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Endogenous Monetary Policy Credibility in a Small Macro Model of Israel

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European Department

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Abstract

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This paper extends a small linear model of the Israeli economy to allow for nonlinearities in the inflation-output process that arise from convexity in the Phillips curve and endogenous monetary policy credibility. We find that the dynamic responses to shocks in the extended model more closely resemble features in the data from the period 2001–03. In particular, the extended model does a much better job in accounting for the deterioration in monetary policy credibility and the output costs of regaining monetary policy credibility once it has been lost.

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I. INTRODUCTION

Small-scale structural macro models can be very useful in helping to produce coherent forecast scenarios and policy analysis inside policy institutions. The model developed here is based on the small linear model of the Israeli economy documented in Epstein and others (2006).² The model does not have explicit micro foundations, but it resembles standard New Keynesian open-economy models as described, for example, in Svensson (2000) and Gali and Monacelli (2005).

A key feature of linear models is that their simulation properties are independent of initial conditions. Moreover, the magnitude of their impulse responses will be linear functions of the magnitude of the disturbances. While this greatly simplifies the analysis and solution procedures, it may not fully capture the effects of large shocks or policy decisions that lead to a loss of monetary policy credibility.

In this paper, we extend the small linear model with features of nonlinearity and endogenous policy credibility. This helps explain the strong reaction of the Israeli economy to sharp policy interest rate cuts and a prolonged period of erosion in policy credibility. We pay particular attention to the period from 2001 to 2003, during which a larger-than-normal policy rate cut led to large movements in the exchange rate and inflation and, as a result, to subsequent sharp reversals in the rate settings. We employ the extended model to argue that the loss of policy credibility was costly and prevented the central bank from properly responding to economic fundamentals. In particular, we try to explain the effects of two policy decisions in late 2001 and early 2002. We first show that the standard linear model cannot explain this episode very well. We then show how an extended model, which allows for nonlinearities in the output-inflation process and endogenous monetary policy credibility, does a much better job in replicating the stylized facts of this historical episode.³

Various studies have provided related definitions of ‘credibility’ of monetary policy based on the following notions: (i) deviations of inflation expectations from the central bank’s target; (ii) variation in long-term interest rates, long-term inflation expectations and the public’s assessment of the central bank’s ability to achieve the target; (iii) the extent to which the public believes that the announced target is indeed the central bank’s actual target; and (iv) the gap between central bank’s objectives and the public’s perception of these objectives.⁴

² See Epstein and others (2006) for a detailed presentation of the model and its properties, and Berg, Karam, and Laxton (2006) for an overview of the complete Forecasting and Policy Analysis System (FPAS) used to create forecasts and risk assessments.

³ These additional features could also be useful in casting light on movements in inflation expectations and long-term interest rates in other countries where policy credibility issues arise.

⁴ See Cukierman and Meltzer (1986), Bomfin and Rudebusch (2000), Faust and Svensson (2001), Laxton and N'Diaye (2002), Stiver (2003) and Rebucci and Rossi (2006).

Our approach gauges the credibility effects via three main channels. *First*, lack of credibility causes a positive inflation expectations bias, which puts upward pressure on inflation through the expectations term in the Phillips Curve (see Isard, Laxton and Eliasson, 2001). *Second*, a buildup in credibility can shift public expectations of future inflation closer to announced targets rather than to past inflation.⁵ In the extended model, enhanced credibility lowers the weight on backward-looking expectations and this improves the inflation-output tradeoff.⁶ *Third*, we assume that credibility also affects the risk premium in the interest parity (IP) condition. In the extended model, credibility builds up when actual inflation converges to the target rather than diverges to some higher level. In this regard, we base our analysis on a two-regime definition (high and low inflation). This allows us to increase credibility even if past inflation is high (but falling) and even if it is not expected to return to the target for some time (due to interest rate smoothing or lags in the transmission mechanism, for example).⁷

Section II discusses the features of a standard *linear* model for Israel. Section III reviews the historical developments associated with the 2001–03 period and exposes the limits of the linear model in explaining them. Section IV introduces the nonlinear Phillips curve and endogenous credibility features. Section V reviews the extended model’s properties by examining the dynamic responses to a variety of shocks (interest rate, credibility and inflation). Section VI concludes.

II. STANDARD FPAS MODEL FOR ISRAEL

We begin with a description of the standard model, developed and applied to Israel in Epstein and others (2006). Here, we review briefly the main equations of the model; the reader is referred to the cited paper for details. There are two sets of equations: the first describes the small Israeli economy, and the other the “rest of the world”, or at least that part of the world that has important effects on the Israeli economy.

⁵ Laxton and N'Diaye (2002), Lalonde (2005) and Keen Meng and Tanuwidjaja (2005) all treated additional credibility as a larger weight on the announced target in the inflation expectations equation.

⁶ We maintain a fundamental assumption that even with high credibility the public does not blindly believe in the authorities’ ability to achieve the inflation target. We justify the positive effect of credibility on rational expectations by assuming that, in high credibility eras, central banks can be more trusted to operate based on a simple, transparent, rule-based reaction function; agents would therefore forecast inflation ‘rationally’ based on that reaction function while paying less attention to past inflation rates (a backward-looking approach).

⁷ Others have characterized different mechanisms for endogenous credibility, rising (i) when observed inflation achieves the target (an outcome-based mechanism), or (ii) when expected inflation is kept close to the target (an action-based mechanism).

A. Output Gap Equation

Domestic output depends on the real interest rate, the real exchange rate, and demand in the rest of the world, represented by the United States. Dynamics are added through past and future domestic output gaps.⁸

$$ygap_t = \beta_{ld} ygap_{t+1} + \beta_{lag} ygap_{t-1} - \beta_{RRgap} (RR_{t-1} - RR_{t-1}^*) + \beta_{zgap} (z_{t-1} - z_{t-1}^*) + \beta_{yus} yusgap_t + \varepsilon_t^y \quad (1)$$

where $ygap$ is the output gap, RR is the real interest rate, z (in logs) is the real exchange rate (measured so an increase is a depreciation), and a ‘*’ denotes an equilibrium value of a variable. The output gap is measured as the deviation, in percentage points, of actual output from a measure of the trend or equilibrium level of GDP (a positive number indicates that output is above trend). Finally, $yusgap_t$ is a similarly measured output gap in the U.S. economy, included to capture spillover effects from world demand to Israeli exports.

B. Phillips Curve

Inflation depends on expected and lagged inflation, the output gap, the exchange rate gap, and movements in the real (relative) price of oil.⁹

$$\begin{aligned} \pi_t = & \alpha_{\pi ld} \pi 4_t^e + (1 - \alpha_{\pi ld}) \pi 4_{t-1} + \alpha_{ygap} [0.5 ygap_t + 0.5 ygap_{t-1}] + \\ & \alpha_z [z_t - z_{t-1}] + \alpha_{rpoil0} \pi rpoil_t + \alpha_{rpoil1} \pi rpoil_{t-1} + \varepsilon_t^\pi \end{aligned} \quad (2)$$

where $\pi 4_t$ is inflation over the last four quarters (four-quarter change in the CPI), and $\pi 4_t^e$ is the expected rate of inflation over the next four quarters. The lag term captures intrinsic inertia in the adjustment coming from sources other than expectations such as adjustment costs or contracts. To close the behavioral model we specify inflation expectations to be partly model-consistent and partly backward-looking:

$$\pi 4_t^e = \alpha_{\pi^e} \pi 4_{t+4} + (1 - \alpha_{\pi^e}) \pi 4_{t-1} + \varepsilon_t^{\pi^e} \quad (3)$$

⁸ Representations such as this one are usually motivated with a first-order condition consistent with optimizing consumers with habit formation. See Smets and Wouters (2003) or Laxton and Pesenti (2003) for a linearized version of the Euler equation for consumption that depends on lagged and expected consumption, real interest rates and a habit-persistence parameter. However, habit persistence alone cannot account for a very large weight on the lagged output gap, which is resolved in DSGE models by adding investment to the model and significant adjustment costs associated with changing the levels of investment.

⁹ Inflation is measured as the annualized quarterly change, in percent, so $\pi_t = 400 [\log(cpi_t) - \log(cpi_{t-1})]$.

The oil-price terms allow for a direct effect on Israeli domestic prices when the real world price changes. The exchange rate term is important in a model of Israeli inflation, since the pass-through effects are strong.¹⁰

C. Exchange Rate Equation

The exchange rate equation (in logs) imposes relative purchasing power or interest parity (IP), an arbitrage condition that says that real interest rates (on investments in different currencies) will be equalized across countries, up to a country risk premium. A real exchange rate definition is used to write the conventional IP condition as a real IP condition as follows:

$$z_t = z_t^e - [RR_t - RR_t^{us} - \rho_t^*] / 4 + \varepsilon_t^z \quad (4)$$

where RR_t^{us} is the U.S. real interest rate and ρ_t^* is the equilibrium risk premium. As before, RR_t is the real policy interest rate and z_t is the real exchange rate.¹¹ Thus, any deviation of interest rates from equilibrium, either at home or abroad, would result in the exchange rate deviating from equilibrium, unless such rate deviations were identical. Any other movement in exchange rates is captured in the residual in the exchange rate equation, which can be thought of as a temporary shock to the risk premium.

We also allow, but do not impose, model-consistent expectations for the exchange rate (i.e., $\delta_z \neq 1$)

$$z_t^e = \delta_z z_{t+1} + (1 - \delta_z) z_{t-1}$$

¹⁰ The monthly pass-through effects of exchange rate changes to measured headline inflation is very strong in Israel. To a large extent this is because contracts for rental housing are denominated in U.S. dollars, and in constructing the CPI it is assumed that the rental equivalent on owner-occupied housing moves one-for-one with rents in the rental market. In 2006, the weight of total housing in the CPI was 19.4 percent with 20 percent of the housing component represented by market rents, 77 percent by owner-occupied housing, and 3 percent by other related expenditures. This simplifying assumption, while common in other countries, obviously tends to exaggerate estimates of exchange rate pass-through.

¹¹ The interest rate term is divided by four because the interest rates and the risk premium are measured at annual rates, where changes in z_t are inherently quarterly prices.

