ONLINE APPENDIX

Two Targets, Two Instruments: Monetary and Exchange Rate Policies in Emerging Market Economies

In this Online Appendix we elaborate on the discussion in the main text in two ways. First, we provide analytical solutions to a simple two-period version of the model presented in the main text; second, we provide simulation results under the fully discretionary (i.e., non-IT) regimes, and compare the initial policy responses across all four regimes.

POLICY RESPONSES UNDER ALTERNATIVE REGIMES: A SIMPLE MODEL

In the text, reference is made to the policy responses to various shocks under four different regimes: (1) discretionary monetary policy with no FX intervention; (2) discretionary monetary policy with FX intervention; (3) inflation targeting with no FX intervention; and (4) inflation targeting with FX intervention. Here we compare discretionary policies and inflation-targeting, where both regimes are assumed to incorporate optimal sterilized intervention (i.e., regimes (2) and (4)).

Aggregate demand is assumed to depend negatively on the real exchange rate, *e*, where an increase in *e* is an appreciation of the home currency, negatively on the real interest rate, and on a demand shock:

$$y_t = -r_t - \beta e_t + u_t \tag{1}$$

Aggregate supply is given by a Lucas-type "surprise inflation" Philips curve:

$$y = \pi_t - \pi_t^e \tag{2}$$

Capital inflows depend positively on the expected real interest rate differential:[1]

$$\Delta k_t = (r_t - r_t^* + (e_{t+1}^e - e_t)) \tag{3}$$

[1] From the uncovered interest rate parity condition: $i_t = i_t^* - (s_{t+1} - s_t)$, where *i* is the nominal interest rate and *s* is the nominal spot exchange rate, subtracting domestic inflation rate yields: $[i_t - (p_{t+1} - p_t)] = [i_t^* - (p_{t+1}^* - p_t^*)] - [(s_{t+1} - s_t) - (p_{t+1}^* - p_t^*) + (p_{t+1} - p_t)]$. Defining $r_t = i_t - (p_{t+1} - p_t)$ and $e_t = (s_t - p_t^* + p_t)$ yields (3).

The current account depends negatively on the real exchange rate and negatively on economic activity:

$$ca_t = -e_t - \alpha y_t \tag{4}$$

Finally, the balance of payments identity relates the current and capital accounts to the accumulation of reserves:

$$ca_t + \Delta k_t = \Delta R_t \tag{5}$$

The monetary authorities are assumed to choose the real interest rate, r, and (sterilized) foreign exchange intervention, ΔR. The foreign interest rate, r^* (where a capital inflow shock corresponds to $r^* < 0$) and the aggregate demand shock, u, are assumed to be uncorrelated, with mean zero and variance $\sigma^2_{r^*}$ and σ^2_u respectively. These shocks are assumed to be observed after the wage-setters form expectations about current period inflation (π^e) but before the central bank must set the interest rate and choose the amount of foreign exchange intervention.

Under the assumption that all capital inflows occur in period 1, and that the capital remains in place in period 2, all period 2 variables of interest equal zero. Hence, we can focus on period 1. Two algebra-simplifying assumptions are: $\alpha = \beta = 0$; these assumptions do not change the main results reported below. As is standard in these models, the central bank is assumed to penalize deviations from its target level of aggregate demand and output, $\bar{y} \geq 0$, which may exceed the natural level of output (here normalized to zero) and of inflation from its target level of inflation (normalized to zero). In addition, however, the central bank is assumed to penalize deviations of the real exchange rate from its value warranted by medium-term fundamentals (zero) due to competitiveness considerations on the appreciation side, and concerns about balance sheet effects of foreign-currency denominated debt on the depreciation side. Finally, the central bank seeks to minimize its foreign exchange intervention due to costs of sterilization. The central bank's objective function may therefore be written:

$$W = Max_{r,R} -\frac{1}{2}\{(y-\bar{y})^2 + a(\pi)^2 + b(e)^2 + cR^2\} \tag{6}$$

where $a, b, c \geq 0$ are the relative welfare weights, with a 1 percent deviation of output from its target level receiving a weight of unity.

