Original Paper

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Partially Anticipated Monetary Policy Shocks – Are They Stabilizing or Destabilizing?

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Abstract: This paper uses a dynamic framework of a small open economy to study the volatility effects of partially anticipated monetary policy shocks in which the public has imperfect information about the size and/or the timing of the future expansionary policy intervention. Our two main results are as follows: (i) Partially anticipated monetary policy shocks may be stabilizing, i. e. lead to a lower volatility than a fully anticipated monetary policy shock of the same form. (ii) However, we typically obtain a trade off in volatilities such that a simultaneous stabilization of inflation and output is not possible. If the public underestimates (overestimates) the size of the shock, output (inflation) may be stabilized. Our results imply that the central bank may have an incentive to withhold information from the public about the true central bank's intention.

Keywords: partial anticipation, news shocks, continuous-time models, monetary policy, volatility, central bank communication

JEL classification: E32, E52, E58

1 Introduction

This paper studies the volatility effects of monetary policy disturbances, which are not fully anticipated by the public. So far, the literature has only considered two extreme cases of anticipation. Either the public has perfect information and fully anticipates the shock process or the public is completely uninformed and does not anticipate the shock process at all. This paper introduces an intermediate scenario of partial anticipation, which covers both extreme scenarios as

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special cases. Under partial anticipation, the public has partially correct and partially incorrect expectations about the exact evolution (i.e. about size and timing) of the monetary shock process. To the best of our knowledge, we are the first to study this kind of partially anticipated shocks.¹

The importance of anticipated shocks in general (like pre-announced future monetary policy interventions), also known as news shocks, for business cycle fluctuations is confirmed by several empirical studies. Most prominently, Schmitt-Grohé and Uribe (2012) find in an estimated real business cycle model that about 50 percent of economic fluctuations can be attributed to fully (or possibly partially) anticipated disturbances.² Milani and Treadwell (2012) focus on anticipated monetary policy. They find that anticipated monetary policy shocks have a larger impact on output fluctuations than unanticipated monetary policy shocks.³ They conclude that the central bank's communication can be an effective monetary policy tool.⁴

Central banks may not be able or not willing to communicate the exact timing and/or size of a (future) monetary intervention in advance so that the public needs to form expectations about it. For example, in July 2012 at the Global Investment Conference in London, the President of the European Central Bank, Mario Draghi, signalized further purchases of government bonds by stating that “the ECB is ready to do whatever it takes to preserve the euro” to bring down risk premiums on government bonds. However, Draghi is mute about the

1 The terminology of partial anticipation was already introduced by Fischer (1979). However, he defines partially anticipated shocks as fully anticipated shocks with reduced length of anticipation. Contrarily, we assume that partially and fully anticipated shocks have the same length of anticipation. The public may, however, have wrong expectations about the length of anticipation.

2 A partially anticipated shock can also be viewed as a combination of a fully anticipated and a non-anticipated shock, where the non-anticipated shock reflects the correction in expectations. Let ε_t^i be a random innovation that is anticipated in t , but materializes in $t+i$ (notation of Schmitt-Grohé and Uribe (2012)). Then, if ε_t^0 (non-anticipated shock) and ε_{t-i}^i are from the same source, this is an indication of partial anticipation. $\varepsilon_t^0 > 0$ and $\varepsilon_{t-i}^i > 0$ may not be two distinct shocks, but instead may be one partially anticipated shock where the public initially underestimates the shock size in $t-i$ and corrects its expectations in t . The difference $\varepsilon_t^0 - \varepsilon_{t-i}^i$ could be interpreted as expectations bias. Note that the variances of $\{\varepsilon_{t-i}^i\}$ can be identified separately for different values of i , see Schmitt-Grohé and Uribe (2012).

3 Further empirical studies include Beaudry and Portier (2006), Beaudry and Lucke (2010), Barsky and Sims (2011), Fujiwara et al. (2011), and Khan and Tsoukalas (2012). The main bulk of the literature, however, emphasizes the role of anticipated technology shocks as in Schmitt-Grohé and Uribe (2012) or of anticipated fiscal policy shocks as in Leeper et al. (2008) and Mertens and Ravn (2010). The idea of these shocks playing an important role in driving business cycle fluctuations goes back to Pigou (1927) and was revived by Beaudry and Portier (2004).

4 For a survey on central bank communication, see Blinder et al. (2008).

exact threshold of risk premiums at which the ECB is planning to intervene. This limited information strategy leaves room for public misperceptions such that the monetary intervention may only be partially anticipated.⁵

The main aim of this paper is twofold: First, we aim to study the (de)stabilizing effects of partially anticipated monetary disturbances on inflation and output fluctuations, where we define stabilization as follows: Partial anticipation (de)stabilizes a particular variable if the variable's volatility under partial anticipation is (larger) smaller than under fully correct anticipation of the same shock process. Second, we aim to derive the optimal central bank's communication strategy. Is it possible to obtain a lower central bank loss by either directly deceiving the public or withholding information about the true monetary policy intentions?

To this end, we consider several partial anticipation scenarios, in which the public initially has incorrect expectations about the size and/or the timing of the monetary disturbances. With interest rates at the zero lower bound, central banks are forced to use unconventional policy instruments to stimulate the economy. In line with this change in policy, we model monetary policy interventions as (temporary) increases in the money growth rate. To discuss the limited information strategy of the ECB during the European sovereign debt crisis, we consider increases in the money growth rate not only in isolation but also as response to increasing risk premiums on government bonds, where the public may have incorrect expectations about the start of the monetary intervention.⁶

As model framework, we use a continuous-time Dornbusch-type⁷ model of a small open economy. This framework has been used in several papers to study the dynamic impacts of (fully) anticipated shocks. Early studies include Turnovsky (1986a, 1986b). More recent studies include Clausen and Wohltmann (2005), who study anticipated and unanticipated monetary and fiscal policy in an asymmetric monetary union and Clausen and Wohltmann (2013), who study anticipated oil price shocks in a similar model of a small open monetary union. Recently, the continuous-time formulation also has gained some attention in the New Keynesian

⁵ As a contrary example to the ECB's communication policy, the recent decision of the Swiss National Bank in January 2015 to discontinue the minimum exchange rate of CHF 1.20 per euro was not announced at all and came as a complete surprise to the market participants. As a result, the Swiss Franc sharply appreciated by roughly 20 percent.

⁶ Recently, the European Central Bank (ECB) indicated to oppose the deflationary risk in the European Union by expanding the ECB's Outright Monetary Transactions (OMT) program. The Federal Reserve, on the other hand, is starting to cut down its asset-purchasing program since December 2013.

⁷ The model is a variant of the famous overshooting model introduced by Dornbusch (1976).

literature. Posch et al. (2011) formulate and solve the New Keynesian model in continuous time.

Our two main results are as follows: (i) Partially anticipated monetary policy shocks may stabilize inflation and output fluctuations, i.e. lead to a lower volatility than a fully anticipated monetary policy shock of the same form. (ii) However, we typically obtain a trade off in volatilities such that a simultaneous stabilization of output and inflation is not possible. If the public underestimates (overestimates) the size of the shock, output (inflation) may be stabilized.

Our results are in line with the literature: The existence of a trade off in volatilities of inflation and output is well known and already described in Taylor (1979) and revisited in Taylor (1994). He finds the trade off in volatilities – in contrast to the trade off in levels – to be stable in the long run for the U.S. economy. Further related to this paper is the literature on news shocks which studies the potential destabilizing effects of completely anticipated shocks. Fève et al. (2009) show in a purely forward-looking discrete-time framework with rational expectations that anticipated shocks destabilize the economy, i.e. lead to a higher volatility than non-anticipated shocks of the same size. The volatility increases with increasing length of anticipation. This result does not hold unambiguously for the hybrid case with backward-looking elements as it is shown by Winkler and Wohltmann (2011).⁸ They find the same trade off in volatilities of inflation and output in the estimated Euro area model of Smets and Wouters (2003). With increasing anticipation horizon, output volatility increases, but inflation volatility decreases. Our paper may help to explain why this trade off in volatilities occurs and why anticipated shocks may lead to a (de)stabilization of the economy.

