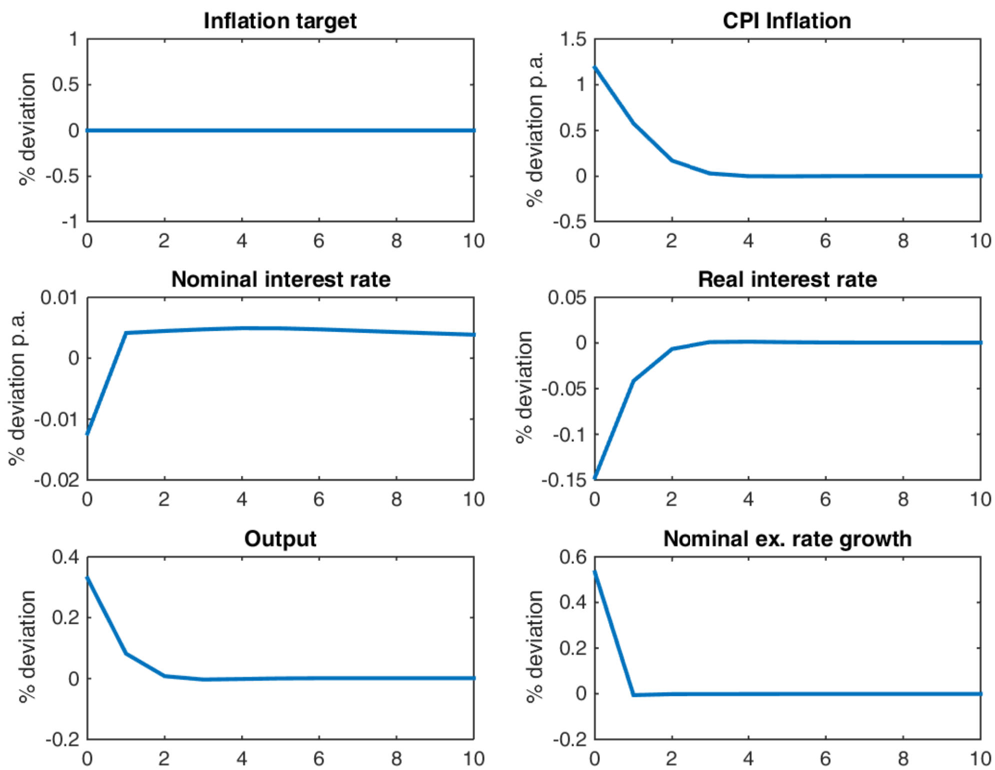
Notes: *(1)* Foreign shocks include foreign-output, foreign-inflation, and foreign interest-rate shocks; *(2)* the contribution units are in % deviation from the linear trend.