Discretionary Monetary Policy with Foreign Exchange Intervention

Substituting the model into the objective function, and taking first-order conditions yields the optimal interest rate and reserves accumulation policies:

$$r_D = \frac{\tilde{b}r^* + u(1+a)(1+\tilde{b}/c)}{((1+a)(1+\tilde{b}/c)+\tilde{b})} \tag{7}$$

$$R_D = \frac{(1+a)(\tilde{b}/c)(u-r^*)}{[(1+a)(1+\tilde{b}/c)+\tilde{b}]} \tag{8}$$

Where r_D and R_D are the optimal interest rate and intervention policies under the discretionary regime, and where $\tilde{b} = b/4$ In the face of a capital inflow shock $r^* < 0$, therefore, the domestic central bank would lower interest rates (to help reduce the inflow) and accumulate reserves to absorb part of the inflow. In both cases, the response is less than one-for-one. In the face of a shock that reduces aggregate demand $u < 0$, the central bank would lower interest rates and decrease its reserve holdings to stabilize the currency.

Since policies do not fully offset the shocks, there is a corresponding impact on the key macroeconomic variables of interest:

$$y_D = -r + u = \frac{\tilde{b}(u-r^*)}{[(1+a)(1+\tilde{b}/c)+\tilde{b}]} \tag{9}$$

$$\pi_D = (\bar{y}/a) + \frac{\tilde{b}(u-r^*)}{[(1+a)(1+\tilde{b}/c)+\tilde{b}]} \tag{10}$$

$$e_D = \frac{1}{2}\left\{\frac{(1+a)(u-r^*)}{(1+a)(1+\tilde{b}/c)+\tilde{b}}\right\} \tag{11}$$

A capital inflow shock, $r^* < 0$, or a positive aggregate demand shock ($u > 0$), thus lead to overheating of the economy ($y > 0, \pi > 0$) and an appreciation of the real exchange rate ($e > 0$). In addition, even in the absence of shocks, the economy inherits an inflationary bias $\pi = (\bar{y}/a) > 0$ that reflects the central bank's incentive to generate surprise inflation. Since this incentive is perfectly anticipated by wage-setters, the central bank does not actually succeed in eroding real wages and boosting aggregate demand. Nevertheless, the central bank's inability to pre-commit to not try to generate surprise inflation imparts this inflationary bias to the economy.[2]

Inflation Targeting with Foreign Exchange Intervention

Under this regime, the interest rate is set according to the IT framework, but the central bank may intervene in the foreign exchange market at will:

$$IT: \pi = 0, \pi^e = 0 \tag{12}$$

which implies: $r = u, y = -r + u = 0$, so the only optimization is over the amount of FX intervention. The objective function becomes:

$$W_R = Max - \frac{1}{2}\{(0-\bar{y})^2 + a(0)^2 + \tilde{b}(R - u + r^*)^2 + cR^2\} \tag{13}$$

Yielding the optimal intervention policy:

$$R_{IT} = \frac{\tilde{b}(u - r^*)}{\tilde{b} + c} \tag{14}$$

So the exchange rate is: $$e_{IT} = \frac{1}{2}\frac{c(u-r^*)}{(\tilde{b}+c)}$$

Comparing IT with discretionary policies shows that:

$$\frac{(1+a)\tilde{b}}{[(1+a)(c+\tilde{b}) + c\tilde{b}]} < \frac{\tilde{b}}{\tilde{b}+c} \Rightarrow R_D < R_{IT} \tag{15}$$

Hence, the central bank undertakes more intervention under IT than it would under full discretion, but because the policy interest rate reacts less vigorously to the capital inflow shock, the exchange rate is nevertheless more appreciated under IT:[3]

---

[2] Even if the central bank does not have such an incentive, $\bar{y} = 0$, but the private sector believes that it has, $\bar{y}^e > 0$, the lack of credibility will itself imply an inflationary bias to the economy.

[3] Under the simplifying assumptions that $\alpha = \beta = 0$, the interest rate does not react at all to the capital inflow shock in the IT regime. More generally, the interest rate will react, but by less than it would under discretion. Although the IT regime involves a smaller interest rate response but greater FX intervention, the exchange rate is necessarily more appreciated in the face of an inflow shock than it would be under discretion. This is because the IT

(continued)

$$\frac{1}{2}\left\{\frac{(1+a)(u-r^*)}{(1+a)(1+\tilde{b}/c)+\tilde{b}}\right\} < \frac{1}{2}\frac{c(u-r^*)}{(\tilde{b}+c)} \Rightarrow e_D < e_{IT} \tag{16}$$

If $r^* < 0, e_D < e_{IT}$: the real exchange rate is more appreciated under IT than under full discretion even though intervention is greater under IT.

Comparing welfare across regimes, it is readily seen that, regardless of the monetary policy regime, welfare will be higher when the central bank intervenes in the FX market than when it does not (since it could always choose to undertake zero intervention in FX intervention regimes). It is also readily shown that the welfare ranking between discretionary and IT regimes depends on the magnitude of the shocks (capital inflows and aggregate demand) relative to the actual $(\bar{y} > 0)$ or perceived $(\bar{y}^e > 0)$ inflationary bias. When shocks are large, the flexibility of discretionary policies dominates; when credibility is low, the discipline of IT dominates.