For the aforementioned results of this paper, we implicitly assume a stable relation between base and broad money such that the central bank can perfectly control the money stock. However, since the outburst of the financial crisis in 2008, such a stable relation in the Euro area is questionable as e.g. De Grauwe and Ji (2013) demonstrate. We, therefore, also study partially anticipated changes in the monetary base that have no effect on the money stock. We find that changes in the monetary base may still have real effects on the economy and may impose cyclical adjustment movements even if the relation between base and broad money is non-existent. This requires, however, that the public indeed believes in a stable relation.

The remainder of the paper is organized as follows: Section 2 describes the model frame-work. Section 3 introduces our (partial) anticipation scenarios and

⁸ Also related to this literature is the paper by Offick and Wohltmann (2013), who investigate the sources of these destabilizing effects.

studies the responses to a temporary increase in the money growth rate. Section 4 introduces our volatility measure and discusses the (de)stabilizing effects of partially anticipated changes in the monetary growth rate for different degrees of expectation biases. Section 5 introduces two communication strategies in which the central bank either deceives the public or withhold information from the public to obtain a lower central bank loss. As a digression, Section 6 discusses the responses to partially anticipated increases in the monetary base in the presence of an unstable relation between base and broad money. Section 7 discusses six modifications including a simultaneous increase in the risk premium on government bonds and in the money growth rate. The last section concludes.

2 Model framework

As model framework we use a dynamic continuous-time Dornbusch-type model for a small open economy. The economy is described by the following set of log-linearized equations:

$$y = (a_0 + a_1 y - a_2(i - E(\dot{p}))) + g + (b_0 - b_1 y + b_2 y^* - b_3 \tau) \quad [1]$$

$$\tau = p - (p^* + e) \quad [2]$$

$$m - p = l_0 + l_1 y - l_2 i \quad [3]$$

$$i = i^* + E(\dot{e}) + s \quad [4]$$

$$\dot{p} = \pi + \delta(y - \bar{y}) \quad [5]$$

$$\pi = \dot{m} \quad [6]$$

$$\bar{y} = f_0 + f_1 \bar{\tau} \quad [7]$$

All variables, except for the (nominal and real) interest rate and the inflation rate, are in logarithm. The notation is as follows: y = real output, $\bar{y}$ = natural output level, i = nominal interest rate, $i - E\dot{p}$ = real interest rate, τ = terms of trade, g = government spending, p = price level, e = exchange rate, m = nominal money stock, $\dot{p}$ = inflation rate, π = augmentation term of the Phillips curve, s = risk premium shock. Foreign variables (i^* , y^* , p^*) are denoted by a superscript star. A dot above a variable ($\dot{p}$, $\dot{e}$, $\dot{m}$) stands for the time derivative (differentiated from the right) of that variable, a bar above a variable ($\bar{y}$, $\bar{\tau}$) stands for its long-run value, and E is the expectations operator. We assume rational expectations. In a deterministic framework this implies $E\dot{p} = \dot{p}$ and $E\dot{e} = \dot{e}$. Depending on the

assumed anticipation scenario, expectations on the exogenous evolution of the money growth may deviate from the true evolution.⁹ Further details will be provided in the subsequent sections.

Equation [1] is a standard IS equation, determining the short-run development of output. The first term in brackets stands for real private absorption depending on real income and the real interest rate. The second term in brackets stands for the trade balance depending on domestic and foreign income and the terms of trade. The terms of trade are defined in eq. [2]. Equation [3] represents the money market equilibrium and is a traditional LM curve. Equation [4] is the uncovered interest rate parity (UIP), and eq. [5] represents a Phillips-type inflation equation. Equation [6] specifies the augmentation term in the Phillips curve, which we set equal to the expected long-term rate of inflation. According to montaristic theory, we assume that inflation is solely determined by the money growth rate in the long run.¹⁰ In the short to medium run, inflation might temporarily deviate from its long-term rate. However, inflation is, as we will see in the subsequent sections, rather tied to the money growth rate.¹¹ For completeness, the last equation describes the long-run relation between output and the terms of trade. Since changes in the money growth rate do not alter the steady state of output and the terms of trade, we can neglect this equation until Section 7, where we also consider changes in the risk premium on government bonds.¹²

The model can be reduced to a two-dimensional system of ordinary differential equations with the terms of trade τ and the real money stock $m^r = m - p$ as state variables. For the parameter calibration given in Table 1, the reduced model exhibits one stable and one unstable eigenvalue. The system then describes a saddle point system. To ensure stability of the system, we assume that the terms of trade are forward-looking and the real money stock is backward-looking such that the number of unstable eigenvalues equals the number of forward-looking variables.¹³

⁹ Turnovsky (1977) labels these expectations as structural where the public has correct information about the structure of the model but false information about the underlying exogenous processes.

¹⁰ See Friedman (1977).

¹¹ As a modification, we assume in Section 7 that the augmentation term is alternatively given by the expected inflation rate of the consumer price index, i. e. $\pi = \dot{p}_c$ with $p_c = \gamma p + (1 - \gamma)(p^* + e)$. $1 - \gamma$ measures the degree of openness.

¹² For details on the model equation and the underlying assumptions, see Clausen and Wohltmann (2005) and Clausen and Wohltmann (2013). They study monetary and fiscal policy in a continuous-time model of an asymmetric monetary union that is of a similar form as the above model.

¹³ For details on the model reduction and solution for fully anticipated, partially anticipated, and non-anticipated changes in the money growth rate and in the risk premium, see the electronic appendix at www.jbnst.de/en.

Table 1: Parameter calibration.

Parameter	Value	Definition
a_1	0.7	Income elasticity of private consumption
a_2	0.3	Real interest rate (semi-)elasticity of private absorption
b_1	0.2	Income elasticity of the trade balance
b_3	0.1	Terms of trade elasticity of the trade balance
l_1	1.0	Income elasticity of money demand
l_2	4.0	Interest rate (semi-)elasticity of money demand
δ	0.2	Slope of the Phillips curve

In the subsequent simulations, we use the calibration given in Table 1.¹⁴ We focus on deviations from the initial steady state. Therefore, we do not need to specify a_0 , b_0 , and b_2 . For the remaining parameters, we broadly follow the textbook calibration given in Galí (2008) and Walsh (2010) and the estimates from Moons et al. (2007), who estimate a stylized open-economy New Keynesian model for the euro area.

The income elasticity and the interest rate semi-elasticity of the money demand are set to $l_1 = 1$ and $l_2 = 4$, respectively, which are the values proposed by Galí (2008). He derives the microfounded money demand equation from a money-in-the-utility approach, which implicitly gives rise to an income elasticity of unity. Estimates of l_1 reported in Walsh (2010) suggest values greater than unity, whereas Ball (2001) finds a value of 0.5. Estimates of l_2 reported in Walsh (2010) range from 1 to 10, which is in line with the estimate of 5 found by Ball (2001).¹⁵ The income elasticity of private consumption is set to $a_1 = 0.7$, which we implicitly derived from an income tax rate of 0.3, a consumption output ratio of 0.7, and a consumption rate of 0.7.¹⁶ The income elasticity of the trade balance is set to 0.2.¹⁷ Then, the net effect of the real interest rate and of the terms of trade on goods demand is given by $a_2/(1 - a_1 + b_1) = 0.6$ and $b_3/(1 - a_1 + b_1) = 0.2$, respectively. Both values match the estimates given in

¹⁴ All computations have been performed by using MATLAB. The codes are available from the authors upon request.