Figure 6: Impulse responses to an inflation-target shock



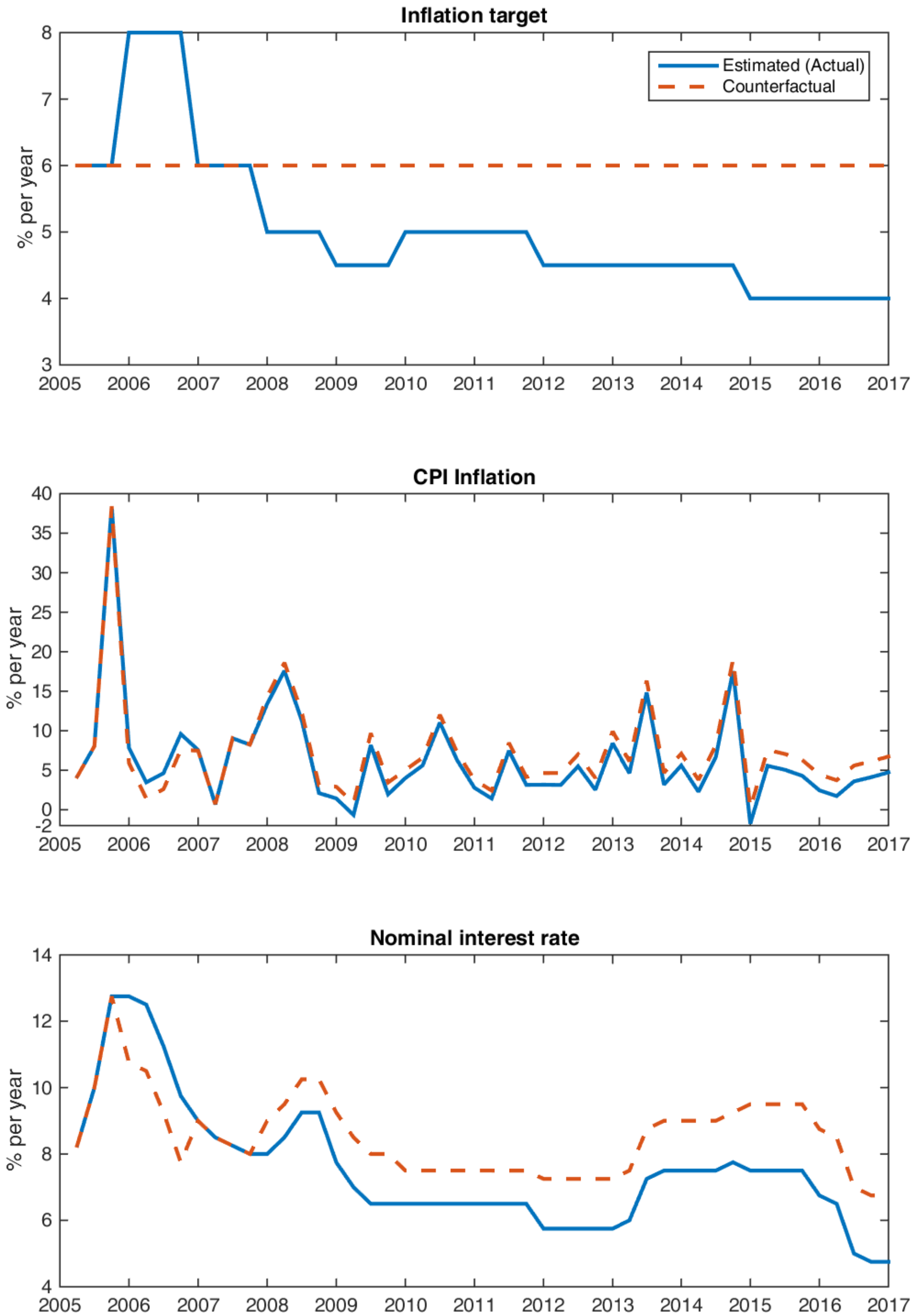
Notes: *(1)* The figure plots the Bayesian impulse responses to a positive one standard deviation inflation-target (IT), i.e. an increase in the target inflation; *(2)* the middle solid line and dotted line correspond to the mean and median responses, respectively, with 68% and 95% HPD (Highest Posterior Density) intervals represented by the dark grey and light grey areas, respectively.

