Risks to Price Stability, the Zero Lower Bound, and Forward Guidance: A Real-Time Assessment*

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This paper employs stochastic simulations of the New Area-Wide Model—a microfounded open-economy model developed at the ECB—to investigate the consequences of the zero lower bound on nominal interest rates for the evolution of risks to price stability in the euro area during the recent financial crisis. Using a formal measure of the balance of risks, which is derived from policymakers' preferences about inflation outcomes, we first show that downside risks to price stability were considerably greater than upside risks during the first half of 2009, followed by a gradual rebalancing of these risks until mid-2011 and a renewed deterioration thereafter. We find that the lower

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bound has induced a noticeable downward bias in the risk balance throughout our evaluation period because of the implied amplification of deflation risks. We then illustrate that, with nominal interest rates close to zero, forward guidance in the form of a time-based conditional commitment to keep interest rates low for longer can be successful in mitigating downside risks to price stability. However, we find that the provision of time-based forward guidance may give rise to upside risks over the medium term if extended too far into the future. By contrast, time-based forward guidance complemented with a threshold condition concerning tolerable future inflation can provide insurance against the materialization of such upside risks.

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1. Introduction

The recent financial crisis has posed serious challenges for the assessment of risks to price stability in the euro area. The sharp contraction in economic activity at the onset of the crisis in 2008 put downward pressure on prices beyond the short-run impact of the drop in commodity prices observed at that time. This gave rise to concerns that the euro area may eventually enter a situation leading to a sustained and broad-based fall in the aggregate price level, i.e., deflation.[1] The European Central Bank (ECB), like other major central banks around the world, responded to the unfolding events by rapidly reducing its key interest rates to historically low levels in order to support aggregate demand and to forestall a further loss of confidence. While the downward pressure on prices eventually receded with the start of a muted, albeit vulnerable, recovery in late 2009, the outlook for the economy has remained subject to a heightened degree of uncertainty.[2]

Against this background, we aim to provide a model-based narrative of the evolution of the risks to price stability in the euro area

[1] See, e.g., International Monetary Fund (IMF) (2009) and *Wall Street Journal* (2009).

[2] In fact, severe setbacks in the recovery were due to the reintensification of the crisis on account of elevated tensions in euro-area sovereign debt markets in the course of 2010 and 2011.

during the course of the financial crisis. We do so by employing stochastic simulations of the ECB's New Area-Wide Model (NAWM), a microfounded open-economy model of the euro area designed for forecasting and policy analysis; see Christoffel, Coenen, and Warne (2008). Importantly, with short-term nominal interest rates at historically low levels, the model-based simulations recognize the existence of a (zero) lower bound on nominal interest rates which limits the scope for monetary policy to provide additional stimulus using its standard interest rate instruments.[3] Moreover, the simulations are conducted in a real-time setting, covering the period from late 2008 to the end of 2011. Thus they enable us to construct predictive distributions for the inflation outlook which capture the uncertainty pertaining to unforeseeable future events at different points in time. To enhance the realism of our risk assessment, we construct the model-based predictive distributions using Consensus Economics forecast vintages as a reference point. In so doing, we account for the sequence of revisions that were made to inflation forecasts over time on the basis of a broader information set as well as different models and analytical perspectives. These revisions have often been substantial, with notable consequences for the assessment of the risks to price stability in the euro area.

Our analysis of risks to price stability builds on a literature that has used structural macroeconomic models to study the consequences of the zero lower bound on nominal interest rates for the efficacy of monetary policy, including studies by Reifschneider and Williams (2000), Coenen, Orphanides, and Wieland (2004), and Williams (2009). While these studies have focused on how the zero lower bound affects the properties of the models' steady-state distributions with a view to designing monetary policy strategies that help to mitigate the zero-lower-bound impact, we study the evolution of risks to price stability during the crisis on the basis of model-based predictive distributions. A similar approach has been

[3]The ECB also implemented a number of non-standard monetary policy measures, including the provision of unlimited liquidity to the banking system, to sustain financial intermediation and to maintain the availability of credit to the private sector; see ECB (2010a). For an analysis of the fiscal response to the crisis in the euro area, see European Commission (2009), ECB (2010b) and Coenen, Straub, and Trabandt (2012, 2013).

taken by Chung et al. (2011), yet with a focus on assessing the likelihood that a range of different models would have predicted the actual macroeconomic outcomes prior to the onset of the crisis.

Our model-based assessment of risks to price stability shows that *deflation risks* (defined as the probability of observing at least four consecutive quarters of negative annual inflation rates over the respective forecast horizon) were highest for the March and June 2009 Consensus Economics forecast vintages. They diminished subsequently, but edged up again in the second half of 2011 following the reintensification of the crisis due to elevated tensions in euro-area sovereign debt markets. By contrast, *excess inflation risks* (defined as the probability of observing at least four consecutive quarters of annual inflation above 2 percent) were lowest for the early 2009 forecast vintages and increased thereafter. A formal measure of the *balance of risks* advocated by Kilian and Manganelli (2007), which is based on policymakers' preferences about inflation outcomes and takes the severity of deflation and excess inflation events into account, suggests that downside risks to price stability were considerably greater than upside risks during the first half of 2009. This episode was followed by a gradual rebalancing of risks until mid-2011. Thereafter the risk balance started to turn negative again. The model-based analysis demonstrates that the zero lower bound has induced a noticeable downward bias in the risk balance throughout the crisis period because of the implied amplification of deflation risks.