¹⁵ Note that the interest rate is – contrarily to output – not logarithmized. Given that the steady state interest rate is relatively small, the interest rate semi-elasticity is typically much larger than the income elasticity of money demand ($l_2 > l_1$).

¹⁶ More details on the derivation of a_1 can be found in the electronic appendix at www.jbnst.de/en.

¹⁷ Note that $a_1 > b_1$ is not a necessary condition for stability. For stability, it is sufficient that $l_2 < l_1 / -\delta$ or $a_2 < (1 - a_1 + b_1) / -\delta$ hold. Further details are given in the electronic appendix at www.jbnst.de/en.

Moons et al. (2007). The former is close to the values given in Galí (2008) and Walsh (2010) and is also in line with Smets and Wouters (2003), who find a mean intertemporal elasticity of substitution of 0.7 with a 90 percent probability band ranging from 0.52 to 1.05.¹⁸ The slope of the Phillips curve is set to $\delta = 0.2$ proposed by Galí (2008) and which is also close to the estimate given in Moons et al. (2007).¹⁹ In Section 7, we investigate how our results change for different parameter values for δ , l_2 , a_2 , and b_3 .

3 Anticipation scenarios and responses to a monetary shock

This section introduces our anticipation scenarios and discusses the responses to a temporary increase in the money growth rate in the above model framework.

The realized but not necessarily correctly anticipated shock process is the same across all anticipation scenarios. The evolution of the shock process is described in Table 2. The increase in the money growth is implemented at a constant rate c over the implementation period $T < t < t_1$ and is temporary in the sense that $\dot{m} = 0$ for $t > t_1$. In $t = 0$, the increase is fully or partially anticipated, or non-anticipated at all by the public. We, therefore, refer to the time period $0 < t < T$ as anticipation period.

Table 2: Evolution of the exogenous increase in the money growth rate.

$0 \leq t < T$	$T \leq t < t_1$	$t > t_1$
$\dot{m} = 0$	$\dot{m} = c$	$\dot{m} = 0$

18 Taking habit formation into account, Smets and Wouters (2003) find that the impact of the real interest rate on consumption is reduced to 0.3.

19 From microfoundation, the slope of the Phillips curve can be expressed as $\delta = \frac{(1-\theta)(1-\beta\theta)}{\theta}(\sigma + \eta)$. Assuming a quarterly interest rate of 1 percent (implying a discount factor of $\beta = 0.99$), a Calvo parameter of $\theta = 0.75$, an inverse elasticity of substitution of $\sigma = 1.5$, and a Frisch elasticity of labor supply of $\eta = 1.5$, we obtain a slope of $\delta = 0.25$. Estimates in Smets and Wouters (2003) and Smets and Wouters (2007) for θ , σ , and η suggest that δ may vary between 0.05 and 0.5. Differences in δ mainly result from differences in the Calvo parameter, which ranges from 0.7 to 0.9.

In the long run, a temporary increase in the money growth rate does not alter the steady state of the real variables.²⁰ The steady state of the nominal money stock changes according to

$$d\bar{m} = \int_0^\infty \dot{m}(z) dz = c(t_1 - T) \tag{8}$$

which implies a change in the steady-state values of the price level and the nominal exchange rate of equal size, i. e. $\frac{dp}{dm} = \frac{de}{dm} = 1$. In the following, we refer to the expression $c(t_1 - T)$ as the size of the shock process. c is the magnitude, T is the start, and t_1 is the end or exit of the shock process.

We consider five anticipation scenarios: one full anticipation scenario in which the public correctly anticipates the full monetary policy intervention (denoted as FA), three partial anticipation regimes in which the public has partially correct and partially incorrect expectations (denoted as PA), and one non-anticipation scenario in which the policy intervention completely comes as a surprise (denoted as NA). Table 3 summarizes the complete set of anticipation scenarios.²¹ In the three scenarios of partially correctly anticipated shocks, the public forms incorrect expectations either about the magnitude c (scenario PA-MAG), about the starting point T (scenario PA-START), or about the exit point t_1 (scenario PA-EXIT) of the increase in the money growth rate. Note that in all three partial anticipation scenarios, the public has incorrect expectations about the size of the shock.

Table 3: Set of anticipation scenarios.

		FA	NA	PA-MAG	PA-START	PA-EXIT
Magnitude	$E(c)$	c	0	$\neq c$	c	c
Start	$E(T)$	T	–	T	$\neq T$	T
Exit	$E(t_1)$	t_1	–	t_1	t_1	$\neq t_1$
Length	$E(t_1 - T)$	$t_1 - T$	–	$t_1 - T$	$\neq t_1 - T$	$\neq t_1 - T$
Size	$E(c(t_1 - T))$	$c(t_1 - T)$	–	$\neq c(t_1 - T)$	$\neq c(t_1 - T)$	$\neq c(t_1 - T)$
Breakpoint	t^*	–	T	T	$\min[E(T), T]$	$\min[E(t_1), t_1]$

²⁰ This nominal neutrality follows from the long-run stability condition that the real money stock and the terms of trade do not change in the long run. In case of a permanent increase in the money growth rate, the steady state of the real money stock changes, but the steady state of most other real variables (including output, terms of trade, and the real interest rate) remains unchanged.

²¹ Note that in scenario NA, the public does not anticipate the increase in the money growth rate at all and therefore has no expectations on the start of the implementation. This is highlighted by a minus sign in Table 3.

Since we aim to study only temporary and not permanent anticipation errors, we have to define how the public switches to correct expectations. For simplicity, we assume that the switch from partially incorrect to fully correct expectations occurs at once at some particular breakpoint t .²² Hence, the public has correct expectations for $t > t^*$ and may have incorrect expectations for $t < t^*$ about the shock process. In line with non-anticipated shocks, we assume that the switch to correct expectations occurs when the public realizes for the first time that the expected evolution of the shock process deviates from the true one. In scenario NA and PA-MAG, the public's expectations deviate from the true shock process for the first time at the start of implementation, i. e. $t^* = T$. In scenario PA-START, the public has incorrect expectations about the start of the monetary intervention. If the public expects an earlier start, i. e. $E(T) < T$, the public already switches in $t^* = E(T)$ to fully correct expectations. If the public expects a later start, i. e. $E(T) > T$, the public switches in $t^* = T$. In scenario PA-EXIT, the public correctly expects the start (T) and the magnitude (c), but has incorrect expectations about the end (t_1) of the shock process. Since $E(t_1) > T$, the public does not switch to correct expectations before T . If the public expects an earlier end of the shock process, i. e. $E(t_1) < t_1$, the public switches in $t^* = E(t_1)$, where $t^* > T$. If the public expects a later end of the shock process, i. e. $E(t_1) > t_1$, the public switches in $t^* = t_1$.

In the following, we subsequently study the responses to the above temporary increase in the money growth rate under the partial anticipation scenarios PA-MAG, PA-START, and PA-EXIT in comparison to the full anticipation scenario FA.

3.1 Scenario PA-MAG and NA

Figure 1 depicts the responses to a temporary increase in the money growth rate under the full anticipation scenario FA and the partial anticipation scenario PA-MAG, where the public either underestimates ($E(c) < c$) or overestimates ($E(c) > c$) the magnitude of the shock. As a special case of PA-MAG, the figure also includes the non-anticipation scenario NA, where the public does not expect the increase at all ($E(c) = 0$). The first (upper-left) plot displays the development of the terms of trade and the real money stock in the phase plane. The remaining plots show the responses in the time domain. The second (upper-right) plot displays the initially expected evolution of the money growth based on the information set in $t = 0$. Note that in the FA scenario, the

²² In Section 7, we modify the mechanism with which the public switches to correct expectations and assume that the public sequentially adapts its expectations in several steps.

Figure 1: Responses to a monetary shock in scenario PA-MAG.

anticipated evolution of the money growth is equal to the realized money growth. We set $c = 3$, $T = 2$, and $t_1 = 5$.