Figure 7: Impulse responses to a monetary-policy shock



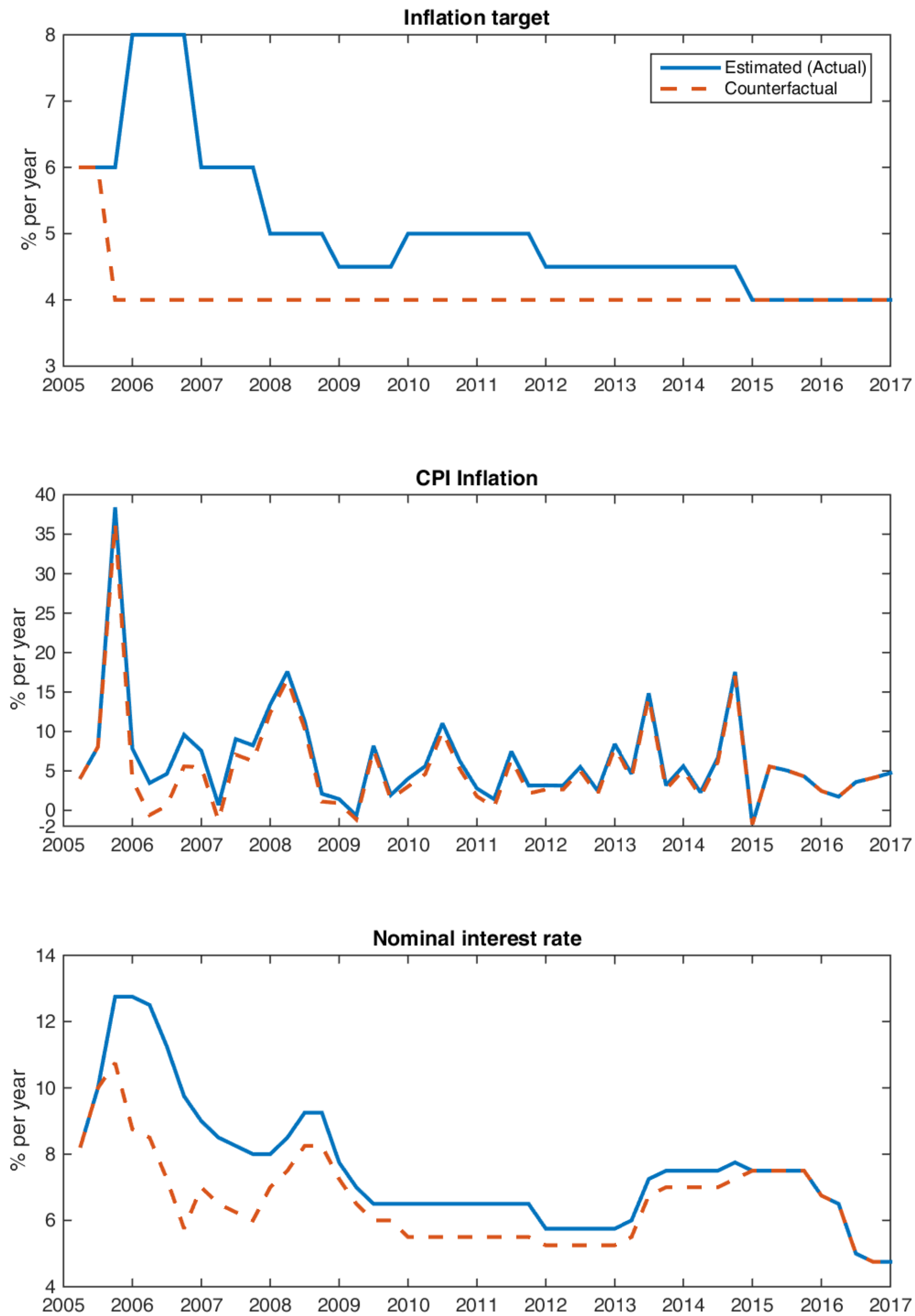
Notes: *(1)* The figure plots the impulse responses to an unanticipated -1% per-annum monetary-policy shock, i.e. an expansionary monetary-policy shock; *(2)* all parameter values are set at their posterior mean estimates.

Figure 8: Counterfactual paths without inflation-target adjustments



Notes: *(1)* The figure plots the counterfactual paths of inflation and nominal interest rate generated under the assumption that the inflation target were kept at 6% per annum (the actual target in 2005.Q2) from 2005.Q3–2017.Q1, versus the estimated paths; *(2)* the estimated paths are equal to the actual paths since the observables include inflation, nominal interest-rate, and inflation-target data; *(3)* all other estimated (smoothed) shocks, besides the inflation-target shocks, are retained.

Figure 9: Counterfactual paths under an immediate, one-time inflation-target adjustment



Notes: *(1)* The figure plots the counterfactual paths of inflation and nominal interest rate generated under the assumption that the inflation target were immediately reduced from 6% per annum to 4% per annum in 2005.Q3, versus the estimated paths — this new target is assumed to be kept constant until the end of the sample (2017.Q1); *(2)* the estimated paths are equal to the actual paths since the observables include inflation, nominal interest-rate, and inflation-target data; *(3)* all other estimated (smoothed) shocks, besides the inflation-target shocks, are retained.