Multilateral Considerations

Next, we consider the multilateral aspects of countries' optimal monetary and exchange rate policies. To take account of spillovers, we recast the capital flow equation as:

$$\Delta k_t = (i_t^a - i_t^* + (e_{t+1}^a - e_t^a)) + \theta(i_t^a - i_t^b + (e_{t+1}^a - e_t^a) - (e_{t+1}^b - e_t^b)) \tag{17}$$

where $\theta \geq 0$ represents the deflection of the capital inflow from country A to country B, depending on the relative interest rate differentials. It is then readily shown that under discretionary uncoordinated policies, the interest rate and intervention policies become:

$$r_{Nash} = \frac{(1+\theta)(1+\theta/2)\hat{b}r^* + (1+a)[1+(\hat{b}/c)(1+\theta/2)]u}{\{(1+a)+(\hat{b}/c)(1+\theta/2)[(1+a)+c(1+\theta)]\}} \tag{18}$$

$$R_{Nash} = \frac{-(\hat{b}/c)(1+\theta/2)r^*}{[1+(\hat{b}/c)(1+\theta/2)]} + \frac{(1+a)(\hat{b}/c)(1+\theta/2)u}{\{(1+a)+(\hat{b}/c)(1+\theta/2)[(1+a)+c(1+\theta)]\}} \tag{19}$$

where $\hat{b} = b/(2+\theta)^2$.

---

regime meets the inflation (and output gap) target exactly, so the deviation of the other targets in the central bank's objective function (*e* and *R*) must be greater than they would be under discretion.

Under coordination, each country recognizes that (in equilibrium) it will be unable to deflect capital to the other, so the optimization is undertaken setting $\theta = 0$:

$$r_{coord} = r_{\theta=0} = \frac{\tilde{b}r^* + (1+a)[1+(\tilde{b}/c)]u}{\{(1+a)(1+\tilde{b}/c)+\tilde{b}\}} \tag{20}$$

which is (7). Likewise (19) collapses to (8):

$$R_{coord} = R_{\theta=0} = \frac{-(\tilde{b}/c)r^*}{[1+(\tilde{b}/c)]} + \frac{(1+a)(\tilde{b}/c)u}{\{(1+a)(1+\tilde{b}/c)+c\}} \tag{21}$$

In response to the capital inflow shock, therefore, the central bank undertakes too little sterilized intervention:

$$R_{Nash} < R_{coord} \Leftrightarrow \frac{-r^*(\hat{b}/c)(1+\theta/2)}{[1+(\hat{b}/c)(1+\theta/2)]} < \frac{-r^*(\tilde{b}/c)}{[1+(\tilde{b}/c)]} \tag{22}$$