To start with, the adjustment process in the anticipation scenario FA can be described as follows: In $t = 0$, the increase in the money growth rate is announced and correctly anticipated by the public. The anticipation of a future expansionary monetary shock leads to an immediate (real) devaluation of the home currency (fall in the terms of trade). Since prices are assumed to be sluggish and do not change on impact, this is represented by a vertical downward adjustment in the phase. The real devaluation continues until the start of the implementation T . Simultaneously, the real money stock continuously declines, which is equivalent to a continuous upward adjustment of prices. The devaluation of the home currency leads via the UIP to a rise in the nominal interest rate. The inflation response on impact and during the anticipation phase is relatively small such that the real interest rate rises. Despite the contractionary real interest rate effect, output unambiguously stays above its steady state value on impact and during the anticipation phase. This immediately follows from the inverse Phillips curve

$$y = \bar{y} - \frac{1}{\delta} \dot{m}^r \quad [9]$$

which determines output by the change in the real money stock.

In $t = T = 2$, the money growth rate increases as expected. Inflation expectations shoot up and induce a sharp rise in the inflation rate, which overshoots the rise in the money growth rate and in the nominal exchange rate. The overshooting continues over the whole implementation phase leading to a further decline in the real money stock and to a continuous real devaluation. Note that the terms of trade are assumed to react discontinuously only to new information. In the FA scenario, the shock process is completely known by the public in $t = 0$ such that the terms of trade behave continuously for the remaining course of adjustment ($t > 0$). Due to the fall in the real interest rate, output shoots up in T , but continuously decreases over the implementation phase.

After the implementation phase ($t > t_1 = 5$), we observe reverse adjustments and all shown variables return to their initial steady state. The real money stock starts to increase and converges from below to its initial steady state. The terms of trade start to decrease and converge from above to their initial steady state.

Note that the impact and anticipation reaction of inflation is relatively small compared to the inflation reaction during the implementation phase. This is mainly due to our assumption that long-term inflation expectations are exclusively driven by changes in the money growth rate.

In the following, we denote this FA scenario as benchmark scenario and compare the responses of the remaining three anticipation scenarios to this

benchmark scenario. Since we only change the nature of anticipation and leave the realized shock process unchanged, differences to the full anticipation case mainly occur on impact and during the anticipation period. After the occurrence of the shock, differences to the benchmark scenario are less visual.

In the anticipation scenario PA-MAG, the public has incorrect expectations about the magnitude c , but is correct about the start and the end of the shock process. In case the public underestimates the magnitude ($E(c) = 1.5 < c = 3$), the public implicitly underestimates the size $c(t_1 - T)$ as well. On impact and during the anticipation phase the economy is driven by expectations. The underestimation of the size of the shock, therefore, leads to a smaller impact and anticipation reaction for all variables in comparison to the benchmark scenario. In $t = T = 2$, the shock occurs with larger magnitude than (originally) expected. We, therefore, assume that the public switches in $t^* = T$ to correct expectations and correctly anticipates the remaining evolution of the shock process. Since the real money stock is assumed to be predetermined, all other variables and, hence, the system as whole are not able to jump on the solution path of the benchmark scenario.²³ The decline in the real money stock is, however, steeper than in the benchmark scenario, converging towards the FA solution path. The terms of trade are, on the other hand, allowed to react discontinuously to this new information. To compensate for the sluggishness of the real money stock, the terms of trade undershoot its benchmark value.²⁴ Likewise, output and inflation overshoot and the real interest rate undershoots their benchmark values. During the implementation phase, the real money stock, output, inflation and the nominal interest rate stay above, and the terms of trade and the real interest rate stay below the benchmark responses.

If the public overestimates the magnitude (and the size) of the shock ($E(c) = 4.5 > c = 3$) until $T = 2$, we see reverse adjustments. During the anticipation phase, the system responds more strongly than in the FA scenario. In $t^* = T$,

23 To illustrate this, consider the LM equation and note that output y and the interest rate i are non-predetermined, whereas the real money stock m^r is predetermined. Let the subscript PA (FA) denote the solution under partial (full) anticipation. According to the LM equation, the difference in the real money stock between the PA and FA scenario in t^* is then given by $m_{PA}^r(t^*) - m_{FA}^r(t^*) = l_1[y_{PA}(t^*) - y_{FA}(t^*)] - l_2[i_{PA}(t^*) - i_{FA}(t^*)]$. If the non-predetermined output and the interest rate jump on the FA solution path in t^* , i. e. $y_{PA}(t^*) = y_{FA}(t^*)$ and $i_{PA}(t^*) = i_{FA}(t^*)$, this would imply that the real money stock jumps on the FA solution path as well (i. e. $m_{PA}^r(t^*) = m_{FA}^r(t^*)$). This, however, would contradict that the real money stock is predetermined.

24 Without price stickiness, the real money stock would be able to react discontinuously to new information. The system then would jump in t^* directly onto the solution path under full anticipation.

the public switches to fully correct expectations. The terms of trade overshoot the benchmark value, but the real money stock stays below the FA scenario.

Scenario NA, where the public does not anticipate the increase in the money growth at all, is equivalent to the special case $E(c) = 0$ in scenario PA-MAG. Until T , all variables remain constant. In $t = T$, the policy intervention completely comes as a surprise. Therefore, we neither have an impact nor an anticipation reaction.

3.2 Scenario PA-START and PA-EXIT

Figure 2 depicts the responses for scenario PA-START. For reference purposes, we again include the benchmark scenario FA, where the public has fully correct expectations. In scenario PA-START, the public has incorrect expectations about the start of implementation. The end t_1 and the magnitude c of the shock process are, on the other hand, correctly anticipated. This implies that the public

Figure 2: Responses to a monetary shock in scenario PA-START.

overestimates (underestimates) the size of the shock $c(t_1 - T)$ if the public expects an earlier (later) start of the monetary intervention.²⁵

Consequently, if the public expects a later start of the monetary policy shock ($E(T) = 4 > T = 2$), the impact and anticipation reaction is smaller than in the FA scenario. In $t^* = T < E(T)$, the shock occurs earlier than expected and the public immediately switches to correct expectations. As in scenario PA-MAG, the terms of trade react discontinuously to this change in expectations, jumping on a lower trajectory. To compensate for the sluggishness of prices, the terms of trade undershoot the benchmark response of scenario FA, which leads to an overshooting of output and inflation.

If the public expects an earlier start of the shock process ($E(T) = 1 < T = 2$), which implies a larger expected shock size, the system overreacts until t^* . This time, however, the switch to correct expectations already occurs during the anticipation phase in $t^* = E(T) < T$, which is the time the public originally expected an increase in the money growth rate, but no change in the money growth rate occurred. Consequently, output and inflation undershoot the benchmark responses already during the anticipation phase.

As a last scenario, Figure 3 shows the responses under scenario PA-EXIT. In this scenario, the public has incorrect expectations about the end of the monetary intervention. The start and the magnitude of the shock process are, on the other hand, correctly anticipated. This implies that the public overestimates (underestimates) the size of the shock $c(t_1 - T)$ if it expects a later (an earlier) end of the monetary intervention implying a stronger (smaller) reaction on impact and during the anticipation phase.

The main difference to the other two partial anticipation scenarios is that the switch to correct expectations now occurs during the implementation phase and not during the anticipation phase. Since the start and the magnitude are correctly anticipated, the public expectations about the shock process and the true shock process do not deviate from one another until $t^* = \min(E(t_1), t_1) > T$. Hence, if the public expects a later end of the shock process ($E(t_1) = 6 > t_1 = 5$), output and inflation stay above the benchmark response over the whole anticipation and implementation phase. If the public expects an earlier end ($E(t_1) = 4 < t_1 = 5$), output and inflation stay below the benchmark responses until $t^* = E(t_1) > T$.