D. Monetary Policy Rule

The monetary policy reaction function is a variant of the Taylor rule—a forward-looking rule because interest rates are set as a function of expected future inflation ($\pi 4_{t+4} - \pi_{t+4}^*$) as well as the output gap ($ygap_t$).¹² When these variables are zero, interest rates are set to ‘normal’ levels ($RR_t^* + \pi 4_t$). As is standard in reaction functions, we allow for “smoothing” in rate setting by introducing a lag term. The policy instrument is a short-term nominal interest rate and the central bank sets this instrument to anchor inflation to a target level, π^* , over time.

$$RS_t = \gamma_{RSlag} RS_{t-1} + (1 - \gamma_{RSlag}) * (RR_t^* + \pi 4_t + \gamma_{\pi} [\pi 4_{t+4} - \pi_{t+4}^*] + \gamma_{ygap} ygap_t) + \varepsilon_t^{RS} \quad (5)$$

The Rest of the World (United States)

The rest of the world is represented by the U.S. economy. The behavioral equations are similar but without the world influences.

Output Gap

$$yusgap = \beta_{usld} yusgap_{t+1} + \beta_{uslag} yusgap_{t-1} - \beta_{RRgap} (RRus_{t-1} - RRus_{t-1}^*) + \varepsilon_t^{yus}$$

Phillips Curve

$$\pi us_t = \alpha_{\pi usld} \pi us_{t+4} + (1 - \alpha_{\pi usld}) \pi us_{t-1} + \alpha_{yusgap} (0.5 yusgap_t + 0.5 yusgap_{t-1}) + \alpha_{\pi rwpoil0} \pi rwpoil_t + \alpha_{\pi rwpoil1} \pi rwpoil_{t-1} + \varepsilon_t^{\pi us}$$

Policy Reaction Rule

$$RSus_t = \gamma_{ruslag} RSus_{t-1} + (1 - \gamma_{ruslag}) (RRus_t^* + \pi us 4_t + \gamma_{\pi us} [\pi 4_{t+4}^{us} - \pi_{t+4}^{us*}] + \gamma_{yus} yusgap_t) + \varepsilon_t^{RSus}$$

¹² Isard and others (2001) found that in light of endogenous credibility and convexity of the Phillips curve (section IV below) a forecast-based rule is expected to outperform a Taylor rule.

E. Standard Model Calibration

The model calibration comes from an eclectic approach that considers various sources of information. The final values of the parameters in the attached table were selected so that the model generated the dynamics that capture the data sufficiently well compared to other established models. Aside from not distinguishing between headline and core inflation, it is the model from Epstein and others (2006).

We now provide a brief recap of some features of the Phillips curve that are important for our extensions. The behavior of the economy depends critically on the weight of the lead in the Phillips curve determined by the values of $\alpha_{\pi ld}$ and α_{π^e} . If there is a high weight on the forward component ($\alpha_{\pi ld}$ and α_{π^e} are 1), then, inflation is equal to the sum of all *future* output and exchange rate gaps. A small but persistent increase in interest rates will have a large and immediate effect on inflation. If on the other hand, there is a lot of inertia ($\alpha_{\pi ld}$ or α_{π^e} are close to zero), then current inflation is a function of lagged values of the gaps, and it may require lengthy periods of monetary pressure to move inflation towards some desired path. The values of those parameters may reflect the degree of monetary policy credibility. Accordingly, in Epstein and others (2006) the authors choose a low weight of 0.1 on the lead ($\alpha_{\pi ld}=0.1$, $\alpha_{\pi^e}=1$). In this paper, we begin with an alternative scenario that reflects increased credibility and therefore raises the values of $\alpha_{\pi ld}$ and α_{π^e} (to 0.70 and 0.5, respectively) for an aggregated weight on the lead term of 0.35. In what follows, under the ‘endogenous credibility’ extension of the model, we experiment with varying the value of α_{π^e} to study the role of the level of credibility in conditioning cycle properties.

III. HISTORICAL PERSPECTIVE ON 2001–03 AND STANDARD MODEL LIMITATIONS

In this section, we begin with a review of the period from 2001 to 2003, during which Israeli monetary policy seems to have suffered a decline in credibility. The discussion refers primarily to data shown in Figure 1. In late 2001, in the face of a weakening economy, the central bank cut the policy rate precipitously by 200 basis points. This led to a depreciation in the sheqel throughout the first half of 2002, which generated upward pressure on prices with headline inflation rising to 7 percent (y-o-y) by July, 2002. The subsequent hikes in interest rates, only five months later and by 450 basis points in three steps, only raised questions about the policy intentions and exacerbated the exchange depreciation at a time when the weaker sheqel was already reflecting deteriorating security and recessionary environment. Inflation continued to rise and long-run inflation expectations (3–4 years ahead) ratcheted upwards to levels well above the 3 percent upper level of the target band. With year-on-year inflation hitting over 6 percent by the second half of 2002 (and nominal depreciation peaking at 16 percent), the central bank maintained a tight stance and held its policy rate steady at around 9 percent until mid-2003, in spite of the fact that the economy was struggling to get out of a long recession.

Growth in 2001–02 came to a halt as a result of the collapse of the high-tech boom, the global slowdown and the deterioration in the security situation. In hindsight, the central bank

kept the policy rate too high for too long and the accompanying exchange rate appreciation pushed inflation into negative territory for a long period in the second half of 2003 and the first half of 2004. Real GDP contracted by 0.6 and 0.9 percent in 2001 and 2002, and grew by a low rate of 1.5 percent in 2003. The recovery began in earnest in 2004 with real GDP growing by 4.8 percent.

An important phenomenon that we seek to capture in the extended model is the deterioration in monetary policy credibility and what implications this had for the dynamics of the Israeli economy. Figure 1 shows that long-run inflation expectations were consistently above the 1–3 percent band from the second quarter of 2002 to end of 2003, in spite of the fact that actual inflation was well below the 1–3 percent band for most of 2003. Moreover, real *market* interest rates—derived by subtracting inflation expectations one-year ahead from the policy rate—rose to 6 percent during the second half of 2002 and remained around that level through mid-2003, while the economy was struggling to recover from a long recession, with the unemployment rate reaching a peak of 11 percent by the end of 2003.

After a sustained period of hovering above the upper band, long-run inflation expectations gradually moved inside the target band at the same time that real market interest rates reverted toward their estimated long-run equilibrium rate of around 3 percent. These events are contrasted with more recent developments when, in 2006, year-on-year headline inflation overshot the upper band as the exchange rate depreciated, oil prices reached record levels, and spare capacity was reduced. In response, the central bank hiked interest rates, but unlike 2002–03, the policy response was measured and did not result in an upward ratcheting in long-term inflation expectations. Indeed, throughout 2006, real market interest rates remained broadly stable, while long-run inflation expectations continued their descent toward the mid-point of the targeting range—see Figure 2.

We next ask whether the standard model can replicate the earlier stylized facts, especially the loss in monetary policy credibility. We simulate the effects of a sharp reduction in interest rates and ask whether the model predicts the large exchange rate depreciation and strong business cycle downturn that were observed in the 2001–03 period. The shock is a temporary and large interest rate cut of 200 basis points for two quarters. This scenario will later serve as the ‘base-case’ against which we will compare the effects of additional features of the model.

The dynamic responses are reported in Figure 3. The immediate short-run responses are mainly felt on nominal and real exchange rates, which depreciate significantly. This combined with the cut in interest rates results in a gradual increase in both output and inflation. However, over time, interest rates must rise to contain inflationary pressures and when this happens output and inflation gradually return back to the values in the control. These results are different from the Israeli experience in 2002–03 in two important ways. The inflation and exchange rate effects are much smaller and the sharp reductions in interest rates do not generate large cumulative costs for the economy—output expands in the short run, but this initial increase in output is not followed by a large contraction in economic activity.

IV. EXTENDING THE STANDARD MODEL

We seek the simplest possible extension of the model, one that provides the nonlinear structure and endogenous credibility, but requires minimal changes to the standard model. Also, we seek to introduce the changes so that they can simply be turned off to revert back to the standard model.

An ideal framework to tackle these questions is provided by Isard, Laxton, and Eliasson (2001). An endogenous credibility variable is introduced whereby inflation expectations and credibility respond endogenously to the monetary authorities' track record in delivering low inflation. Thus, an element of inflation expectations 'bias' can result under low credibility; and through the Phillips curve, inflation expectations have a direct effect on actual inflation.

To allow the extended model to embody the appropriate inflationary response to lower policy credibility—i.e., a worsening inflation-output tradeoff and higher persistence in inflation—we expand the original setup in two ways:

- We introduce a nonlinear effect of the output gap on inflation that induces severe inflationary and real costs following an overly expansionary monetary policy.
- The backward-looking weight $(1 - \alpha_{\pi^e})$ in the inflation expectations equation is raised reflecting a stronger “show-me” attitude, where the promises of the inflation target as reflected in where the model will take inflation are treated with more skepticism.¹³

A. Non Linear Phillips Curve

We begin by introducing a nonlinear response of inflation to the output gap. Explicitly, we replace the output gap term in the Phillips curve equation (2) by $\alpha_{ygap} \left(\frac{ygap_t}{y_{max} - ygap_t} y_{max} \right)$.

This term implies that the output gap cannot exceed a maximum value of y_{max} , calibrated here to equal 6 percent.¹⁴ In the region where the output gap is close to zero, the marginal effect on inflation is the same as in the linear case ($\alpha_{ygap} * ygap_t$). As the gap approaches y_{max} , it has a much stronger positive effect on the inflation rate. An economy that enters these areas will subsequently have to incur costs—long periods of negative output gaps—before the economy reverts back to the desired inflation target.

¹³ The exchange rate risk premium will also be higher for reasons we discuss later.

¹⁴ This estimate of the maximum output gap is consistent with some empirical work by Laxton, Meredith and Rose (2005).

B. Credibility Stock

The credibility stock measure we use has values ranging between zero (no credibility) and one (full credibility). In order to define the credibility stock, we introduce two hypothetical inflation processes—‘L’ and ‘H’, for ‘Low’ and ‘High’ inflation regimes.

In the ‘L’ scenario, inflation converges to the inflation target (π_t^*) as announced by the monetary authorities:¹⁵

$$\pi 4_t^L = 0.5 * \pi 4_{t-1} + (1 - 0.5) * \pi_t^* + \varepsilon_t^{\pi^L} \quad (6)$$

Estimation of this equation during the full-fledged inflation-targeting era (1997–2006) yields a coefficient of 0.2 on the inflation target. We consider this too low since that estimation period includes a mix of low and high credibility episodes, and our objective is to express inflation dynamics under a high credibility scenario. We therefore calibrate the coefficient to a higher value, 0.5, but which still implies gradual convergence of inflation to target.¹⁶ A value of 0.5 coincides with the baseline case value of α_{π^e} .