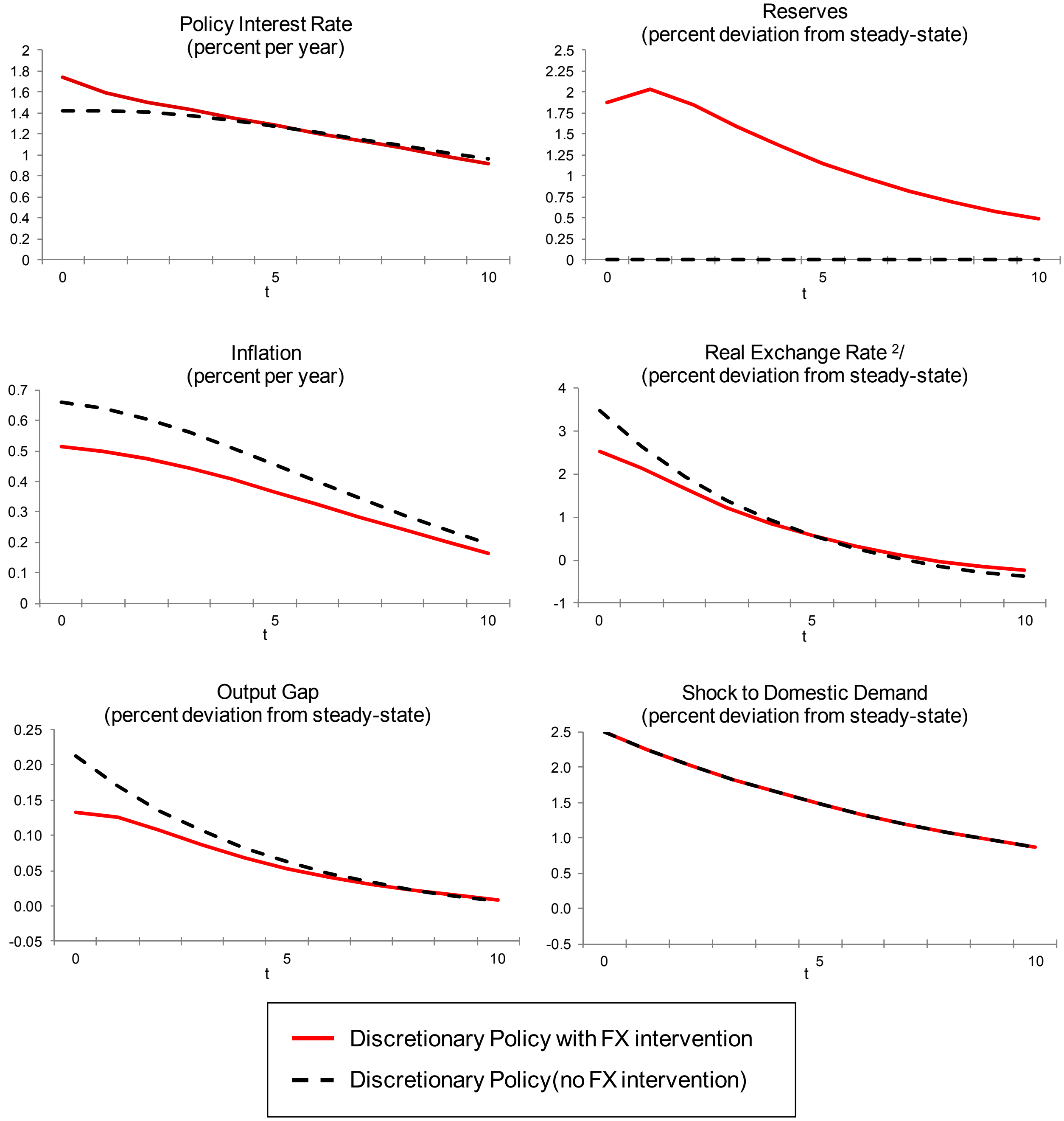
and maintains the policy interest rate too low:

$$r_{Nash} < r_{coord} \Leftrightarrow \frac{(1+\theta)(1+\theta/2)\hat{b}r^*}{\{(1+a)+(\hat{b}/c)(1+\theta/2)[(1+a)+c(1+\theta)]\}} < \frac{\tilde{b}r^*}{\{(1+a)+(\tilde{b}/c)[(1+a)+c]\}} \tag{23}$$

The net effect on the exchange rate is ambiguous since $e = (r - R - r^*)/2$ and the interest rate is lower under Nash than under coordination, but so is the extent of FX intervention. Depending on the parameter values, the combination of lower policy rates with less sterilized intervention may lead to more or to less appreciation in the Nash equilibrium than under coordination. But for most parameter values, the exchange rate will appreciate more in the Nash equilibrium as each country tries to deflect capital to the other country by appreciating its exchange rate.