In view of the severity of the financial crisis with an exceptionally sharp contraction in economic activity and a rapid and sustained reduction in short-term nominal interest rates to historical lows, it is important to recognize that such extreme events are very unlikely to occur from the perspective of models like the NAWM, which are primarily estimated on pre-crisis data displaying rather moderate fluctuations. Accordingly, the predictive distributions constructed on the basis of the NAWM may understate the incidence and persistence of lower-bound events and their adverse impact on the balance of risks to price stability. In a similar vein, the predictive distributions rest on the assumption that longer-term inflation expectations remain well anchored, thereby limiting the buildup of stronger deflationary momentum. If the analysis were to allow for a sensitivity of longer-term inflation expectations to the protracted, albeit moderate, fall in observed inflation during the crisis, the estimated downside risks to price stability would have been larger throughout. In this regard, it is reassuring that—on the basis of long-term Consensus Economics inflation forecasts, for example—there is little evidence that the anchoring of longer-term inflation expectations in the euro area has been adversely affected by the crisis.

Whereas our analysis offers first and foremost a real-time narrative of the consequences of the financial crisis for the evolution of risks to price stability through the lens of the NAWM, the employed methodology of stochastic simulations can also be used to examine the effects of counterfactual policy measures. As an illustration, we examine the effectiveness of providing *forward guidance* concerning the path of future short-term nominal interest rates as a means of delivering additional stimulus in a situation where nominal interest rates are close to zero and where downside risks to price stability prevail.[4] Within the NAWM, forward guidance is implemented as a time-based *conditional commitment* to keep the nominal interest rate at the zero lower bound for a certain number of additional quarters, over and above the number of quarters for which the interest rate would be constrained by the zero lower bound in the absence of the conditional commitment. Focusing on the December 2011 forecast vintage as a reference point, the model-based simulations suggest that this form of forward guidance imparts the intended stimulus and can be successful in reducing the prevailing downside risks to price stability by offsetting the asymmetry in the predictive distribution for inflation caused by the lower-bound constraint. Yet if extended too far into the future, it may—through its impact on inflation expectations—create higher inflationary momentum than desired, eventually leading to upside risks to price stability over the medium term. In this regard, we show that complementing the time-based commitment with a threshold condition concerning tolerable future inflation developments can provide insurance against the materialization of such upside risks.

[4]For an exposition of the theoretical underpinnings of forward guidance at the zero lower bound, see, e.g., Eggertsson and Woodford (2003), Adam and Billi (2006), Nakov (2008), Walsh (2009) and Levin et al. (2010). Woodford (2012) offers a broader perspective on forward guidance, including on the practical experience of the Federal Reserve with the introduction of forward guidance.

While the simulations with the NAWM illustrate the general merits of forward guidance, it is important to note that the two forms of forward guidance considered in this paper differ from the forward guidance policy actually adopted by the ECB in summer 2013. Specifically, the ECB's forward guidance is formulated in qualitative terms and does not specify the concrete period of time over which its accommodative monetary policy stance is expected to be maintained or particular threshold conditions, like in the simulations.[5] It is also important to note that the effects which we obtain using the NAWM are likely to provide an upper bound for the potency of forward guidance to the extent that the commitment in the model-based analysis is perfectly credible. Throughout our analysis we abstract from issues that could arise under imperfect credibility, and focus on the case—as in nearly all of the existing zero-lower-bound literature—where the policymaker has a perfect commitment technology. A notable exception is the recent study by Bodenstein, Hebden, and Nunes (2012), which considers the case of imperfect credibility and addresses the inherent time inconsistency of forward guidance because of the temptation to tighten policy once the economy strengthens and/or inflation resurfaces.

The remainder of the paper is organized as follows. Section 2 examines the evolution of deflation and excess inflation risks over the crisis period, focusing on the probabilities of certain deflation and excess inflation events. Section 3 proceeds by introducing and evaluating a formal measure of the balance of risks to price stability and ascertains its sensitivity to alternative assumptions. Section 4 studies the effects of forward guidance, and section 5 concludes. A brief overview of the NAWM and technical details of the analysis are deferred to appendices.

2. Risks to Price Stability and the Lower Bound

Forecasts are a central element in the deliberations of monetary policymakers regarding the outlook for the economy and the calibration of the stance of monetary policy. Yet point forecasts fail to convey

[5]For details on the modalities of the forward guidance provided by the ECB's Governing Council, see ECB (2013).

the large uncertainty which pertains to unforeseen events and developments over the forecast horizon. That uncertainty can be captured by density forecasts, or predictive distributions.

In an attempt to characterize the forecast uncertainty prevailing at different points in time over the crisis period and to gauge the evolution of the associated risks to price stability, we will utilize predictive distributions based on the ECB's New Area-Wide Model (NAWM), which is a microfounded open-economy model of the euro area designed for use in the ECB/Eurosystem staff projections and for policy analysis.[6] In deriving the predictive distributions, we shall allow the short-term nominal interest rate to react to shocks that may occur over the forecast horizon according to the NAWM's estimated monetary policy rule, while recognizing the zero lower bound on nominal interest rates.[7] As we shall demonstrate below, the existence of the zero lower bound has important consequences for the evolution of the risks to price stability over the crisis period.