In the ‘H’ scenario, inflation converges to an assumed higher level of inflation, π_t^{*H} , of 10.8 percent, with an estimated α_{π^e} parameter value of 0.45. This equation is based on estimation of an autoregressive equation using data from 1992 to 1996—the first stage of inflation targeting in Israel, when inflation remained above 10 percent, on average.

$$\pi 4_t^H = 0.55 * \pi 4_{t-1} + (1 - 0.55) * 10.8 + \varepsilon_t^{\pi^H} \quad (7)$$

The intuition behind this equation is that if the public begins to suspect that monetary policy is allowing inflation to return to the high levels experienced in the mid-1990s, the loss of credibility may imply that expectations become anchored, at least temporarily, to a higher level of inflation.

The credibility stock (γ_t) takes the following autoregressive form:

¹⁵ In the Israeli context, the inflation target is defined as the mid-point of the 1–3 percent targeting range.

¹⁶ Isard and others (2001) set this parameter to 0.65 generating an expectation of fast convergence to the target under high credibility. Our choice reflects the approach in Laxton and N'Diaye (2002) who argue that even under high credibility inflation may converge gradually to target and that therefore a reasonable estimate would fall between 0.3 and 0.5.

$$\gamma_t = 0.7 * \gamma_{t-1} + (1 - 0.7) * \lambda_{t-1} + \varepsilon_t^\gamma \quad (8)$$

where:

$$\lambda_t = \frac{(\pi 4_t^H - \pi 4_t)^2}{(\pi 4_t^H - \pi 4_t)^2 + (\pi 4_t^L - \pi 4_t)^2} \quad (9)$$

and where the disturbance term, ε_t^γ , is considered as a shock to central bank credibility. The term (λ_t), as defined in equation (9), provides a measure of the extent to which inflation outcomes are seen as consistent with the 'Low' inflation scenario. Consider two extreme cases.¹⁷ In the 'L' case, inflation is converging gradually to the inflation target as implied by equation (6). λ_t equals 1, given that the term $(\pi 4_t^L - \pi 4_t)$ in the denominator of equation (9) equals 0;¹⁸ furthermore, according to equation (8), the credibility stock (γ_t) converges to 1, establishing full credibility. In the 'H' case on the other hand, inflation exhibits an upward trend as implied by equation (7). λ_t equals 0 ($\pi 4_t^H - \pi 4_t = 0$),¹⁹ and γ_t converges to zero, implying complete lack of credibility. In general, it can be said that credibility is lost if inflation diverges to levels above the announced target.²⁰

C. Credibility Stock Effects in the Extended Model

The credibility stock, γ_t , interacts in three different ways with the model equations: *first*, through the 'bias' factor in inflation expectations; *second*, through the weight of the forward-looking behavior of agents in the economy as encapsulated in pricing decisions; and *third*, via the risk premium embedded in the IP condition.

The one-year-ahead inflation expectations from equation (3) are assumed to be some weighted combination of a forward-looking and a backward-looking component, namely: (i) a model-consistent prediction of inflation ($\pi 4_{t+4}$), and past inflation given by a one-

¹⁷ We can think of inflation as specified in equations 6 and 7 to evolve according to a first-order, stationary autoregressive process, reverting in the long run to a targeted level of inflation π^* in the 'L' case and 10.8 percent in the 'H' case. The parameter values on lagged inflation are indicative of the rate of convergence to the steady state with high persistence values implying a longer time to converge.

¹⁸ This term is the expectation error of the low hypothetical inflation expectation.

¹⁹ This term is the expectation error of the high hypothetical inflation expectation.

²⁰ The convergence rate parameter of the credibility stock was calibrated to 0.7, i.e., it takes 1.5–2.0 years for credibility to rebuild from some below-full level of initial credibility.

quarter lag of the four-quarter inflation rate ($\pi 4_{t-1}$). Equation (3) is rewritten in the following way to allow for an explicit role for credibility:

$$\pi 4_t^e = \left(\frac{\gamma_t}{2}\right) \pi 4_{t+4} + \left(1 - \frac{\gamma_t}{2}\right) \pi 4_{t-1} + b_t + \varepsilon_t^{\pi^e} \quad (10)$$

where b_t is the inflation expectations ‘bias’ term, which is discussed further below.

Evidently, equation (10) exhibits two of the three above-mentioned credibility effects. *First*, a gain in credibility (as defined by an increase in γ_t) results in a rise in the weight on the forward-looking term. In turn, this will tie inflation more tightly to the target, which will mean that the central bank will have to do less in response to shocks and that convergence to the target rate will be faster. *Second*, the inflation bias term b_t generates higher inflation expectations and higher inflation.

The one-year-ahead inflation expectations implied by the hypothetical ‘L’ and ‘H’ equations, (6) and (7), are written as follows:

$$\pi 4_t^{e,L} = (1 - 0.5) * \pi_t^* * \sum_{i=0}^3 0.5^i + 0.5^4 * \pi 4_t \quad (11)$$

$$\pi 4_t^{e,H} = (1 - 0.55) * 10.8 * \sum_{i=0}^3 0.55^i + 0.55^4 * \pi 4_t \quad (12)$$

Consequently, the inflation expectations ‘bias’ is simply defined as a proportion of the deviation of a weighted average of the two forecasts from the inflation target, where the weights reflect the credibility stock γ_t :

$$b_t = 0.15 \left(\gamma_t * \pi 4_t^{e,L} + (1 - \gamma_t) * \pi 4_t^{e,H} - \pi_t^* \right) \quad (13)$$

Based on this equation, as credibility approaches unity, the bias converges to zero, given that under full credibility $\pi 4_t^{e,L}$ will tend to converge to the inflation target. Under the no-credibility scenario ($\gamma_t = 0$), the inflation bias is positive and is defined by the difference between the high hypothetical inflation expectations and the target.

To unravel the *third* interactive role of the credibility mechanism in the model, we modify the IP condition to include the b_t term as follows:

$$z_t = z_{t+1}^e - [RR_t - RR_t^{us} - \rho_t^*] / 4 + 0.66b_t + 2.3(b_t - b_{t-1}) + \varepsilon_t^z \quad (14)$$

Since our review of the historical episode suggested a strong link between exchange rate changes and the loss of credibility, we treat the bias (in both level and growth terms) as influencing the country risk premium. In the modified IP condition, extra nominal depreciation (positive sign) will come as credibility falls. All else equal, a loss of credibility that generates a (high) 1-percentage-point expectations bias will, temporarily, cause a 3 percent real depreciation, thereafter leaving the country risk premium higher by 0.66 percent.

V. EXTENDED MODEL PROPERTIES: DYNAMIC RESPONSES TO SHOCKS

A. Interest Rate Shocks

In section III, we discussed the effects of a decline in nominal (policy) interest rates by 2 percentage points for a short duration (two quarters). We designated that scenario as the base case against which we now compare the implications of the newly added features in the extended model. We also contrasted the muted effects of the base-case scenario on inflation, the exchange rate and the output gap with the observed Israeli experience during 2001–03 following the sharp 200 basis points policy rate cut in late 2001. Figure 3 depicts the impulse responses to the shock under the assumptions of (i) a strictly *linear* model, and (ii) *no endogenous credibility* (fixing γ_t at 1 in the extended model).

Figure 4 repeats the same shock with the extended model, assuming full credibility ($\gamma_t = 1$) at the start of the exercise.²¹ The drop in the policy rate in itself causes a rise in the inflation rate. Inflation is initially above target and then rises further, owing to an endogenous drop in credibility (by 12 percent at its peak after 5 quarters). The (nominal) exchange rate depreciates and peaks at 5.5 percent (above control), while inflation peaks at 2.5 percentage points above control. Both price movements (inflation and the exchange rate) are substantially larger than generated in the linear base-case scenario. Under this extended-model scenario, rebuilding credibility and bringing inflation back to the target rate is costly—interest rates need to be raised to 350 basis points above control, compared to only 150 basis points in the base-case scenario.

Note, furthermore, that endogenous credibility tends to generate more variability in output; the peak in the output gap (boom) is at 2.1 compared to 1.6 percentage points in the base case. We attribute this accentuated change partly to the additional effect of the exchange rate channel, coming from an endogenous rise in the risk premium. Thereafter, we witness a boom-bust cycle as interest rates rise sharply to contain the inflationary pressures (in contrast

²¹ We started with a steady-state control solution. With a nonlinear model, the initial conditions will affect shock-control properties.

to the almost non-negative output gap response in the base case). The negative output gap peaks at -0.8 percentage point below control during the bust cycle.

B. Implications of Different Initial Levels of Credibility

Interest Rate Shock

In the following scenarios, we lower the ‘initial’ credibility gradually from its highest possible value of one. Figures 5 and 6 depict the impulse responses to the same (200 bps) interest rate shock under the lower ‘initial’ credibility scenarios of 0.8 and 0.5, respectively. Initial lower credibility induces higher inflation expectations, a worse inflation-output tradeoff and a higher risk premium. As is clear from these figures, this creates greater nominal and real responses to the erratic monetary policy intervention. In Figure 5, where initial credibility is 0.8, inflation peaks at more than 3.5 percentage points, the exchange rate depreciation at 8 percent and nominal interest rates at 6 percentage points above control. Output gap volatility is higher (the trough of the negative gap is now 1.7 percentage points).

One interesting feature that emerges is that credibility does not fall immediately. This is because as credibility falls it requires more to trigger further declines. Only when year-on-year inflation peaks is the (temporary) divergence of inflation large enough to trigger a further drop in credibility from the initially lower level.

Credibility Shock

The implications of lower credibility can also be studied through shocks to credibility itself. Figures 7 and 8 compare the dynamic responses of inflation and exchange rate under two initial credibility values of 1.0 and 0.8, respectively. Interest rate shocks are turned off in these experiments.

We can deduce from Figure 8 that the lower initial credibility scenario (0.8) brings about a larger ‘bias’ in expectations and the risk premium. Inflation is higher (peaking at 0.35 percentage points above control after one year) and the real exchange rate depreciates in the short run. Regaining control of inflation under the circumstances of higher bias in inflation expectations, coupled with a higher risk premium and stronger backward-looking component in inflation expectations, would require that nominal (and real) interest rates increase causing losses in output with a trough of -0.13 percentage point after six quarters. Also notable in this experiment is that once credibility is disturbed, it takes a long time (over 2 years) before the monetary authorities can bring it back to control.

Inflation Shock

The implications of shocks arising from the economy are studied next.²² Figures 9, 10 and 11 illustrate the impulse response following a cost-push shock in the domestic Phillips Curve equation (1 percentage point for one quarter).