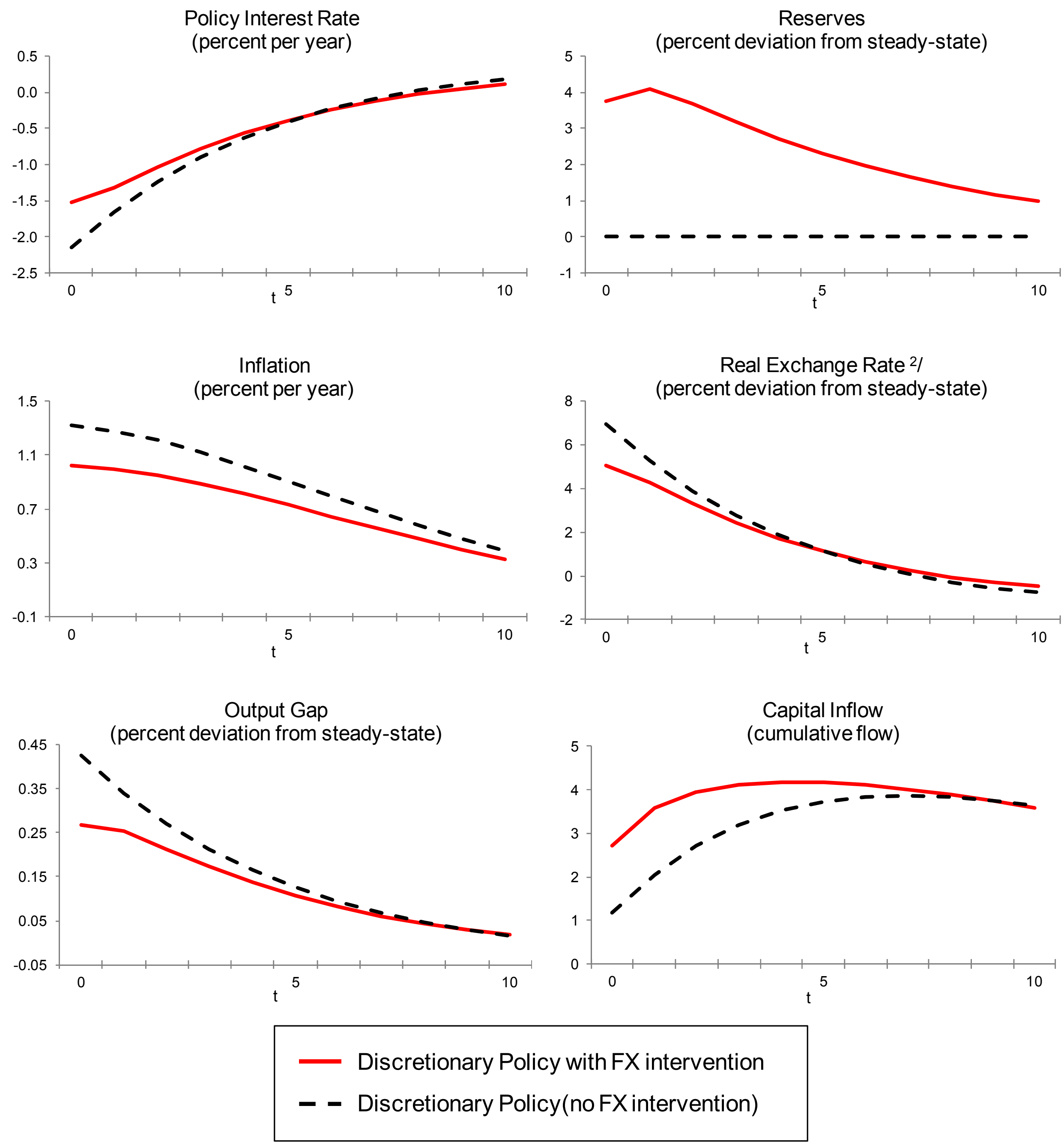
Macroeconomic Responses Under Discretionary Policies

Figure A1. Policy Response to a Demand Shock under Discretionary Policies
(Analogous to Figure 1 in the main text) 1/



1/ The shock is based on a 2.5 percentage-point increase in domestic demand.
2/ Real exchange rate defined such that an increase represents an appreciation of the currency.

Figure A2. Policy Response to a Capital Inflow Shock Under Discretionary Policies
(Analogous to Figure 2 in the SDN) 1/



1/ The capital inflow shock is based on a 5 percentage-point decline in the world interest rate.
2/ Real exchange rate defined such that an increase represents an appreciation of the currency.

In order to facilitate the comparison regimes, the impact change in policies and key macroeconomic variables across the different regimes in the face of a capital inflow shock may be summarized as:

Table A1. Initial response to a temporary inflow shock (in percent) 1/

	2 instruments (R and r)	1 instrument (r)
IT	r=-1.3, R= 4.4 π=0, e=5.4	r=-2.0, R= 0 π=0, e=7.8
Discretionary Policy (Non-IT)	r=-1.5, R= 3.7 π=1.0, e=5.0	r=-2.2, R= 0 π=1.3, e=6.9

1/ Variables r, R, π and e denote the policy interest rate, FX reserves, inflation, and real exchange rate, respectively. Values correspond to the change on impact plotted in Figure 2 of the main text for the IT regimes, and Figure A2 of this appendix for the discretionary regimes.

Welfare will always be higher under the policies that use two instruments rather than one (unless the use of the second instrument had detrimental effects that are not captured by our model). Similarly, in the absence of an inflationary bias, welfare will necessarily be higher under discretionary policies than under IT (since the latter adds a constraint to the central bank's response to ensure the primacy of the inflation target). When there is an inflationary bias, however, or if the central bank lacks credibility (i.e., it does not have an inflationary bias but the private sector believes it may wish to stimulate the economy above its natural rate), then inflation-targeting may improve welfare by constraining monetary policy and therefore anchoring expectations.