To the extent that policymakers do not base their deliberations mechanically on any single model-based forecast, however, we start from baseline forecasts that incorporate a wider range of data and account for different models and perspectives, namely the forecast vintages provided by Consensus Economics. These vintages are released at a quarterly frequency in early March, June, September, and December of each calendar year. We then employ stochastic simulations of the NAWM to obtain predictive distributions around these baseline forecasts.[8] That is, we rely on a model-based characterization of uncertainty, including the effects that arise from the zero lower bound on nominal interest rates, but account for the

[6]For a detailed description of the NAWM, see Christoffel, Coenen, and Warne (2008). A sketch of its basic structure is provided in appendix 1.

[7]That is, we do not allow for a feedback from the quantified risks to price stability to the interest rate prescriptions of the estimated policy rule. Rather, the risk assessment is conducted ex post on the basis of the model's predictive distributions which depend, inter alia, on the characteristics of the policy rule.

[8]For details on the compilation of the Consensus Economics forecast vintages that we use in the analysis and the construction of our real-time data set, see appendix 2. Technical details on the stochastic simulations that we conduct around the baseline forecasts and on the solution method that we use to solve the NAWM subject to the zero-lower-bound constraint are provided in appendix 3.

sequence of revisions that were made to the baseline forecasts over time on the basis of a broader information set.[9]

2.1 Risks to Price Stability: March 2009

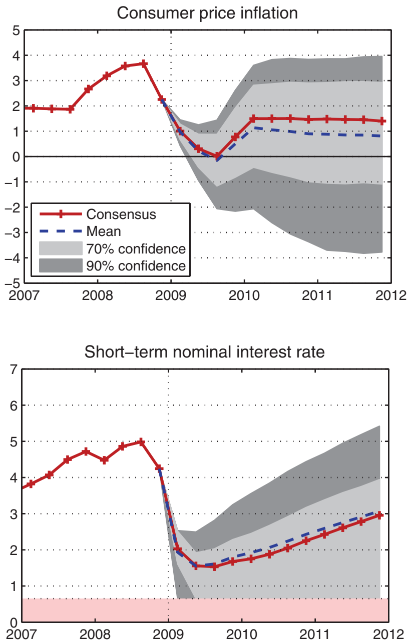
By means of example, figure 1 displays the March 2009 Consensus forecast vintage as well as the mean and the 70 percent and 90 percent confidence bands of the associated NAWM-based predictive distributions for annual consumer price inflation (measured in terms of the private consumption deflator), annual real GDP growth, and the short-term nominal interest rate (corresponding to the annualized three-month Euribor).

With regard to consumer price inflation (see the upper left panel in figure 1), an increasing part of the predictive distribution lies below zero, while a substantial part continues to lie above inflation rates consistent with the ECB's quantitative definition of price stability with inflation below, but close to, 2 percent. Accordingly, the distribution is markedly skewed to the downside, and its mean falls increasingly below the Consensus baseline path over the outer years of the forecast horizon. Similar properties are found for the predictive distribution of real GDP growth (see the upper right panel in the figure).

The reason for the asymmetry of the predictive distributions is that, with short-term nominal interest rates having been lowered to unprecedented levels to support the economy in the face of large negative demand shocks, the reaction of monetary policy to further recessionary and deflationary shocks over the forecast horizon is eventually constrained by the zero lower bound on nominal interest rates. In the simulations, this happens with an average incidence of 15.9 percent across all quarters of the forecast horizon. Hence, the lower-bound constraint implies a piling up and a skew to the upside

[9] Throughout our paper, we maintain the assumption that the forecasters surveyed by Consensus Economics have not taken into account the consequences of the zero lower bound themselves. This assumption will be correct if the forecasters are agnostic about the lower bound, or if they rely on linear models and tools in producing their forecasts which do not account for the non-linearity induced by the lower bound. Otherwise our analysis may overestimate the importance of the zero lower bound as a factor determining downside risks to price stability. Accordingly, our assessment ought to be seen as providing an upper bound for the importance of downside risks in connection with the zero lower bound.

Figure 1. Predictive Distributions for Consumer Price Inflation, Real GDP Growth, and the Short-Term Nominal Interest Rate, March 2009



Notes: The predictive distributions are derived from stochastic simulations of the NAWM and are centered on the structural shocks that the model has identified for the March 2009 Consensus forecast vintage. Consumer price inflation and real GDP growth are expressed in annual terms. The short-term nominal interest rate in the NAWM corresponds to the annualized three-month Euribor. The lower bound is imposed at an interest rate level of 65 basis points, reflecting the average spread between the Euribor and the Eonia over the horizon of the forecast vintage.

of the predictive distribution for the short-term nominal interest rate, with the interest rate being somewhat higher on average than in the baseline path (see the lower left panel in figure 1).[10] If the

[10]In the NAWM, the lower bound is actually imposed at an interest rate level of 65 basis points, reflecting the fact that the interest rate path for the March 2009 forecast vintage is derived from three-month Euribor futures, which differ from market expectations of the Eonia by a spread representing counterparty and

zero lower bound were not to be taken into account, the predictive distributions for consumer price inflation, real GDP growth, and the short-term nominal interest rate would all be symmetric, and their means would be equal to the values in the baseline paths.