In Figure 9 we use the linear model. Figures 10 and 11 use the nonlinear endogenous credibility framework with initial credibility of 1.0 and 0.5 respectively. Figure 10 points to moderate loss in credibility as a result of the inflation shock: this is due to the immediate response of monetary policy in the right direction. Therefore, inflation and interest rates are only moderately higher in the endogenous credibility case. When credibility is initially lower (Figure 11), inflation outcomes are somewhat higher, but they remain moderate. This result is consistent with a common wisdom in monetary policy analysis: monetary policy credibility is usually lost as a result of obvious policy errors not as a result of the economy being hit by shocks (provided that monetary policy responds in an appropriate and timely fashion).

VI. CONCLUSIONS

The use of small structural models for monetary policy analysis has been very helpful in producing medium-term baseline forecasts and risk assessments. The standard model's relatively simple form makes risk assessment through shock analysis straightforward. At the same time, the standard framework limits the extent to which the model can properly capture the dynamic responses to unusual shocks, especially policy shocks. Building on earlier contributions in the literature, we extend the standard model of the Israeli economy, making the Phillips curve nonlinear and introducing a means of capturing endogenous changes in monetary policy credibility.

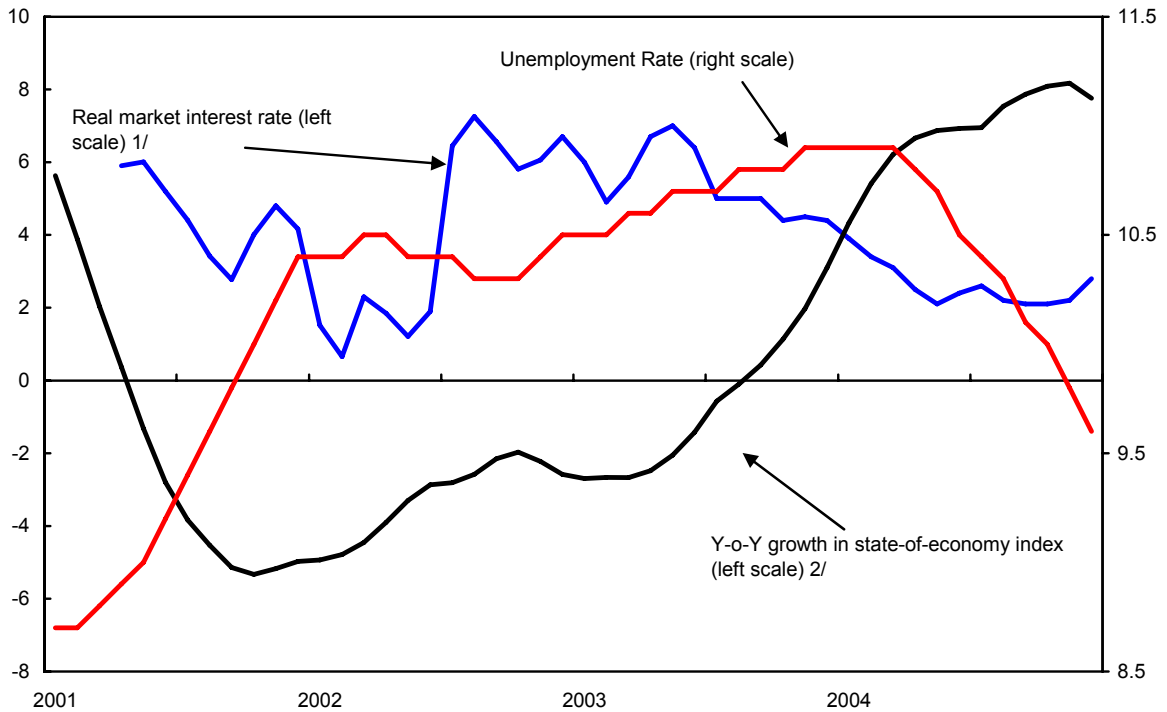
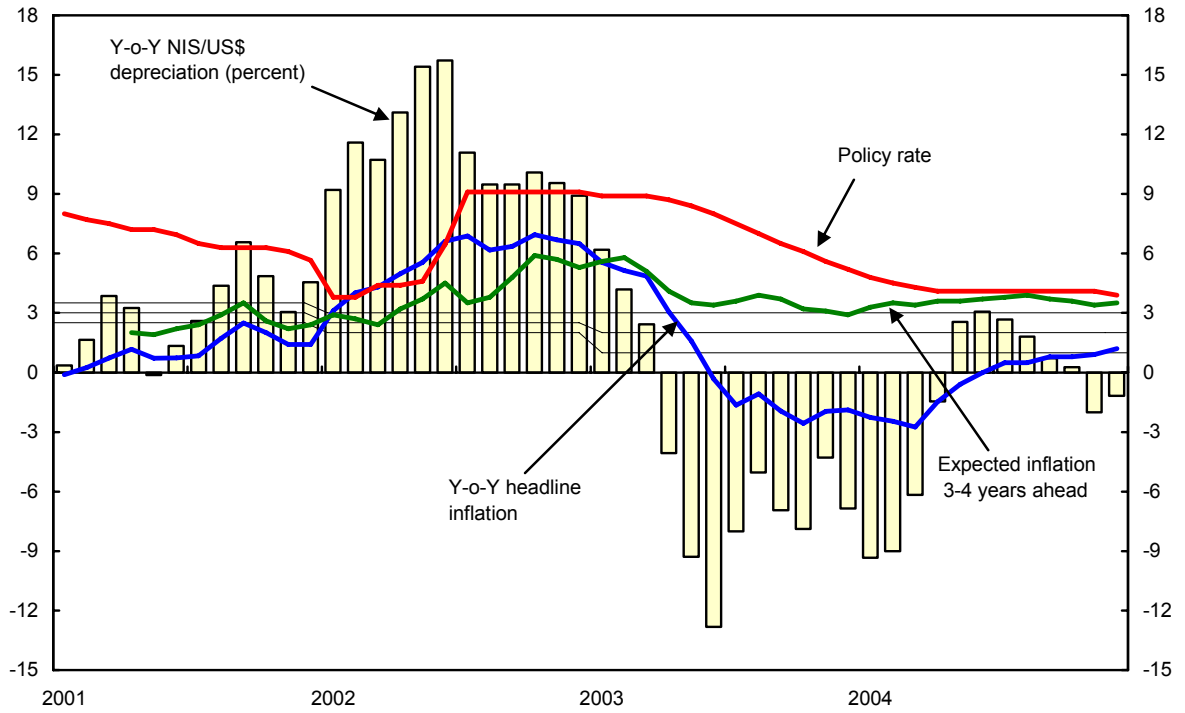
With these extensions, we find that the dynamic responses of the model to shocks more closely resemble the properties we see in the Israeli data. In particular, the extended model does a good job of accounting for the deterioration in credibility and the resulting movements in the exchange rate, inflation and output, following the apparent monetary overreaction to conditions in late 2001. The extended model also captures the relatively long time it took to rebuild credibility, and that bringing inflation back to the target and rebuilding credibility can be very costly—interest rates must be raised substantially higher, inducing greater variability in output. Analysis of a standard shock to the economy, in this case a price shock, suggests that credibility will not be lost because of normal shocks, even large ones, as long as the central bank is seen to be reacting consistently to deal with economic conditions. Rather, credibility is put at risk when policy is the source of the shock, that is, when the central bank does appear to be at odds with the announced goals of policy.

²² Because this shock may cause prices to rise for any given level of output, it is sometimes called a supply shock. Firms could raise prices owing to an increase in monopoly power; wages could rise due to an increase in workers' bargaining power.

Table. Standard FPAS Model Calibration

Output Gap Equation		Phillips Curve		Exchange Rate		Monetary Policy	
Israel							
β_{ld}	0.25	$\alpha_{\pi ld}$	0.70	δ_z	0.25	γ_{RSlag}	0.5
β_{lag}	0.60	α_{π^e}	0.50			γ_{π}	2.5
β_{RRgap}	0.15	α_{ygap}	0.30			γ_{ygap}	0.5
β_{zgap}	0.05	α_z	0.23				
β_{yus}	0.15	$\alpha_{rpoil0}, \alpha_{rpoil1}$	0.01,0				
United States							
β_{usld}	0.10	$\alpha_{\pi usld}$	0.20			γ_{RSlag}	0.75
β_{uslag}	0.60	α_{yusgap}	0.30			γ_{π}	2.0
$\beta_{usRRgap}$	0.15	$\alpha_{rwpoil0}, \alpha_{rwpoil1}$	0.006			γ_{ygap}	0.5

Figure 1. Israel: Interest Rates, Inflation, Exchange Rate, Growth and Unemployment Rate, 2001–04 (In percent)

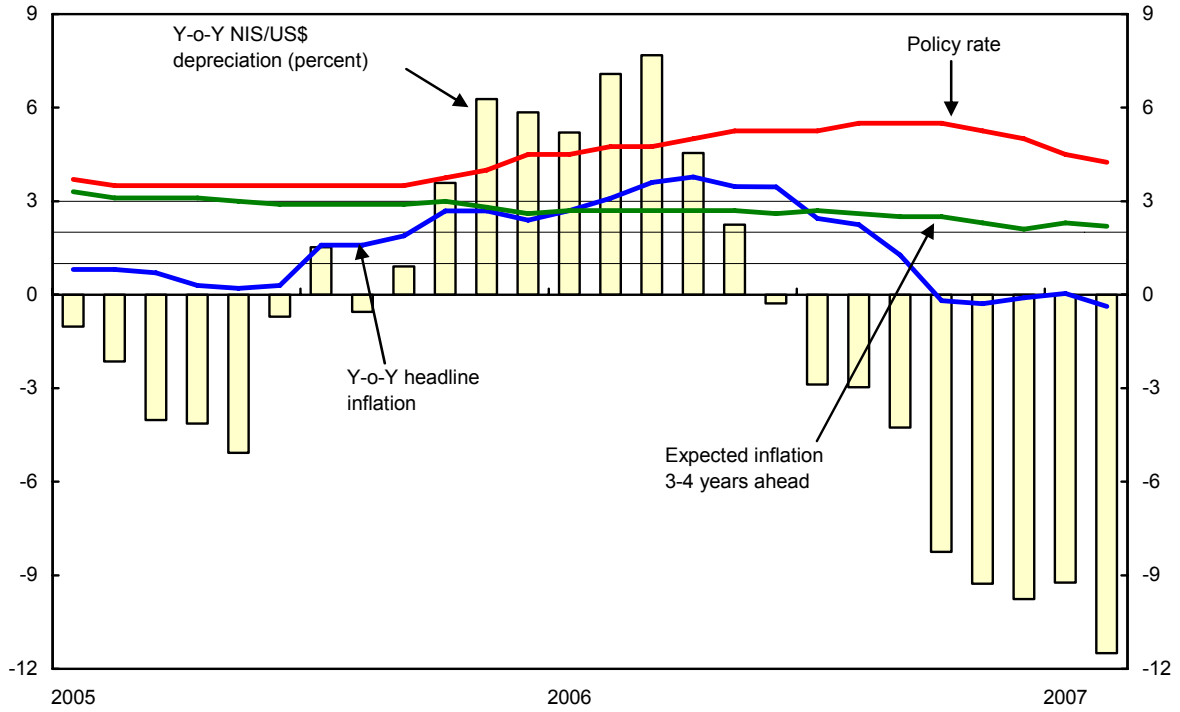


Sources: Bank of Israel; Central Bureau of Statistics; and IMF staff estimates.