²⁵ In Section 5, we also consider the scenario PA-ST/EX where we change $E(T)$ and $E(t_1)$ simultaneously such that the length and the size of the shock are correctly anticipated. The responses and the relative volatilities are very similar to scenario PA-START.

Figure 3: Responses to a monetary shock in scenario PA-EXIT.

4 Measuring the (de)stabilization effects

In order to study the (de)stabilizing effects of partially anticipated monetary policy interventions, we use a relative volatility measure, which relates the volatility under partial anticipation to the volatility under full anticipation. The relative volatility for $x \in \{y, \pi\}$ in scenario $S \in \{\text{PA - MAG, PA - START, PA - EXIT}\}$ is defined as

$$RV(x|S) = \frac{V(x|S)}{V(x|FA)} \quad [10]$$

where $V(x|S)$ and $V(x|FA)$ measure the quadratic deviations of x from its initial steady state $\bar{x}_0$ over the time domain D given the expectation assumptions of scenario S and FA , respectively:²⁶

²⁶ Let the time domain D be defined over the interval $[a, b]$. Then, we can approximate eq. [11] by $V(x) \approx \frac{1}{n} \sum_{j=1}^{bn} (x(j/n) - \bar{x}_0)^2 - \frac{1}{n} \sum_{j=1}^{an} (x(j/n) - \bar{x}_0)^2$ for a sufficiently small step length $1/n$. During the computation, we set $n = 100$.

$$V(x) = \int_{t \in D} (x(t) - \bar{x}_0)^2 dt \quad [11]$$

Figure 4 shows the relative volatilities of output and inflation as defined in eq. [10] for all three partial anticipation scenarios for different degrees of expectation biases. We compute the relative volatility for $E(c)$ ranging from -1 to 6 in scenario PA-MAG, for $E(T)$ ranging from 0.5 to 3.5 in scenario PA-START, and for $E(t_1)$ ranging from 2.5 to 7 in scenario PA-EXIT. With correct expectations ($E(c) = c = 3$, $E(T) = T = 2$, and $E(t_1) = t_1 = 5$), the relative volatilities of output and inflation intersect at unity. Values greater (smaller) than unity means that the volatility in the partial anticipation scenario is larger (smaller) than in the FA scenario. The four columns of Figure 4 correspond to four different phases. The first column shows the overall relative volatility over the whole adjustment process ($0 < t < \infty$). The remaining columns show the relative volatility in the three distinct phases: (i) the anticipation phase ($0 < t < T$), (ii) the implementation phase ($T < t < t_1$), and (iii) the return phase ($t > t_1$).

Let us first have a look at the overall relative volatility over the whole adjustment process. In scenario PA-MAG and PA-START, we have a trade off

Figure 4: Relative volatilities in scenario PA-MAG, PA-START, and PA-EXIT.

between output and inflation stabilization. If the public underestimates the size of the shock $c(t_1 - T)$ (either by $E(c) < c$ or $E(T) > T$), the volatility in inflation is higher and the volatility in output may be smaller than in the FA scenario. If the public overestimates the size of the shock (either by $E(c) > c$ or $E(T) < T$), inflation is stabilized and output is destabilized. Contrarily, in scenario PA-EXIT, both inflation and output may be stabilized simultaneously if the public expects an earlier end (implying a smaller expected shock size).

Next, we consider the relative volatility during the three subperiods. Two points are common in all three scenarios: First, the trade off in volatilities that we obtain based on the overall adjustment process in scenarios PA-MAG and PA-START is not present if we consider the three phases in isolation. In all three subperiods, output and inflation are both either stabilized or destabilized. Second, during the anticipation and return phase, the relative volatility in output and inflation is even identical.²⁷ Differences in the relative volatility only occur during the implementation phase. This follows from the structure of the Phillips curve [5], where the expected future inflation is pinned down by the money growth rate. During the anticipation and return phase, the money growth rate is at its steady state level such that changes in the inflation rate are proportional to changes in output.²⁸ During the implementation phase ($T < t < t_1$) the money growth is different from its steady state and, therefore, we obtain different relative volatilities in inflation and output.

During the anticipation phase ($0 < t < T$), the system is driven by expectations and, hence, in all three scenarios, the volatility in inflation and output is reduced if the public underestimates the shock size $c(t_1 - T)$ (either by $E(c) < c$, $E(T) > T$, or $E(t_1) < t_1$). Contrarily, the volatility in output and inflation is enhanced during the anticipation phase if the public overestimates the shock size.

During the implementation phase ($T < t < t_1$), the underestimation of the shock size leads to a destabilization of inflation and output in scenario PA-MAG and PA-START. Recall from the previous section that the non-predetermined variables overreact for $t > t^*$ (i. e. do not jump on the FA solution path) to compensate for the sluggishness in prices. In scenario PA-MAG and PA-START, a smaller (stronger) reaction during the anticipation phase causes the system to respond more strongly (less strongly) during the implementation phase.

²⁷ Graphically, the dashed and solid curves completely overlap such that only one solid graph is visual during the implementation and return phase.

²⁸ Formally, the volatility of inflation over the time domain D can be written as

$$V(\pi) = \int_{t \in D} (\pi(z) - \bar{\pi}_0)^2 dz = \int_{t \in D} [\dot{m}(z) - \bar{m}_0 + \delta(y(z) - \bar{y}_0)]^2 dz$$

For $0 < t < T$ and $t > t_1$, $\dot{m}(t) = \bar{m}_0$ such that $V(\pi) = \delta^2 V(y)$ and $RV(\pi) = RV(y)$.

This trade off between stabilizing the system during the anticipation (and return) phase and during the implementation phase is not present in scenario PA-EXIT. The main reason is that in this scenario the switch to correct expectations occurs much later during the implementation phase. If the public underestimates the shock size ($E(t_1) < t_1$), not only the reaction on impact and during the anticipation phase is smaller, but also partly during the implementation period.²⁹

During the return phase ($t < t_1$), the volatility results are qualitatively the same as during the anticipation phase, which follows from the fact that responses are reversed compared to the anticipation phase and no new information is revealed such that the terms of trade behave continuously for $t > t_1$.

The question arises, why do we face in scenario PA-MAG and PA-START a trade off between inflation and output over the whole adjustment process, but not in any of the three subperiods separately. This trade off in overall volatilities results from the combination of the following two arguments: First, as described above, output and inflation can not be stabilized in all three subperiods simultaneously. A smaller (stronger) reaction during the anticipation phase causes the system to respond more strongly (less strongly) during the implementation phase. Second, inflation strongly responds to realizations in the money growth rate during the implementation phase, whereas the anticipation effect on inflation is relatively small. The difference between anticipation and implementation reaction is less pronounced for output. Under fully correct expectations, the volatility share of the anticipation phase contributing to overall volatility only amounts to 0.2 percent for inflation and to almost 12 percent for output.³⁰ Therefore, we find that the anticipation effect is dominant for output, whereas the opposite implementation effect is dominant for inflation.

5 Two communication strategies

In the last section, we have shown that the volatility in inflation and output under partial information can be reduced below the volatility under full anticipation, although not necessarily simultaneously. This section discusses the policy implication of partially anticipated monetary shocks. We introduce two communication strategies and show how these strategies may improve the

²⁹ If we let the switch already occur in $t^* = T$, the same trade off occurs as in the other two scenarios. See next Section 5 for details.

³⁰ The volatility share of the implementation phase contributes with 99 percent to overall inflation volatility and with 69 percent to overall output volatility. For more details, see Section 7 and Table C.1 in the electronic appendix at www.jbnst.de/en.

central bank loss compared to the FA scenario. The first communication strategy presumes that the central bank has a sufficiently strong influence on private expectations and is, thereby, able to control the expectations $E(c)$, $E(T)$, and $E(t_1)$ directly. Since this strategy involves to create biased news about the future monetary intervention, we refer to this strategy as deception strategy.