In assessing risks to price stability on the basis of the predictive distribution for consumer price inflation, we distinguish between downside and upside risks. We associate downside risks with the emergence of *deflation*, which can be defined as the event that annual inflation falls below zero for at least four consecutive quarters. This definition is motivated by the widely held belief that negative inflation rates ought to become a concern for policymakers only in cases where they are persistent and translate into a sustained fall in the aggregate price level.[11] Similarly, we consider upside risks, with the notion of *excess inflation* being defined as an event that annual inflation is above 2 percent for at least four consecutive quarters.[12] Based on these definitions, the deflation risk—i.e., the probability that the deflation event occurs—is found to equal 13.9 percent on average across all quarters of the forecast horizon, whereas the excess inflation risk is 11.6 percent.

Does the March 2009 forecast vintage, and the associated predictive distribution for inflation, signify a period with heightened deflation risks as feared, inter alia, by the IMF (2009)? To address this question we examine next the evolution of the downside and upside risks to price stability, from the onset of the crisis in late 2008 until the end of 2011.

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liquidity risk of about 65 basis points on average over the forecast horizon. In other words, the lower bound considered in the model-based simulations derives from a zero bound on the Eonia, which then translates into a lower bound on the Euribor given by the average spread.

[11]The same definition has been used by, e.g., IMF staff when assessing deflation risks in Japan, the United States, and the euro area with the Global Projection Model (GPM); see Clinton et al. (2010).

[12]The confidence bands for consumer price inflation in figure 1 allow for spells of inflation above 2 percent and inflation spells below zero that are shorter than four consecutive quarters. Since the shortest spell can be only one quarter, the confidence bands represent medium-term as well as short-term risks. The focus of the analysis in this paper is on the former. Probabilities for differing definitions of excess inflation or deflation events can be easily obtained from the predictive distribution of inflation.

2.2 Risks to Price Stability: December 2008 to December 2011

Our findings regarding the evolution of deflation and excess inflation risks from the December 2008 to the December 2011 forecast vintage are summarized in table 1, while the underlying predictive distributions are shown in figure 5 in appendix 4. In order to assess the significance of the deflation and excess inflation risks associated with the individual forecast vintages, we consider the risks that are implied by the predictive distribution for inflation initialized in the NAWM's deterministic steady state; see the values in the bottom row of the table. An especially important parameter in this context is the NAWM's steady-state nominal interest rate of 4.4 percent per annum, which is composed of a steady-state inflation rate of 1.9 percent per annum, consistent with the ECB's quantitative definition of price stability, and an equilibrium real interest rate of 2.5 percent per annum.

Compared with an implied *steady-state* deflation risk of 1.5 percent, our findings indeed suggest that deflation risks in March 2009 were significantly elevated, yet with deflation risks in June 2009 being even somewhat higher, at 14.8 percent on average. From September 2009 onwards, the deflation risks have gradually diminished, but they edged up again in the second half of 2011 following the reintensification of the crisis due to the buildup of tensions in some euro-area sovereign debt markets.[13] By contrast, excess inflation risks were exceptionally low throughout 2009 and have increased thereafter, reaching a peak in the first half of 2011, noticeably above the steady-state excess inflation risk of 28.7 percent.

One important factor explaining the heightened deflation risks in the first half of 2009 is the profile of the baseline forecasts for annual

[13]The estimated probabilities are based on the full length of the respective forecast sample. This means that nine quarters are included in the sample for the December forecast vintages, ten for the September, eleven for the June, and twelve for the March vintages; see appendix 2 for details. Since the width of the predictive distributions increases with the sample length, there is a small bias in the estimated probabilities in comparison to those obtained when only the first nine quarters are counted. See table 8 in appendix 4 for the corresponding probabilities estimated for a uniform sample length of nine quarters.

Table 1. Gauging Risks to Price Stability and the Lower-Bound Incidence

	Risks to Price Stability		
	Deflation	**Excess Inflation**	**Lower-Bound Incidence**
December 2008	4.4	15.3	6.0
March 2009	13.9	11.6	15.9
June 2009	14.8	9.8	11.0
September 2009	12.2	10.1	16.5
December 2009	9.2	9.3	17.7
March 2010	11.1	12.9	19.1
June 2010	10.5	15.8	24.7
September 2010	8.0	18.8	22.4
December 2010	5.6	19.8	19.0
March 2011	4.2	30.7	8.1
June 2011	3.6	33.5	9.2
September 2011	7.3	23.9	25.2
December 2011	6.8	24.6	29.0
Steady State	1.5	28.7	0.3

Notes: This table shows the evolution of risks to price stability and of the importance of the lower-bound constraint for short-term nominal interest rates over the period from December 2008 to December 2011. The deflation (excess inflation) risk corresponds to the probability of annual inflation being below zero (above 2 percent) for at least four consecutive quarters, expressed in percent. The lower-bound incidence is equal to the probability that the short-term nominal interest rate is constrained by its lower bound, in percent. The risk measures and the lower-bound incidence are based on the NAWM's predictive distributions for annual inflation and the short-term nominal interest rate, which have been constructed around successive Consensus forecast vintages. In the computations, the short-term nominal interest rate corresponds to the three-month Euribor. The lower-bound constraint is imposed at interest rate levels between 30 and 70 basis points, reflecting the average spread between the Euribor and the Eonia over the horizon of the respective Consensus forecast vintage. The steady-state values are calculated from the predictive distributions for inflation and the nominal interest rate initialized at the model's steady state and expressed as averages over the different lengths of the forecast horizons within a calendar year.

inflation; see figure 5 in appendix 4. Following the sharp fall in commodity prices in the second half of 2008, inflation rates decelerated markedly, with a trough below, albeit near, zero reached in summer 2009. Owing to base effects and a partial reversal of the previous drop in commodity prices, inflation rates picked up in autumn 2009, even though underlying inflationary pressures remained contained on account of the slack in the economy and on the back of a muted recovery.