1/ Policy rate minus expected inflation one year ahead.

2/ A broad (monthly) index that proxies for real GDP developments.

Figure 2. Israel: Interest Rates, Inflation, Exchange Rate, Growth and Unemployment Rate, 2005–07 (In percent)

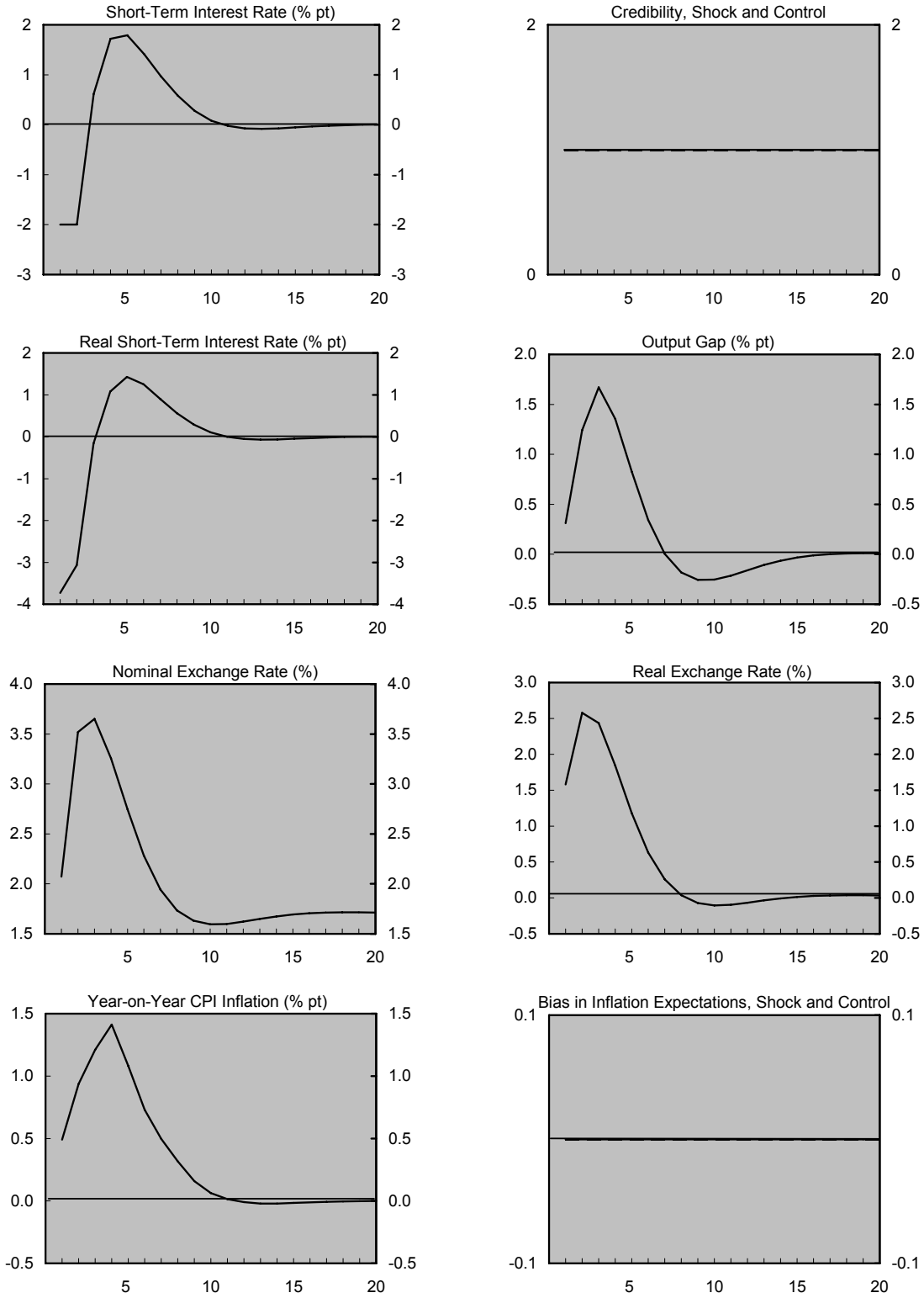


Sources: Bank of Israel; Central Bureau of Statistics; and IMF staff estimates.

1/ Policy rate minus expected inflation one year ahead.

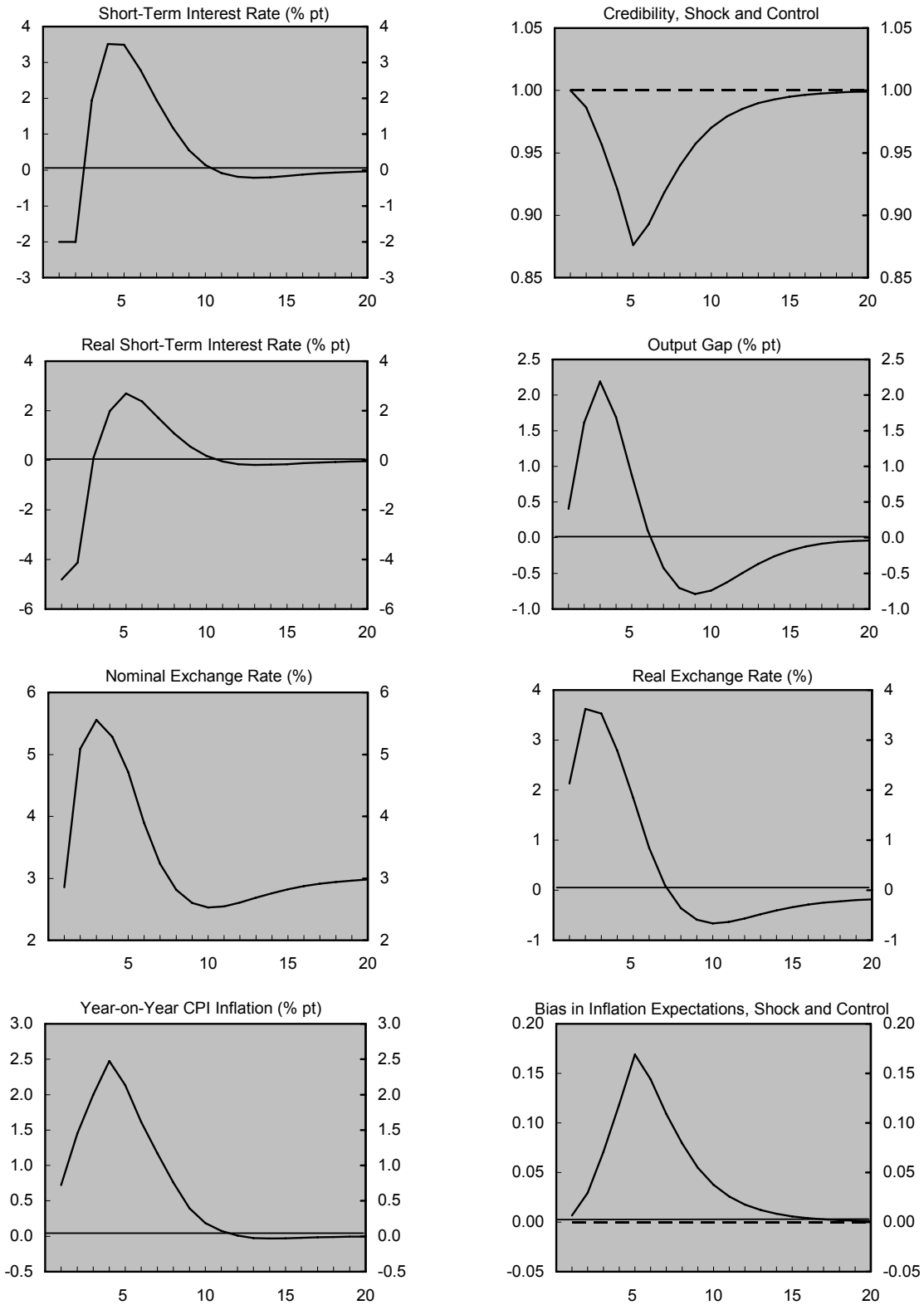
2/ A broad (monthly) index that proxies for real GDP developments.

Figure 3. Interest Rate Shock—Linear Model, No Endogenous Credibility
(Deviation from Control)