In the second communication strategy, the central bank does not create, but is confronted with biased expectations about its future monetary intervention. The central bank now controls the breakpoint, at which the central bank is revealing the true evolution of the monetary shock and the public switches to fully correct expectations. We denote this breakpoint as t_{CB}^* to make clear that it is now set exogenously by the central bank and to distinguish it from the breakpoint t^* , at which the public (independently from the central bank) realizes its expectation biases by itself. This strategy presumes that the central bank is able to correctly monitor the private expectation biases. In this strategy the central bank does not actively deceive the public, but (only) withhold information from the public. We, therefore, refer to this strategy as withholding strategy.

The central bank aims to stabilize inflation and output. In particular, we assume that the central bank's loss function is given by

$$L_0 = \int_{t=0}^{\infty} \left\{ (\pi(z) - \bar{\pi}_0)^2 + \alpha(y(z) - \bar{y}_0)^2 \right\} dz = V(\pi) + \alpha V(y) \quad [12]$$

During the simulation, we set $\alpha = 0.5$. That is, the central bank's main objective is the stabilization of inflation (flexible inflation targeting).³¹ To compare the loss between partially and fully anticipated increases in the money growth rate, we compute the relative loss, which is the ratio of the loss under partial anticipation and under full anticipation.

We start with the deception strategy. Figure 5 shows the relative loss for different values of $E(c)$, $E(T)$, and $E(t_1)$ in scenario PA-MAG, PA-START, and PA-EXIT, respectively. Values smaller (greater) than unity mean that the loss under partial anticipation is lower (higher) than in the FA scenario. We further add the (overall) relative volatilities of output and inflation that were already shown in the last section.

In all three partial anticipation scenarios, it is possible to improve the central bank loss in comparison to scenario FA. The lowest loss is obtained in scenario PA-EXIT if the public expects an earlier end (lower size) of the shock process, i. e. $E(t_1) < t_1 = 5$. This is not surprising since in scenario PA-EXIT the volatility in inflation and output can be reduced simultaneously (cf. Figure 4). Contrarily, in scenario PA-MAG and PA-START, the central bank faces a trade off

³¹ See e. g. Svensson (1999).

Figure 5: Optimal private expectation bias (deception strategy).

between output and inflation stabilization, which may, however, be more favorable than in the FA scenario. Although inflation stabilization is assumed to be the primary central bank's objective ($0 < \alpha < 1$), we find that the central bank can improve its loss if the public expects a smaller shock size (either by $E(c) < c = 3$ or $E(T) > T = 2$) and, thereby, can reduce the volatility in output at the cost of a higher volatility in inflation.

Next, we discuss the withholding strategy. Until now, we have assumed that the public switches to fully correct expectations in the very last possible moment in t^* , i. e. when the public realizes for the first time that the expected evolution of the shock process deviates from the true one. We now discuss how the central bank loss and the volatility in inflation and output change if the switch to correct expectations occurs earlier than assumed so far ($t_{CB}^* \leq t^*$). Figure 6 shows the relative loss and the relative volatility for output and inflation for different values of t_{CB}^* for all three scenarios. The earliest possible time to switch is $t_{CB}^* = 0$, which is equivalent to the FA scenario. The latest possible time to switch (which we have used so far) depends on the anticipation scenario.³² In the top three plots of Figure 6, the central bank is confronted with a public that initially underestimates the shock size (either by $E(c) < c$, $E(T) > T$, or $E(t_1) < t_1$). In the lower three plots, the central bank is confronted with a public that initially overestimates the shock size (either by $E(c) > c$, $E(T) < T$, or $E(t_1) > t_1$).

If the central bank reveals the true shock process during the anticipation phase ($0 < t_{CB}^* < T$), we have a trade off between output and inflation stabilization

³² We have used $t^* = T$ in scenario PA-MAG, $t^* = \min(E(T), T)$ in scenario PA-START, and $t^* = \min(E(t_1), t_1)$ in scenario PA-EXIT (cf. Table 3 of Section 4).

Figure 6: Optimal time of expectations correction (withholding strategy).

in all three anticipation scenarios including scenario PA-EXIT. If the public underestimates the shock size (either by $E(c) < c$, $E(T) > T$, or $E(t_1) < t_1$), output is stabilized and inflation is destabilized. If the public overestimates the shock size (either by $E(c) > c$, $E(T) < T$, or $E(t_1) > t_1$), output is destabilized and inflation is stabilized. The difference between output and inflation volatility decreases with decreasing length of withholding the true shock process (with decreasing t_{CB}^*). In scenario PA-EXIT, the switch to correct expectations may also occur during the implementation phase ($T < t_{CB}^* < t_1$). For a sufficiently late switch (t_{CB}^* sufficiently large), the trade off between output and inflation stabilization vanishes.

Under the loss function [12], the best communication strategy is as follows: If the public overestimates the size of the shock (lower three plots), the FA scenario produces the best outcome, i. e. the best central bank's policy is to inform the public as soon as possible about the true evolution. If, on the other

hand, the public underestimates the size of the shock (upper three plots), the best central bank's policy is to inform the public as late as possible. Note that this communication strategy typically stabilizes output, but destabilizes inflation (unless $t_{CB}^* > T$) and, therefore, is only optimal if the central bank's concern about output stabilization is sufficiently strong. If e. g. the central bank's only objective is to achieve inflation stability (strict inflation targeting), this strategy typically does not achieve an optimal outcome.³³

This section has shown that the central bank may have the incentive to improve the central bank loss by either actively deceiving private expectations (deception strategy) or by withholding information about the true evolution of the shock process (withholding strategy). However, this section should not be understood as a policy advice since both strategies may involve drawbacks that have not been mentioned so far, including the following: First, both strategies, particularly the deception strategy, may involve reputational costs by reducing the central bank's credibility in future periods. Second, the central bank has to be able to correctly monitor the expectations bias. Withholding information about the true shock process may, therefore, lead to a higher central bank loss if the public is biased in the opposite direction.

6 Unstable money multiplier

Until now, we have assumed that the central bank can perfectly control the money growth rate, which requires a stable relation between the (adjusted) monetary base and broad money. This stable relation implies that the asset purchases from central banks – without neutralization – lead to increases in the money stock. Since the financial crisis in 2008, we do not observe such a stable relation between base and broad money in the euro zone.³⁴ Therefore, we consider in this section the case $c=0$, which implies that the money growth rate and the money stock do not change (see Table 2 in Section 3).

Central bank interventions (e. g. asset purchases) that lead to an expansion of the monetary base then have no effect on the economy if the public correctly

33 Under strict inflation targeting ($\alpha=0$), the central bank's best communication strategy is typically reversed to the strategy under flexible inflation targeting: If the public overestimates the size of the shock (lower three plots), the best strategy is to inform the public in $t_{CB}^* = T$. If the public overestimates the size of the shock (upper three plots), the best strategy is to inform the public as soon as possible (unless $t_{CB}^* > T$ is possible).

34 See e. g. De Grauwe and Ji (2013), who finds a stable relation prior to 2008 and an unstable relation thereafter.

Figure 7: Unstable money multiplier (MM) with single and multiple expectations adjustments.

anticipates this unstable relation. Figure 7 shows two scenarios in which expansions in the monetary base have real effects even without a stable money multiplier. In both scenarios, we presume that the public initially believes in a stable money supply multiplier and expects in $t=0$ that the central bank interventions will indeed lead to a monetary expansion at a particular future time $T=2$. In the first scenario, the public immediately switches to fully correct

expectations in a single step after its expectations failed for the first time. In the second scenario with multiple expectations adjustments, the public sequentially updates its expectations and expects a later start (and end) of the increase in the money stock before it switches to fully correct expectations. For reference purposes, we also include the responses to a fully anticipated increase in base money with stable money multiplier from Figure 1 in Section 3.