A second important factor, which we emphasize in our paper, concerns the role of the zero lower bound on nominal interest rates. The short-term nominal interest rate had been sharply reduced by early 2009 in swift response to the unfolding crisis, and the incidence of hitting the lower bound has consequently shifted upward to on average 15.9 percent in March 2009, compared to a steady-state incidence of 0.3 percent; see the far right column in table 1. The even higher lower-bound incidence recorded for the June and September 2010 forecast vintages is due to a downward shift in the expected paths of future short-term nominal interest rates; see figure 5 in appendix 4. This downward shift was triggered by the intensification of the crisis during the first half of 2010 as a result of the deteriorating fiscal situation in a number of euro-area countries. The heightened lower-bound incidence gave rise to an increased skew to the downside of the predictive distributions for both real GDP growth and consumer price inflation, amplifying the prevailing deflation risks. The increased downside skew in turn interacted with the lower bound via a negative feedback loop, as nominal interest rates could not be lowered to balance such skew, and further elevated the lower-bound incidence. Similar developments occurred in the second half of 2011, when the tensions in sovereign debt markets reintensified.

Nevertheless, the growing impact of the lower-bound incidence on deflation risks in 2010 was eventually offset by upward revisions to the baseline forecast for inflation in 2010 and in early 2011 (see figure 5 in appendix 4), with the net effect that deflation risks decreased. However, with the worsening of sovereign debt market tensions in the second half of 2011, when short-term interest rates were lowered further and market expectations of future interest rates fell to unprecedented levels, the lower-bound incidence reached historical highs and deflation risks started to rise again.

Table 2. Gauging Risks to Price Stability and the Lower-Bound Incidence in 2011

	Risks to Price Stability		
	Deflation	Excess Inflation	Lower-Bound Incidence
March 2009	16.3	18.8	11.9
June 2009	14.8	15.7	6.5
September 2009	14.0	15.4	10.8
December 2009	12.5	12.9	11.8
March 2010	9.7	10.9	18.3
June 2010	4.3	13.3	28.0
September 2010	1.2	19.2	25.0
December 2010	0.1	19.1	21.2
March 2011	0.0	48.4	7.4

Notes: This table shows the evolution of risks to price stability and of the importance of the lower-bound constraint for a particular calendar year, namely 2011, as obtained from the predictive distributions for annual inflation and the short-term nominal interest rate constructed around successive Consensus forecast vintages. See table 1 for further details.

2.3 Risks to Price Stability: The Calendar Year 2011

Whereas table 1 provides an assessment of the evolution of deflation and excess inflation risks for the forecast vintages from December 2008 to December 2011 and for the full length of the respective forecast horizons, table 2 zooms in on the risks pertaining to a particular calendar year, namely 2011. This year is covered in full by all our forecast vintages up to March 2011, except for the December 2008 vintage. Deflation risks for 2011 are found to diminish from one forecast vintage to the next, the underlying factors being twofold. First, the forecast horizon is moving forward by one quarter for each consecutive forecast vintage. Therefore, with the predictive distributions gradually fanning out over the forecast horizon, an increasingly smaller part of the predictive distribution for inflation tends to lie below zero in the calendar year 2011. And second, the diminishing deflation risk reflects the successive upward revisions of the baseline forecasts for inflation in 2011; see figure 5 in appendix 4.

These two factors are partly offset by the increased downward bias in the predictive distributions for inflation on account of the heightened zero-lower-bound incidence in 2011. Similarly, excess inflation risks for 2011 are reassessed over time to be increasing, following a sequence of downward revisions in 2009 and early 2010.

3. Assessing the Balance of Risks to Price Stability

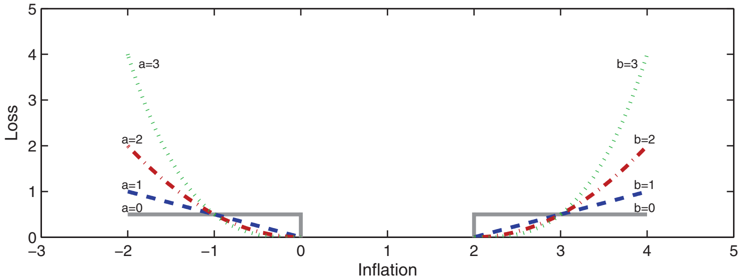
The risk measures in tables 1 and 2 are given by the probabilities that certain deflation and excess inflation events will occur based on the predictive distributions of the NAWM. Measures of risk, however, may also take the *severity* of the events of concern into account (see, e.g., Machina and Rothschild 1987). For example, an average excess inflation rate of 2.5 percent with an excess inflation probability of 20 percent may be regarded as less risky than an average excess inflation rate of 4 percent with a probability of 5 percent. Risk measures that take the severity of events into account were initially considered in the context of portfolio allocation decisions (see Fishburn 1977 and Holthausen 1981) but have more recently been adapted to macroeconomic forecasting (see Kilian and Manganelli 2007).