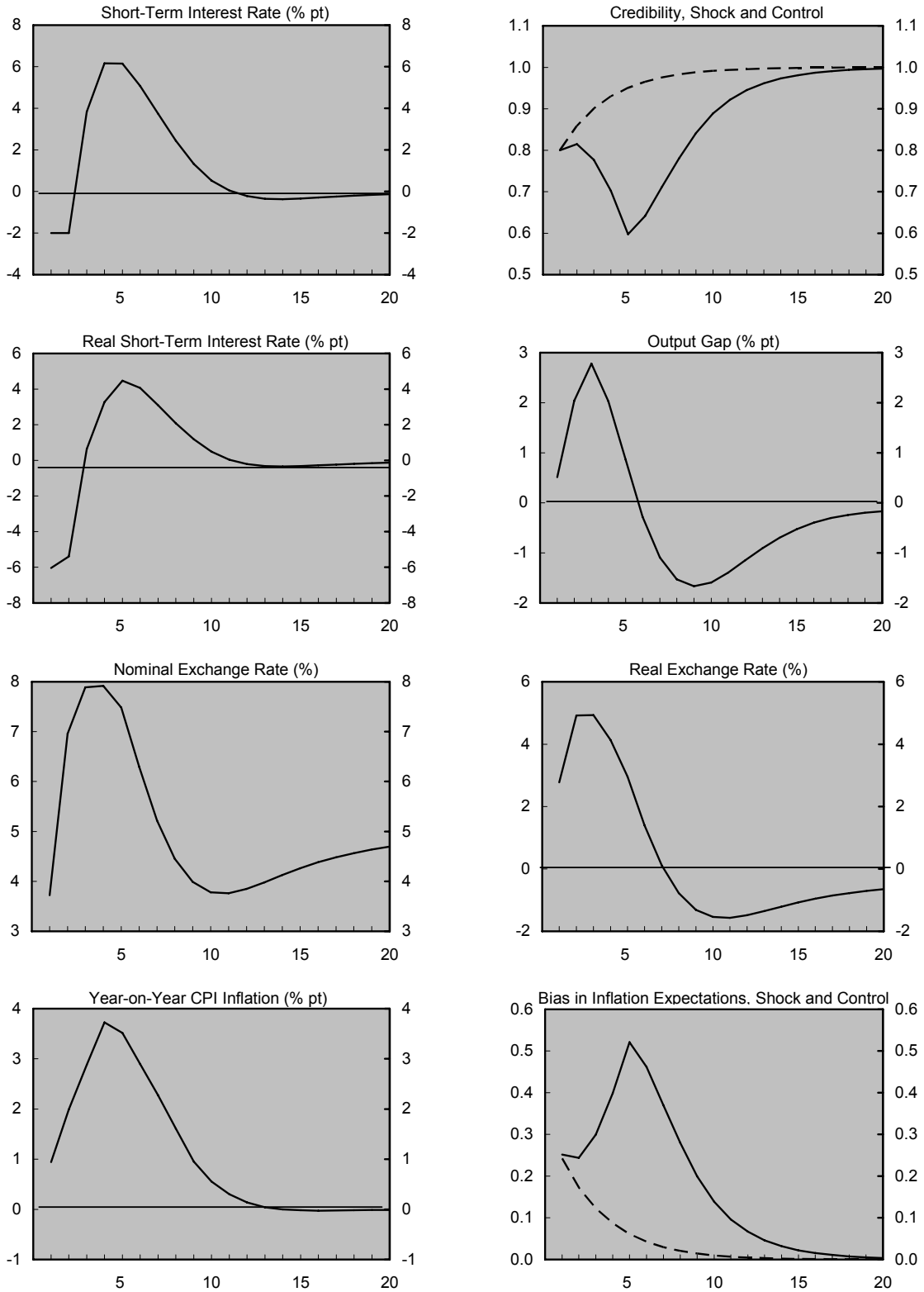
Source: IMF staff estimates.

Figure 4. Interest Rate Shock - Initial Credibility = 1.0
(Deviation from Control)



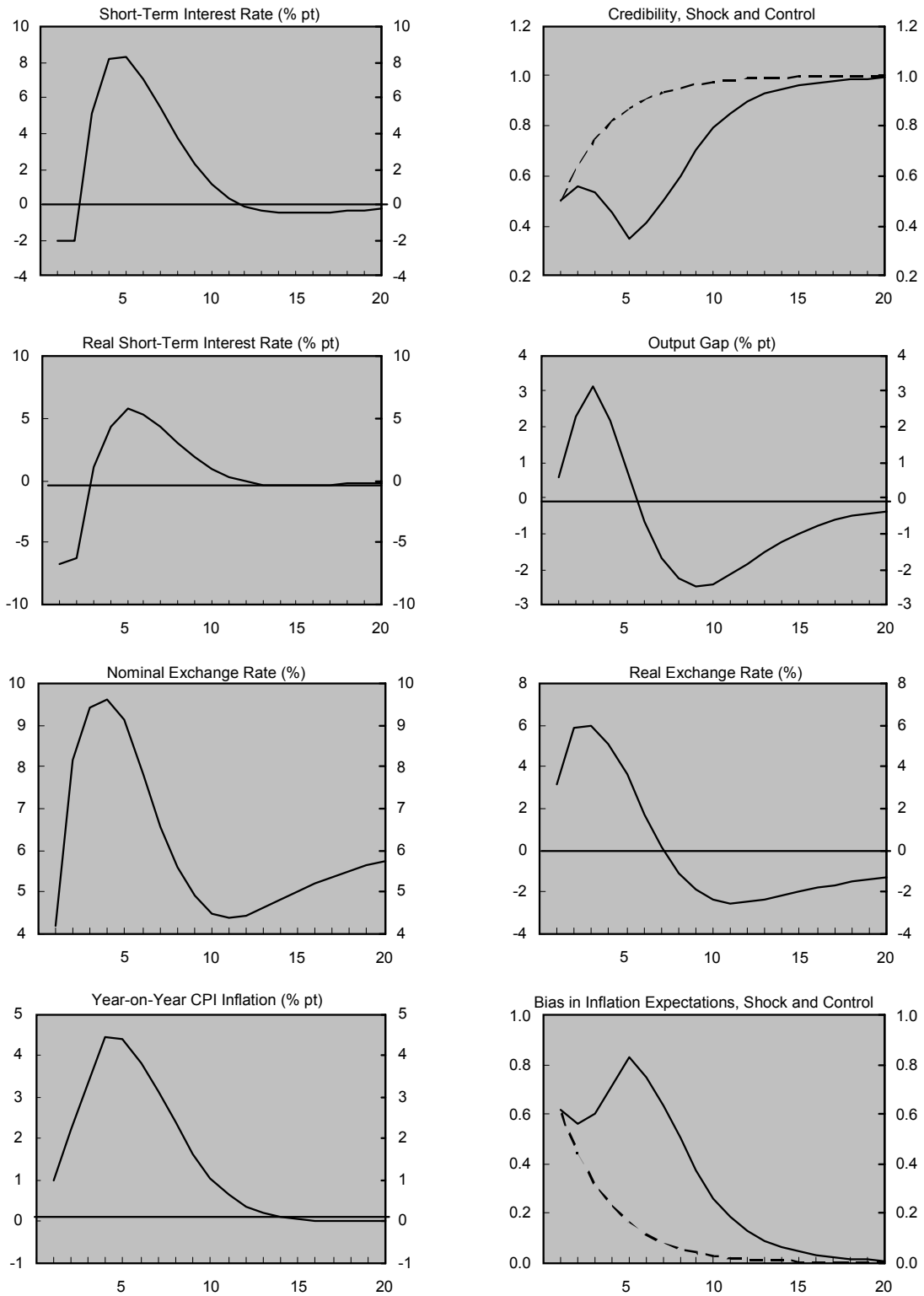
Source: IMF staff estimates.

Figure 5. Interest Rate Shock - Initial Credibility = 0.8
(Deviation from Control)



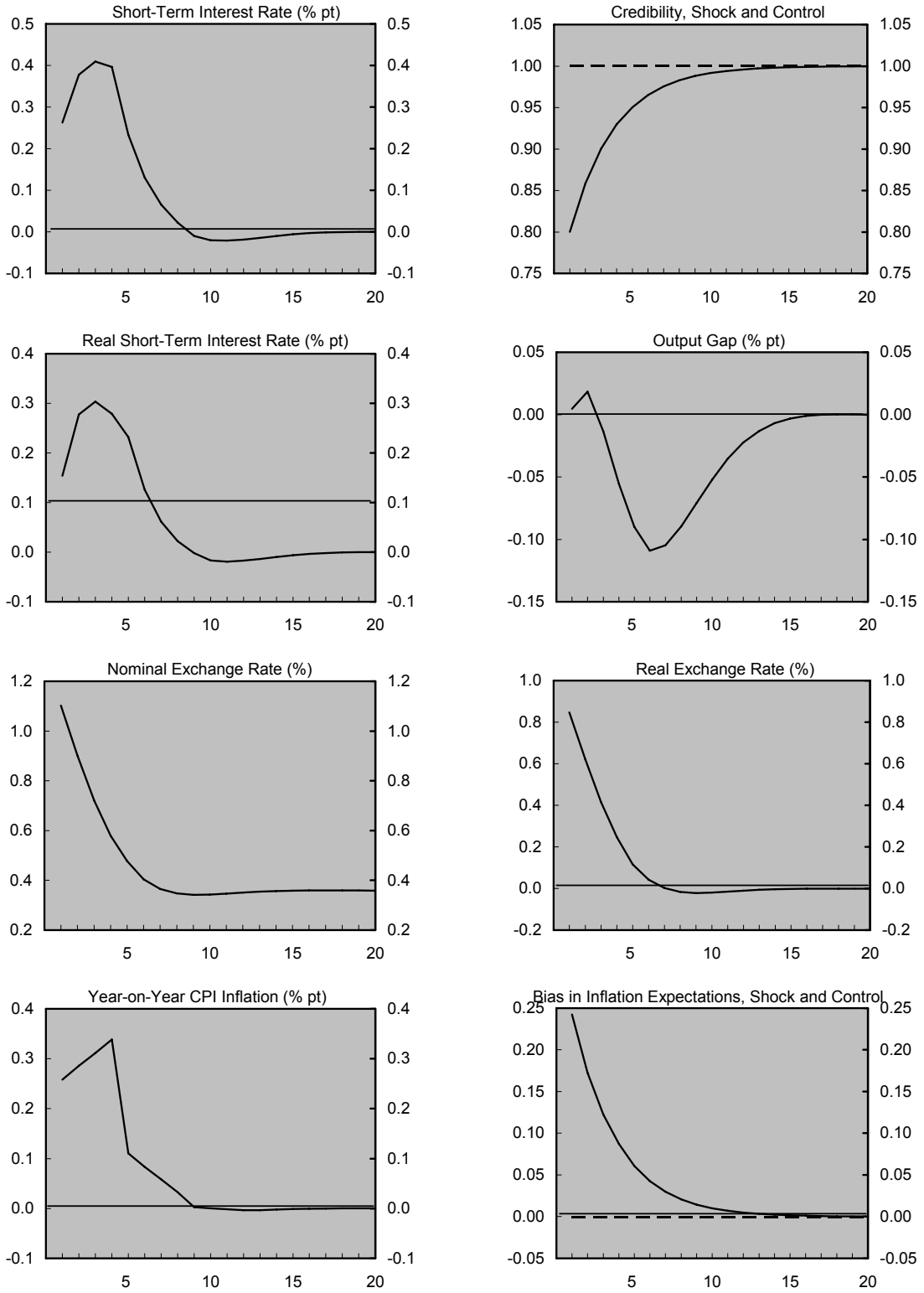
Source: IMF staff estimates.