In the following, we discuss the two scenarios in more detail. On impact and during the anticipation phase, the two scenarios produce the same responses as under a stable money multiplier since the initial expectations on the increase in the money growth rate are the same. In $T = 2$, the public realizes that – contrarily to its expectations – no increase in the money stock occurred. In the first scenario (single expectations adjustment), the public, therefore, immediately switches in T to fully correct expectations and correctly expects no change in the money growth rate (i. e. $E(c) = 0$ for $t > T$). In the phase plane, we see an immediate vertical jump upwards onto the original saddle path and a subsequent adjustment from above along the saddle path to the old and new steady state. Similarly, output and inflation jump downward in T and converge from below to the old steady state.

In the second scenario (multiple expectations adjustment), the public believes in T still in a stable money multiplier and sequentially expects a later start of the increase in the money stock. Note that we assume that the public also sequentially updates its expectations on the end of the increase in the money growth rate t_1 such that the expectations on the size of the shock remain the same. In $T = 2$, the public expects a start in $T_1 = 4 > T$. In T_1 , no change in the money stock occurred and the public expects a start in $T_2 = 6 > T_1$ and so forth. This sequential updating of expectations leads to a cyclical adjustment path. Whenever the public updates its expectations (in $T, T_1, T_2, \dots$), the system jumps on a higher trajectory in the phase plane, which corresponds with an immediate output contraction. During two contractions, output gradually increases in anticipation of the expansionary increase in the money stock. Only after several expectations adjustments (in $t = 8$) does the public realize that no change in the money stock will occur and switches to fully correct expectations. Not until then does the system jump on the initial stable saddle path and converges from above towards the initial steady state.

To sum up, this section has shown that changes in the monetary base may have real effects on the economy and may impose cyclical adjustment movements even if a stable relation between the monetary base and a broader money aggregate is non-existent. This requires, however, that the public indeed believes in a stable relation between base and broad money and expects a future increase in the money growth rate.

7 Modifications

In this section, we apply six modifications. First, we change our parameter calibration. Second, we modify the length of anticipation relative to the length of the implementation phase. Third, we consider a further partial anticipation scenario PA-ST/EX which is an intermediate scenario of PA-START and PA-EXIT. Fourth, we change the mechanism with which the private expectations switch to correct expectations. Fifth, we modify the augmentation term in the Phillips curve. Finally, we consider a simultaneous increase in the risk premium s and in the money growth rate $\dot{m}$. Figures and tables to which we refer in this section can be found in the electronic appendix at www.jbnst.de/en.

1. Parameter calibration: To check the robustness of our volatility results, we simulate our model for different parameter calibrations for scenario PA-MAG, where the public has incorrect expectations about the magnitude c of the increase in the money growth rate. We consider the following alternative parameter specifications: We use $l_2 = \{1, 10\}$ for the interest rate semi-elasticity of the money demand, $\delta = \{0.1, 0.5\}$ for the slope of the Phillips curve, $a_2 = \{0.1, 0.6\}$ for the interest rate semi-elasticity of private absorption, and $b_3 = \{0.03, 0.6\}$ for the terms of trade elasticity of the trade balance.³⁵ Figures C.1 and C.2 show the relative volatility of output and inflation. Figures C.3 and C.4 show the corresponding responses to a fully anticipated increase in the money growth rate. Table C.1 gives the volatility share of the three subperiods on overall inflation and output volatility in the full anticipation scenario.

The volatility results for the alternative parameter specifications are as follows: First, we do not find any qualitative change in the relative volatility during the three subperiods. During the anticipation phase, the differences are so small that they are not visual. Second, for all parameter specifications, we find that an isolated stabilization of output and inflation is possible while a simultaneous stabilization is not possible. Indeed, we obtain the same trade off in overall volatility as in the baseline calibration. This trade off vanishes only when the anticipation effect of output is sufficiently small, i. e. the volatility share of the anticipation phase has to be at least below 1.3 percent.³⁶ Third, the anticipation

³⁵ In particular, we consider nine different parameter sets. In eight of these nine sets, we only change one parameter at a time and keep the remaining parameters at their baseline values. In the ninth set, we change all four parameters simultaneously.

³⁶ For a volatility share of 1.3 percent, the trade off in volatilities still remains. Only at the border of the parameter space (e. g. if we simultaneously set $l_2 = 1$, $\delta = 0.5$, $b_3 = 0.03$, and $a_2 = 0.6$) do we find that the anticipation effect of output is small enough (below 0.1 percent) so that output and inflation may be stabilized simultaneously.

effect of inflation remains very small for all parameter sets under consideration. Therefore, we obtain no qualitative change in the overall inflation volatility.

2. Anticipation length: In this modification, we change the length of the anticipation phase relative to the length of the implementation phase in scenario PA-MAG. Until now, we have assumed that the anticipation and implementation period are of similar length, where we set the anticipation length to $T = 2$ and the implementation length to $t_1 - T = 3$. We now consider two different length of anticipation. In Figures C.5 and C.6, we set the relative length of anticipation to 1/10th of the length of implementation phase (i. e. $T = 0.3$ and $t_1 = 3.3$). In Figures C.7 and C.8, we set the relative length anticipation to 10 times the length of the implementation phase (i. e. $T = 30$ and $t_1 = 33$). We find that the volatility differences increase with increasing length of anticipation. Our volatility results, however, do not change qualitatively. For $T = 0.3$ and $T = 30$, we obtain the same trade off in volatilities as for $T = 2$.

3. Scenario PA-ST/EX: In this modification, we consider the partial anticipation scenarios PA-ST/EX, which is a combination of scenarios PA-START and PA-EXIT. So far, in each of the three partial anticipation scenarios, the public has implicitly incorrect expectations about the size of the shock. In scenario PA-ST/EX, the public has incorrect expectations about the start and the end of the monetary shock, but is correct about the length and the size. That is, the expectations bias on the start and the end of the shock has to be the same.³⁷ Figure C.9 depicts the responses to a temporary increase in the money growth rate, and Figure C.10 shows the relative volatility in this scenario. Both, the responses and the relative volatility are very similar to scenario PA-START. Consequently, not only the expected size of the shock, but also the expected timing of the shock matters.

4. Sequential correction of expectations: So far, we have assumed that the switch to correct expectations occurs immediately at one particular point in time t^* . We now assume that the public sequentially adapts its expectations over time in several steps. With each step the public gains more information about the true evolution of the shock process. For simplicity, we assume that the information gain is equally distributed over time. Figure C.11 shows the response of the three anticipation scenarios (PA-MAG with $E(c) < c$, PA-START with $E(T) < T$, and PA-EXIT with $E(t_1) < t_1$) for three different degrees of frequency, i. e. number of expectations adjustments: (i) With frequency one, which is equivalent to the

³⁷ The same assumption is made in the previous section in the scenario with multiple expectations adjustments.

one-step adjustment of Section 3, (ii) with frequency two, and (iii) with a frequency of 200, which gives a quasi-continuous expectations adjustment. To save space, we only show the responses in the phase plane.

The more frequent the public adjusts its expectations, the smaller is the discontinuous adjustment in the non-predetermined variables for $t < t^*$ and the smoother is the adjustment path during the anticipation phase. In the limit case of a continuous adjustment of expectations, the non-predetermined variables behave continuously after the impact during the anticipation phase ($0 < t < T$).

For all three scenarios, we compute the relative volatility using continuous expectations adjustments instead of the single adjustment frequency of Section 3. Figure C.12 summarizes our results. We find no notable differences to the relative volatility analysis from Section 4. In Section 5, we have seen that our volatility results crucially depend whether the switch to correct expectations occurs during the anticipation or during the implementation phase. However, this modification has shown that the pace with which the switch occurs is somewhat irrelevant.