3.1 Loss-Function-Based Risk Measures

Following Kilian and Manganelli (2007), figure 2 displays a parametric family of loss functions for the preferences of a policymaker regarding alternative inflation outcomes.[14] In line with the exposition in the previous section, it is assumed that the lower bound defining deflation is equal to zero, while excess inflation is determined by the upper bound of 2 percent. Within these bounds the loss is zero, whereas a positive loss is attached to inflation outcomes outside the range of $[0, 2]$. The graphs in the figure can be interpreted as an index of the degree of dissatisfaction that the policymaker experiences as the inflation rate varies. Parameter a is the exponential

[14] To the extent that the policymaker is also concerned about fluctuations in output around potential, like in the vast literature on flexible inflation targeting (see, e.g., Svensson 1997), it is possible to augment the family of loss functions with an output-gap term; see Kilian and Manganelli (2008).

Figure 2. Loss Functions for Alternative Inflation Preferences



Notes: The parametric family of loss functions depicts the preferences of a policymaker regarding alternative inflation outcomes, with a zone of indifference defined by a lower bound of zero and an upper bound of 2 percent.

weight attached to downside deviations from zero, while parameter b is the exponential weight given to upside deviations from 2 percent. Since these parameters need not necessarily be equal, the policymaker's preferences can be asymmetric with respect to downside and upside risks.

Given that the policymaker wishes to minimize the expected loss, his preferences are weighted by the probabilities attached to alternative inflation outcomes. When parameter a is zero, the policymaker only cares about the probability of deflation and not about the severity of the deflation outcome. This is reflected in the loss being constant for all inflation outcomes below zero. Similarly, if parameter b is zero, the policymaker only cares about the probability of excess inflation and not about the extent to which inflation exceeds 2 percent. These two cases correspond to the risk analysis undertaken in the previous section with its focus on deflation and excess inflation probabilities. The larger the parameters a and b, the more dissatisfied the policymaker becomes as inflation exceeds the thresholds by a given amount. Likewise, the parameters a and b may be regarded as the degree of risk aversion on the part of a policymaker who is concerned about deflation and excess inflation events. For the assumed family of loss functions, $a = 1$ ($b = 1$) implies risk neutrality with respect to deflation (excess inflation), risk-seeking behavior is implied by values less than unity, and risk-averse behavior follows from values greater than unity.

Formally, let L be the lower bound and U the upper bound for which the loss is zero whenever inflation falls between L and U. With π denoting inflation, the downside risk is measured as the expected loss of deflation given that inflation is below the threshold L times the probability that this event occurs,

$$DR(L, a) = -\mathrm{E}[(L - \pi)^a | \pi < L] \cdot \Pr[\pi < L],$$

while the upside risk is measured as the expected loss of excess inflation given that inflation is above the threshold U times the probability that this event occurs,

$$UR(U, b) = \mathrm{E}[(\pi - U)^b | \pi > U] \cdot \Pr[\pi > U].$$

With the adopted convention of defining downside risks as a negative number and upside risks as a positive number, the overall expected loss is given by

$$\mathrm{E}[Loss(L, U, a, b)] = -\omega \, DR(L, a) + (1 - \omega) \, UR(U, b),$$

where the parameter ω is the weight on downside risks relative to upside risks in the underlying loss function.

Yet as pointed out by Kilian and Manganelli (2007), in a discussion of risks it seems natural to focus on the distribution of the upside and downside risks, as opposed to the overall extent of the risks. Recognizing that the underlying loss function establishes a link between the optimal level of inflation from the policymaker's point of view and the distribution of risks, Kilian and Manganelli show that to this effect a measure of the *balance of risks* can be obtained under optimality arguments as a weighted average of the first derivatives of the quantified upside and downside risks with respect to inflation,[15]

$$RB(L, U, a, b) = \omega \, a \, DR(L, a - 1) + (1 - \omega) \, b \, UR(U, b - 1).$$

[15] Kilian and Manganelli (2007) argue that changes in the balance-of-risk measure should trigger a policy response. In this paper, we focus on the use of the risk balance as a means of evaluating the evolution of risks to price stability ex post and do not pursue this idea further. See also the discussion in footnote 7.

Accordingly, the balance of risks may remain unchanged even though both downside and upside risks are assessed as having risen.[16]

In the following, the computation of all balance-of-risk measures will be based on the assumption that the weight ω given to losses from deflation relative to losses from excess inflation is equal to 0.5 (as was assumed in the construction of the graphs in figure 2).[17]

3.2 Benchmark Results

The first column of table 3 shows the evolution of the balance of deflation and excess inflation risks for the forecast vintages from December 2008 to December 2011 assuming a quadratic loss function ($a = b = 2$).[18] This balance-of-risk measure, normalized by its steady-state value, will serve as our benchmark measure and is equal to the probability-weighted sum of the mean of deflation and the mean of excess inflation conditional on the events that annual inflation has been either below zero ($L = 0$) or above 2 percent ($U = 2$) for at least four consecutive quarters; see the second and the fourth column in the table. A value of zero therefore implies that upside and downside risks are balanced relative to the steady state, while negative (positive) values imply that downside (upside) risks dominate. Accordingly, our benchmark risk-balance measure suggests that downside risks were markedly greater than upside risks for the March and June 2009 forecast vintages, followed by a gradual rebalancing of these risks until summer 2011. Thereafter the risk balance turned negative again on account of the worsening of the euro-area sovereign debt crisis.

[16]Notice that the risk-balance measure is only defined for risk aversion on the part of the policymaker, i.e., when $a, b > 1$.