Figure 6. Interest Shock - Initial Credibility = 0.5
(Deviation from control)



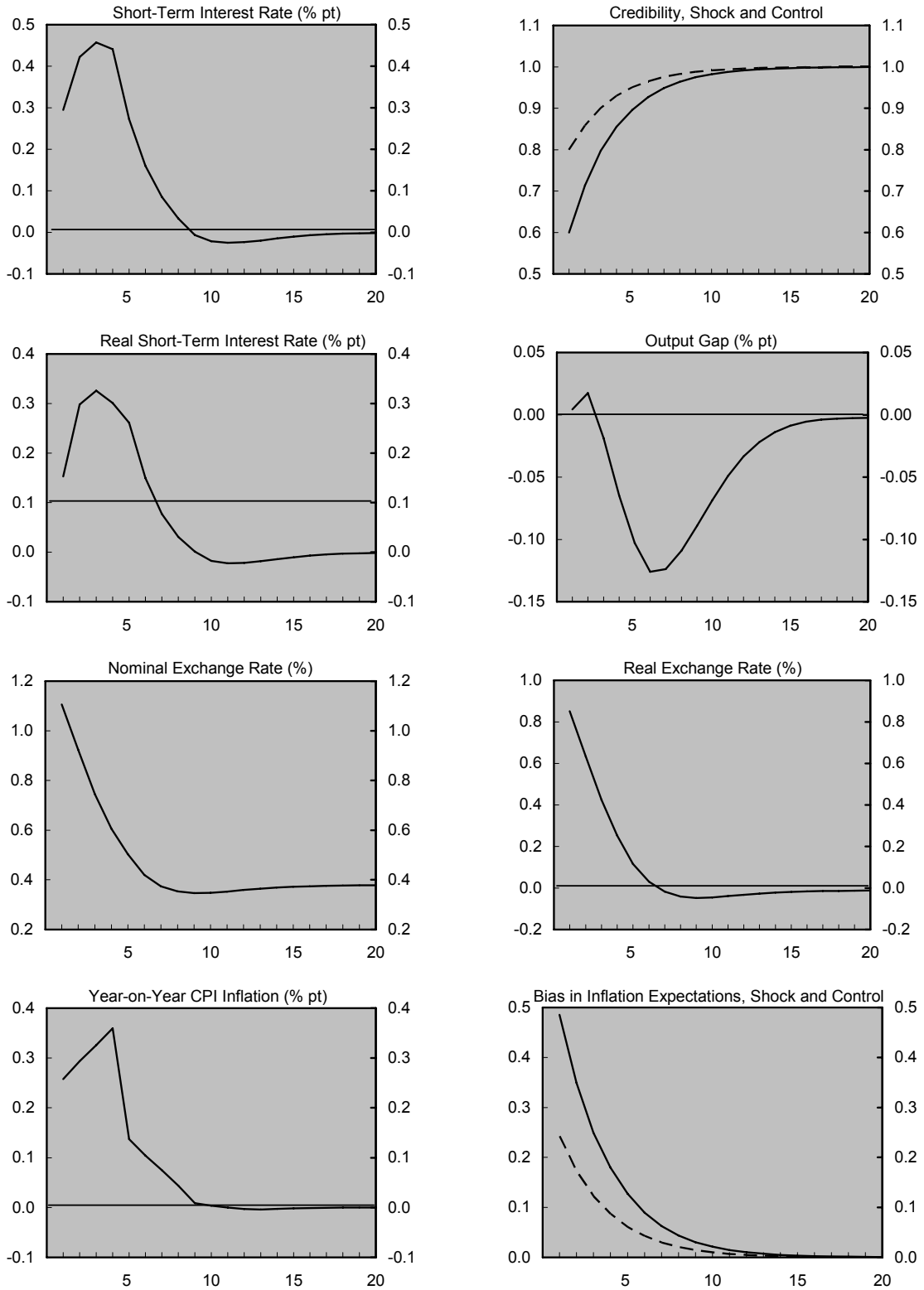
Source: IMF staff estimates.

Figure 7. Credibility Shock - Initial Credibility = 1.0
(Deviation from Control)



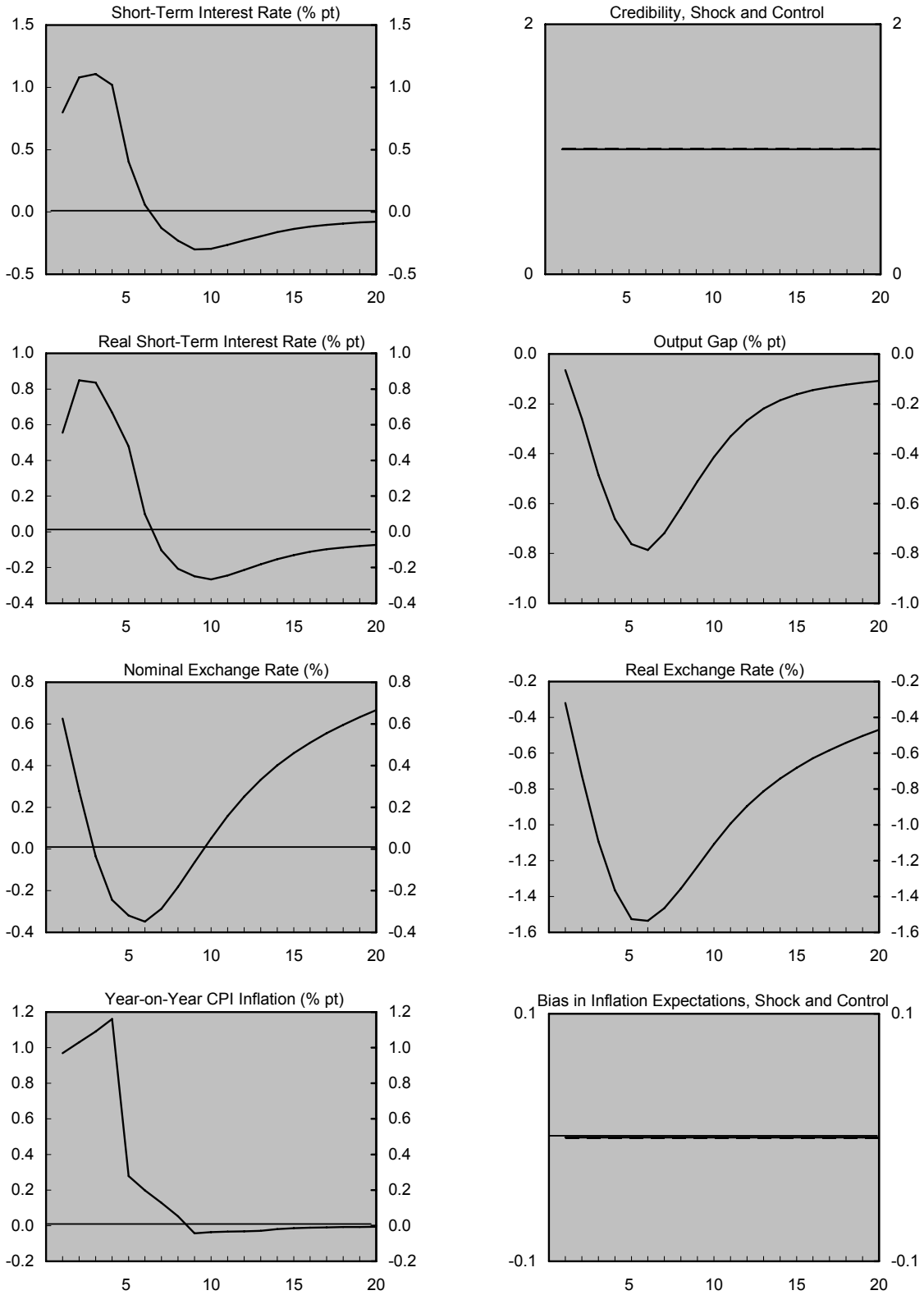
Source: IMF staff estimates.

Figure 8. Credibility Shock - Initial Credibility = 0.8
(Deviation from Control)



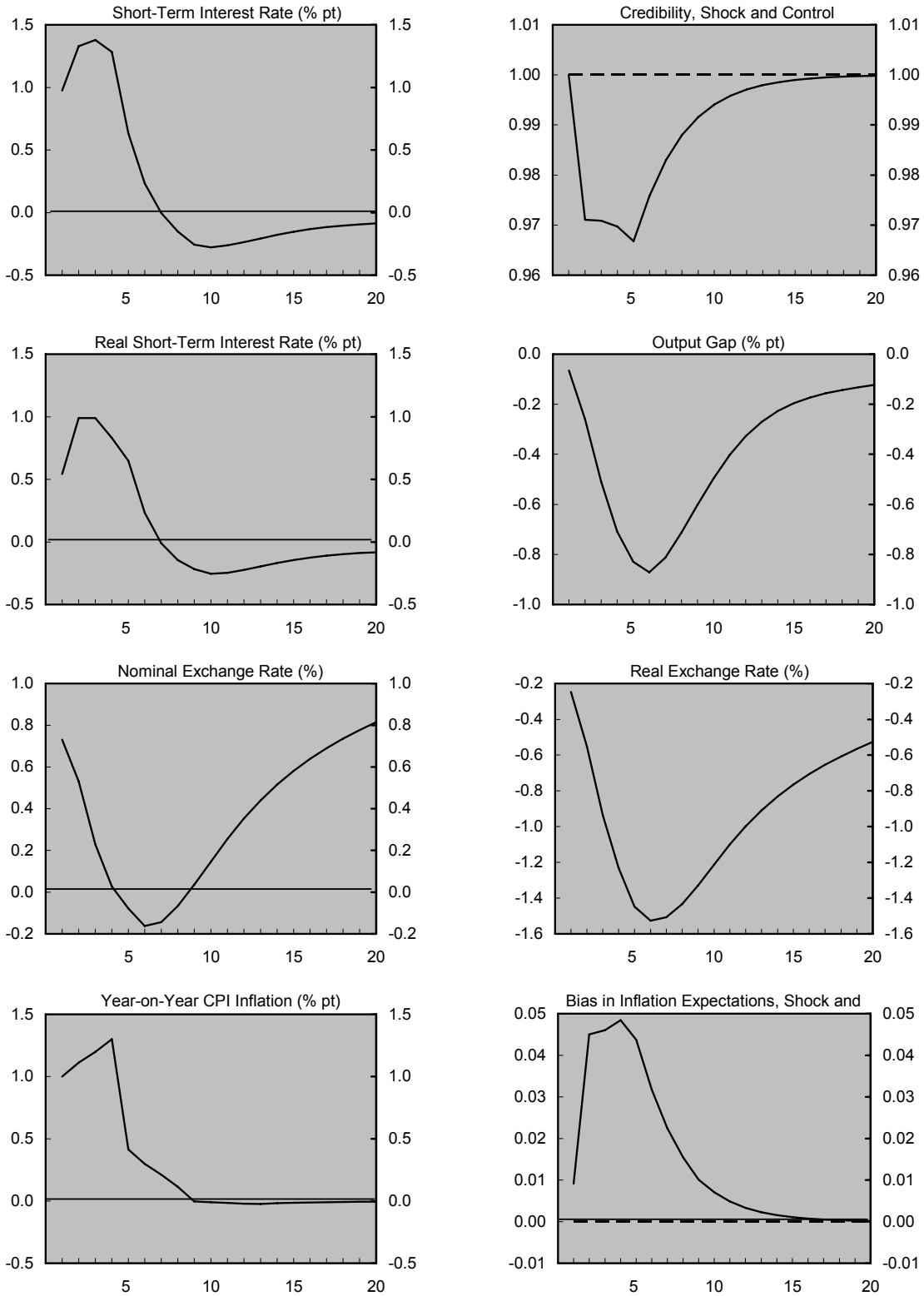
Source: IMF staff estimates.