5. Inflation expectations based on consumer price index: Until now, we have assumed that the augmentation term in the Phillips curve is given by the trend rate of inflation $\pi = \dot{m}$. Figures C.13 to C.16 show the responses and the relative volatilities if the formation of inflation expectations in the Phillips curve is based on the (short-run) consumer price index p_c for scenario PA-MAG, PA-START, and PA-EXIT. The augmentation term then reads as

$$\pi = \dot{p}_c = \gamma \dot{p} + (1 - \gamma)(\dot{p}^* + \dot{e}) \quad [13]$$

where $1 - \gamma$ measures the degree of openness and γ is set equal to 0.6.

We do not observe a qualitative change in the relative volatility during the three subperiods. Furthermore, an isolated reduction in the overall volatility of output and inflation is possible. Again, a simultaneous stabilization of output and inflation is not possible, even in scenario PA-EXIT. However, this trade off in volatilities is reversed compared to our baseline model: If the public underestimates (overestimates) the size of the shock, output (inflation) may be destabilized, i. e. not stabilized as in our baseline model.

The reason for this reversed trade off in volatilities is as follows: First, inflation responds now much more strongly during the anticipation phase than in our baseline model. Inflation expectations in the Phillips curve are not anchored anymore to the exogenous money growth, which does not change until T . Instead, inflation expectations that are based on CPI inflation already change during the anticipation phase. The last row of Table C.1 shows that more

than 50 percent of overall inflation volatility is accumulated during the anticipation phase in case $\pi = \dot{p}_c$ (in contrast to 0.2 percent in our baseline model). Therefore, the relative volatility during the anticipation phase contributes much more to the overall volatility and dominates the volatility effects during the implementation phase.

Second, the volatility share of the anticipation phase also increases for output, i.e. output reacts more strongly during the anticipation phase. However, the relative output volatility during the implementation phase is now much more sensitive to anticipation errors than in our baseline model. Therefore, the implementation effect is now dominant for output and overall output volatility may only be stabilized if it is stabilized during the implementation phase.

6. Risk premium shock: In the sixth and last modification, we apply our volatility analysis to the recent developments during the European sovereign debt crisis, where several (southern) European countries are suffering from increasing risk premiums on government bonds. To oppose these risk premiums, the President of the ECB, Mario Draghi, signalized in July 2012 further purchases of government bonds at the Global Investment Conference in London. He is, however, mute about the exact threshold $\bar{s}$ of risk premiums at which the ECB is willing to intervene. This leaves room for private misperceptions such that the public may only partially anticipate the size and the timing of the announced monetary intervention. We aim to study the consequences of this limited information strategy with respect to the volatility of inflation and output.

To this end, we consider a simultaneous increase in the risk premium and in the money growth rate. The true, but not necessarily correctly anticipated evolution of the increase in the risk premium and in the money growth rate is summarized in Table C.2: In $t = t_0$, the risk premium starts to gradually increase. In $t = T$, the risk premium reaches the threshold $\bar{s}$ at which the monetary authority starts to purchase government bonds at a constant rate c . Without neutralization and stable money supply multiplier, this is equivalent to a temporary increase in the money growth rate and a permanent increase in the money stock. We assume that this monetary intervention leads quasi-endogenously to a gradual decline in the risk premium until it reaches its initial level in $t = t_1$.

In $t = 0$, the public starts to form expectations about both the risk premium and the monetary policy intervention. The public correctly anticipates and observes the increase in the risk premium, but may have incorrect expectations about the start T of the monetary intervention and, therefore, on the start of the decline in the risk premium. Contrarily to an isolated monetary shock in scenario

PA-START, the public overestimates (underestimates) the size of the risk premium shock and the monetary intervention if the public expects a later (an earlier) monetary intervention. Table C.3 summarizes the expectation biases under partial anticipation.

The responses under full and partial anticipation are shown in Figure C.17. Figure C.18 and C.19 summarize our volatility results: If the public expects an earlier intervention of the central bank to bring down the risk premiums on government bonds, the volatility in output and inflation may be reduced. Under flexible inflation targeting, the best central bank's communication policy then is to withhold information about the true shock process as long as possible. If, on the other hand, the public expects a later monetary intervention, output is and inflation may be destabilized. Under flexible inflation targeting, the fully correct anticipation scenario then typically gives the lowest central bank loss. Hence, the best policy is to inform the public as soon as possible about the true intentions of the central bank.³⁸

8 Conclusion

In this paper, we use a continuous-time Dornbusch-type model of a small open economy to study the (de)stabilizing effects of fully anticipated, fully non-anticipated, and partially anticipated increases in the money growth rate. Under partial anticipation, the public has either imperfect information about the magnitude, the start, and/or the end of the future monetary policy intervention, and, therefore, has implicitly imperfect information about the size of the shock.

Our main results are as follows: (i) Partially anticipated monetary policy shocks may stabilize inflation and output fluctuations, i. e. lead to a lower volatility than a fully anticipated monetary policy shock of the same form. (ii) However, we typically obtain a trade off in volatilities of output and

38 If the size of the monetary intervention is sufficiently small, inflation and output may be simultaneously stabilized. The reason is that the anticipation and implementation reaction of the inflation rate in response to an isolated increase in the risk premium is of similar magnitude. If the monetary intervention is sufficiently large compared to the increase in the risk premium, we obtain a trade off between inflation and output stabilization. During the simulation, we set $\bar{s}=3$, $c=1$, $t_0=2$, $T=5$, and $t_1=8$, implying that the change in the money stock is given by $dm=3$. Note that the interest rate and the risk premium shock are not logarithmized. Assuming a interest rate steady state of $\bar{i}_0=0.01$ implies that the risk premium shock is 100 times larger than the monetary shock in terms of percentage deviations from the steady state.

inflation over the whole adjustment process such that a simultaneous stabilization of output and inflation is not possible. If the public underestimates (overestimates) the size of the shock, output (inflation) may be stabilized. (iii) This trade off in volatilities does typically not exist during the three subperiods (anticipation phase, implementation phase, and return phase) separately. If the public underestimates (overestimates) the size of the shock, both output and inflation are stabilized (destabilized) during the anticipation phase and are destabilized (stabilized) during the implementation phase. (iv) The volatility gain/loss from partial anticipation is (much) larger for output than for inflation. Under flexible inflation targeting, the best central bank's communication strategy, therefore, is typically to stabilize output fluctuations. If the public underestimates the size of the shock, the central bank then has an incentive to withhold information from the public about the true central bank's future policy intentions.

The aforementioned results can be explained as follows: First, during the anticipation phase the economy is driven by expectations. If the public overestimates (underestimates) the shock size, both output and inflation respond more strongly (less strongly) than under fully correct expectations. Under price stickiness, the economy is not able to jump on the solution path of fully correct expectations. To compensate for this price stickiness, the system (including output and inflation) overreacts when the true shock process is revealed and typically leads to smaller (larger) reaction of output and inflation during the implementation phase. This leads to the opposite volatility pattern during the anticipation and the implementation phase as described in result (iii). Second, we find that the anticipation response of inflation is relatively small compared to the anticipation response of output. Therefore, the volatility share of the anticipation contributing to overall volatility is smaller for inflation than for output. In combination with result (iii), this gives rise to an overall trade off in output and inflation volatility.

We find two exceptions in which results (ii) and (iii) do not or only partially hold: First, when the public underestimates the shock for a sufficiently long time (i. e. the expectations are biased also during the implementation of the shock), overall output and inflation may be stabilized in all three subperiods simultaneously. Therefore, a simultaneous stabilization of output and inflation over the whole adjustment process is possible and the overall trade off in volatilities vanishes. Second, if the anticipation effect of inflation (output) is sufficiently large (small), result (ii) may be reversed. That is, inflation (output) may be stabilized if the public underestimates (overestimates) the shock.

We further study partially anticipated monetary interventions in the presence of an unstable money multiplier. We find that changes in the monetary

base may have real effects on the economy and may impose cyclical adjustment movements even if the relation between the monetary base and a broader money aggregate is non-existent. This requires, however, that the public indeed believes in a stable relation between base and broad money and expects a future increase in the money growth rate.

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