[17]The parameters of the loss function can in principle be estimated; see Kilian and Manganelli (2008). If the loss function were to be augmented with an output-gap term, estimation of the loss function parameters would make it possible to evaluate the assumption of quadratic and symmetric preferences typically underlying Taylor-type monetary policy rules, and would allow us to obtain further insights into the consistency of using the policy rule of the NAWM with the risk-management approach advocated by Kilian and Manganelli (2007, 2008). This is, however, beyond the scope of our paper.

[18]For an earlier application of balance-of-risk measures based on a quadratic loss function, see Smets and Wouters (2004), who study the forecasting properties of a DSGE model for the euro area.

Table 3. The Balance of Risks to Price Stability and Additional Risk Measures

	Risk Balance $[L = 0; U = 2; a = 2; b = 2]$	Deflation Risk		Excess Inflation Risk	
		Mean	Variance	Mean	Variance
December 2008	−0.7	−1.7	2.9	3.1	0.7
March 2009	−1.6	−2.5	6.4	3.3	0.7
June 2009	−1.5	−1.9	3.7	3.2	0.6
September 2009	−1.3	−1.8	2.9	3.2	0.7
December 2009	−1.2	−1.9	2.7	3.0	0.6
March 2010	−1.3	−2.2	4.0	3.2	0.7
June 2010	−1.3	−2.6	5.5	3.2	0.6
September 2010	−1.0	−2.4	3.9	3.1	0.6
December 2010	−0.7	−1.9	2.7	3.0	0.6
March 2011	−0.2	−1.8	2.3	3.2	0.7
June 2011	0.0	−1.9	2.8	3.2	0.6
September 2011	−0.7	−2.4	4.2	3.1	0.5
December 2011	−0.7	−2.3	3.8	3.1	0.5
Steady State	0.0	−1.0	0.5	3.2	0.7

Notes: This table shows the evolution of the balance of risks to price stability and of related risk measures over the period from December 2008 to December 2011. The risk balance is calculated from the predictive distribution of annual inflation as the probability-weighted mean of deflation and excess inflation, conditional on the respective deflation and excess inflation event, and expressed as the percentage deviation from its steady-state value. The upper and lower bounds defining the deflation and excess inflation events (L and U) are zero and 2 percent, respectively. The degrees of risk aversion assumed to quantify the deflation and excess inflation risks (a and b) are equal to 2, corresponding to a quadratic loss function on the part of the policymaker. The steady-state means and variances are calculated from the predictive distribution of annual inflation initialized at the model's steady state, conditional on the event of interest, and expressed as averages over the different lengths of the forecast horizons within a calendar year.

The bottom row in table 3 provides the values of the deflation and excess inflation means based on the NAWM's predictive distribution for inflation initialized in the model's steady state. The steady-state deflation mean of −1 percent is higher than the average mean of −2 percent that is obtained for the predictive distributions of inflation associated with the thirteen forecast vintages from December 2008 to December 2011. By contrast, the average excess inflation mean remains close to the steady-state value of 3.2 percent. Consequently, the steady-state risk balance is higher than the risk-balance measures for the individual forecast vintages, as reflected in the negative values of the normalized risk-balance measure in the first column of the table.

The evolution of the risk-balance measure in table 3 displays a pattern which is similar to the pattern of the deflation and excess inflation probabilities in table 1. This reflects the fact that the time profile of the risk balance is primarily determined by the time profiles for the deflation and excess inflation probabilities. In particular, while the deflation mean falls from –1.7 percent for the December 2008 forecast vintage to, on average, around –2 percent for the forecast vintages in 2009, the deflation probability increases from around 4 percent to above 12.5 percent on average. Furthermore, while the deflation probability diminishes from the September 2009 forecast vintage onwards, until the renewed deterioration in the second half of 2011, the deflation mean remains relatively stable over this period, with some further, albeit temporary, declines in summer 2010 and autumn 2011 because of a stronger downward skew of the predictive distributions for inflation on account of the heightened lower-bound incidence over these periods. This pattern contrasts with the finding that the excess inflation mean stays fairly constant over all forecast vintages.

The third and the fifth columns in table 3 show the variances of deflation and excess inflation, conditional on the respective deflation and excess inflation events. These variances form the basis for alternative measures of the risk balance that assume higher degrees of risk aversion with respect to deflation and excess inflation events. We turn to such measures in the next section. Here we note that the time profile of the deflation variance resembles closely the time profile of the deflation mean, with elevated levels assumed in early 2009, mid-2010, and late 2011. The fluctuations in the excess inflation variance are less pronounced, like for the excess inflation mean.

3.3 Sensitivity Analysis

The benchmark risk-balance measure which is used to determine the values reported in table 3 relies on particular upper and lower bounds defining the deflation and excess inflation events ($L = 0$, $U = 2$). Moreover, the benchmark measure is based on particular values for the parameters that represent the degrees of risk aversion used to quantify the upside and downside risks to price stability ($a = b = 2$). To study its robustness to changes in these parameters, five alternative risk-balance measures have been considered.