Figure 9. Inflation Shock - Linear Model, No Endogenous Credibility
(Deviation from Control)



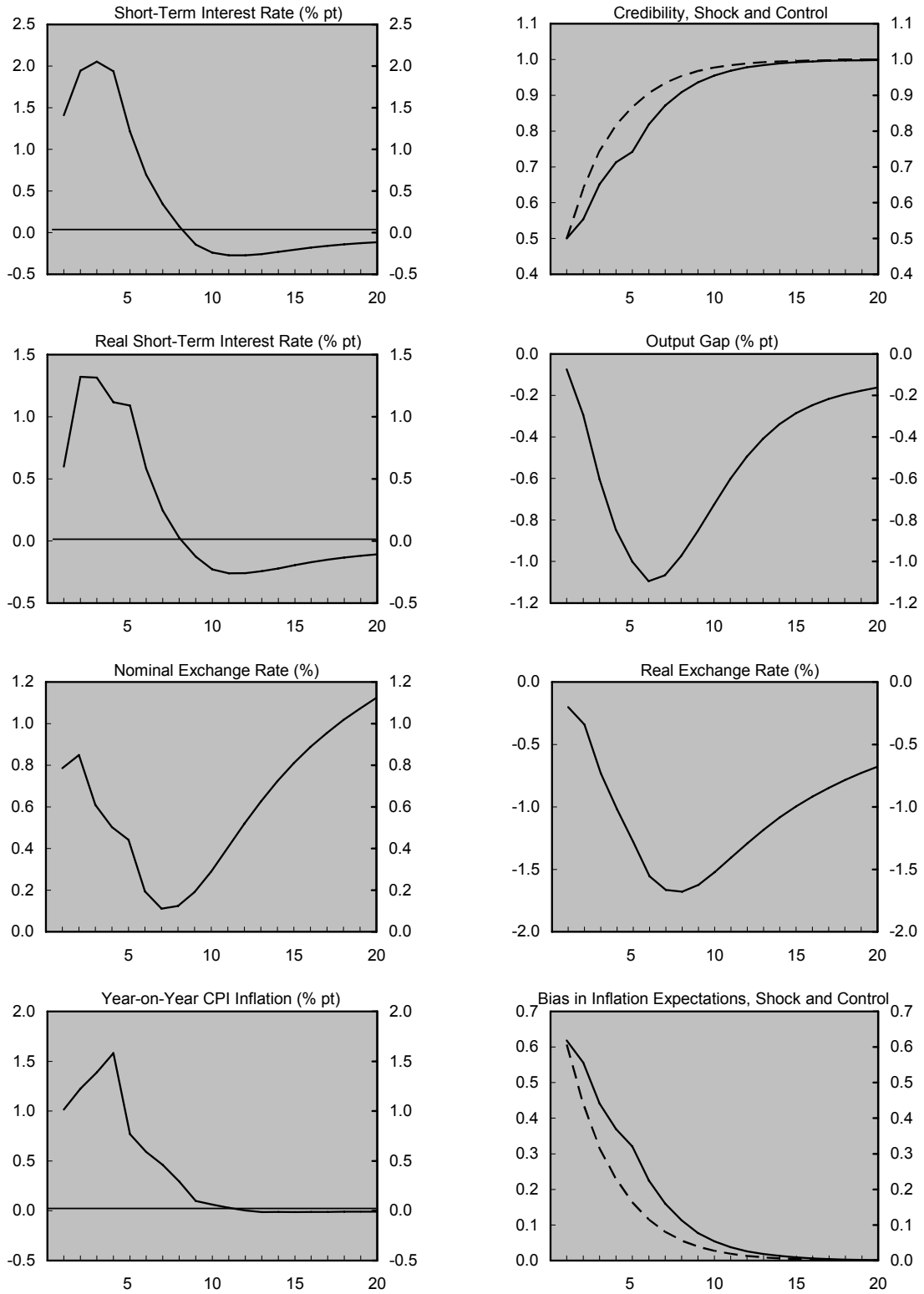
Source: IMF staff estimates.

Figure 10. Inflation Shock - Initial Credibility = 1.0
(Deviation from Control)



Source: IMF staff estimates.

Figure 11. Inflation Shock - Initial Credibility = 0.5
(Deviation from Control)



Source: IMF staff estimates.

APPENDIX. THE MODEL

Variable Definitions

$ygap$	output gap, deviation of actual from potential output, in percentage points
y_{\max}	constrained maximum output gap value
z	real exchange rate (in logs); an increase implies a real exchange rate depreciation
π	cpi inflation, quarterly at annualized rate, percentage points
$\pi 4_t$	four-quarter change in the CPI, annualized rate, percentage points
$\pi_{rpoil,t}$	change in the relative price of oil, quarterly at annualized rate, percentage points
γ_t	credibility stock measure; values ranging between 0,1
λ_t	indicator of credibility; values ranging between 0, 1
$\pi 4_t^L$	hypothetical ‘Low’ inflation state process
$\pi 4_t^H$	hypothetical ‘High’ inflation state process
π^*	target inflation rate, annualized rate in percentage points
$\varepsilon_t^{\pi^L}$	expectation error of the ‘Low’ hypothetical inflation expectations
$\varepsilon_t^{\pi^H}$	expectation error of the ‘High’ hypothetical inflation expectations
$\pi 4_t^e$	one-year ahead inflation expectations
$\pi 4_t^{e,L}$	one-year ahead inflation expectations implied by the ‘Low’ inflation state process
$\pi 4_t^{e,H}$	one-year ahead inflation expectations implied by the ‘High’ inflation state process
b_t	bias term in one-year ahead inflation expectations
RR	real interest rate, in percentage points
z^*	equilibrium real exchange rate (in logs); an increase implies a depreciation
RR^{US}	U.S. real interest rate, in percentage points
$yusgap$	U.S. output gap, deviation of actual from potential output, in percentage points
ρ^*	equilibrium risk premium
RR^*	equilibrium real interest rate, in percentage points.
RR^{*US}	equilibrium U.S. real interest rate, in percentage points

Main Model Equations

Nonlinear inflation equation:

$$\pi_t = \alpha_{\pi ld} \pi 4_t^e + (1 - \alpha_{\pi ld}) \pi 4_{t-1} + \alpha_{ygap} * y_{\max} \left(\frac{ygap_t}{y_{\max} - ygap_t} + \frac{ygap_{t-1}}{y_{\max} - ygap_{t-1}} \right) + \alpha_z [z_t - z_{t-1}] + \alpha_{rpoil 0} \pi rpoil_t + \alpha_{rpoil 1} \pi rpoil_{t-1} + \varepsilon_t^\pi + \varepsilon_t^\gamma \quad (A1)$$

Stock of credibility (γ_t):

$$\gamma_t = 0.7 * \gamma_{t-1} + (1 - 0.7) * \lambda_{t-1} + \varepsilon_t^\gamma \quad (A2)$$

Indicator of credibility based on High and Low inflation states:

$$\lambda_t = \frac{(\varepsilon_t^{\pi^H})^2}{(\varepsilon_t^{\pi^H})^2 + (\varepsilon_t^{\pi^L})^2} \quad (A3)$$

Hypothetical Low and High inflation state processes:

$$\pi 4_t^L = 0.5 * \pi 4_{t-1} + (1 - 0.5) * \pi_t^* + \varepsilon_t^{\pi^L} \quad (A4)$$

$$\pi 4_t^H = 0.55 * \pi 4_{t-1} + (1 - 0.55) * 10.8 + \varepsilon_t^{\pi^H} \quad (A5)$$

One-year-ahead inflation expectations:

$$\pi 4_t^e = \left(\frac{\gamma_t}{2} \right) \pi 4_{t+4} + \left(1 - \frac{\gamma_t}{2} \right) \pi 4_{t-1} + b_t + \varepsilon_t^{\pi^e} \quad (A6)$$

One-year-ahead inflation expectations implied by the hypothetical ‘L’ and ‘H’ equations:

$$\pi 4_t^{e,L} = (1 - 0.5) * \pi_t^* * \sum_{i=0}^3 0.5^i + 0.5^4 \cdot \pi 4_t \quad (\text{A7})$$

$$\pi 4_t^{e,H} = (1 - 0.55) * 10.8 * \sum_{i=0}^3 0.55^i + 0.55^4 \cdot \pi 4_t \quad (\text{A8})$$

Bias term in one-year ahead inflation expectations:

$$b_t = 0.15 \left(\gamma_t * \pi 4_t^{e,L} + (1 - \gamma_t) * \pi 4_t^{e,H} - \pi_t^* \right) \quad (\text{A9})$$

Output gap:

$$ygap_t = \beta_{ld} ygap_{t+1} + \beta_{lag} ygap_{t-1} - \beta_{RRgap} (RR_{t-1} - RR_{t-1}^*) + \beta_{zgap} (z_{t-1} - z_{t-1}^*) + \beta_{yus} yusgap_t + \varepsilon_t^y \quad (\text{A10})$$

Monetary policy reaction function (an inflation-forecast-based Taylor rule):

$$RS_t = \gamma_{RSlag} RS_{t-1} + (1 - \gamma_{RSlag}) * (RR_t^* + \pi 4_t + \gamma_{\pi} [\pi 4_{t+4} - \pi_{t+4}^*] + \gamma_{ygap} ygap_t) + \varepsilon_t^{RS} \quad (\text{A11})$$

Modified interest parity (IP) condition to include the b_t term:

$$z_t = z_{t+1}^e - [RR_t - RR_t^{us} - \rho_t^*] / 4 + 0.66b_t + 2.3(b_t - b_{t-1}) + \varepsilon_t^z \quad (\text{A12})$$

where,

$$\rho_t^* = 4(z_t^* - z_{t+1}^*) + (RR_t^* - RR_t^{*US})$$

Backward-looking and model-consistent expectations for the exchange rate ($\delta_z \neq 1$):

$$z_t^e = \delta_z z_{t+1} + (1 - \delta_z) z_{t-1}$$

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