The findings from this sensitivity analysis are summarized in table 4. First, the risk-balance measure is recomputed under the assumption that the bound defining a deflation event is increased from zero to 1 percent ($L = 1$), possibly reflecting some margin that accounts for a bias in inflation measurement, while the bound for excess inflation remains at 2 percent. The results are reported in the panel of the table titled "Higher Deflation Bound."[19] Second, the bound defining an excess inflation event is increased from 2 percent to 3 percent ($U = 3$), while the deflation bound remains unchanged at zero. The corresponding panel is labeled "Higher Inflation Bound" and may manifest the view that the welfare costs of high inflation start to materialize only at levels substantially above 2 percent. Third, the "Higher Deflation Aversion" panel reflects a higher aversion to downside risks ($a = 3$), while the aversion to upside risks remains equal to the benchmark case. Fourth, for the panel labeled "Higher Inflation Aversion," the aversion to upside risks is increased ($b = 3$), whereas the aversion to downside risks remains unchanged. The latter two cases with higher deflation and higher inflation aversion, respectively, are based on the bounds from the benchmark case, i.e., with a deflation bound of zero and an excess inflation bound of 2 percent. Finally, the panel titled "Symmetric Bounds Around 1.9 Percent" assumes inflation preferences which are centered on the model's steady-state inflation rate of 1.9 percent, consistent with the

[19] Another reason for a higher deflation bound is the possibility that the risks associated with deflation may materialize already at positive values for average inflation in a fragmented monetary union, where adverse deflationary feedback loops occur at the level of a small group of member countries.

Table 4. The Sensitivity of the Balance of Risks to Price Stability

	Benchmark [$L = 0; U = 2; a = 2; b = 2$]	**Higher Deflation Bound [$L = 1; U = 2; a = 2; b = 2$]**	**Higher Inflation Bound [$L = 0; U = 3; a = 2; b = 2$]**
December 2008	−0.7	−1.2	−1.9
March 2009	−1.6	−3.3	−5.9
June 2009	−1.5	−3.1	−5.3
September 2009	−1.3	−2.8	−4.5
December 2009	−1.2	−2.6	−4.1
March 2010	−1.3	−2.6	−4.3
June 2010	−1.3	−2.4	−4.9
September 2010	−1.0	−1.8	−3.7
December 2010	−0.7	−1.3	−2.5
March 2011	−0.2	−0.3	−0.9
June 2011	0.0	−0.1	−0.6
September 2011	−0.7	−1.4	−3.2
December 2011	−0.7	−1.3	−3.2
	Higher Deflation Aversion [$L = 0; U = 2; a = 3; b = 2$]	**Higher Inflation Aversion [$L = 0; U = 2; a = 2; b = 3$]**	**Symmetric Bounds around 1.9 Percent [$L = -0.1; U = 3.9; a = 2; b = 2$]**
December 2008	−1.8	−0.5	−0.1
March 2009	−9.2	−0.9	−0.3
June 2009	−5.9	−1.0	−0.3
September 2009	−4.4	−0.9	−0.2
December 2009	−3.6	−0.9	−0.2
March 2010	−5.3	−0.8	−0.2
June 2010	−6.7	−0.8	−0.2
September 2010	−4.0	−0.6	−0.2
December 2010	−2.1	−0.5	−0.1
March 2011	−0.9	−0.1	−0.1
June 2011	−0.8	0.1	−0.0
September 2011	−3.8	−0.5	−0.2
December 2011	−3.3	−0.5	−0.1

Notes: See table 3. The benchmark case is computed from a deflation bound (L) of zero and an excess inflation bound (U) of 2 percent, with deflation and inflation aversion parameters (a and b) equal to 2. When the deflation (excess inflation) bound is higher, it is equal to 1 percent (3 percent). The cases with higher deflation or inflation aversion are based on increasing the respective aversion parameter from 2 to 3. The balance-of-risk measures are normalized and expressed as percentage deviation from the respective steady-state value, except for the balance-of-risk measure in the case with symmetric bounds around the model's steady-state inflation rate of 1.9 percent, for which the steady-state risk balance is virtually zero.

ECB's quantitative definition of price stability. In this case, the preferences are assumed to be quadratic ($a = b = 2$), with the lower and upper bounds equal to -0.1 percent and 3.9 percent, respectively.

Overall, the changes in the parameters of the risk-balance measure do not qualitatively change the time-series pattern of the balance of deflation and excess inflation risks. In particular, treating each measure as an index, all indices confirm that deflation risks were most sizable for the March and June 2009 forecast vintages and that excess inflation risks have thereafter become gradually more important before receding again in late 2011. The only measure that deviates from this finding concerns the case where the degree of deflation aversion is increased. For the March and June 2010 vintages, this risk-balance measure temporarily decreases further, reflecting a large increase in the deflation variance relative to the December 2009 vintage; see the third column in table 3. The growing deflation variance is, like the decline in the deflation mean, closely linked to the development of the lower-bound incidence which increases from 17.7 percent in the December 2009 vintage to, respectively, 19.1 percent and 24.7 percent in the March and June 2010 vintages; see the far right column in table 1.

4. Risks to Price Stability and Forward Guidance

Once interest rates are approaching their lower bound, different non-standard monetary policy measures can be implemented. Amongst these non-standard measures, *forward guidance* regarding the path of future short-term nominal interest rates amounts to a commitment on the part of the monetary policymaker to keep nominal interest rates low for longer to ensure a faster return of the economy to macroeconomic stability. The theoretical underpinnings of forward guidance are well understood: It revolves around the idea of influencing the private sector's interest rate and inflation expectations in an attempt to provide additional stimulus to the economy through lower expected future real interest rates.[20]

Typically, studies have analyzed the effects of forward guidance once short-term nominal interest rates have reached the zero lower

[20]See, among others, Eggertsson and Woodford (2003), Adam and Billi (2006), Nakov (2008), Walsh (2009), and Woodford (2012).

bound following a sequence of recessionary shocks and often in a deterministic setting.[21] Here, we again employ stochastic simulations using the NAWM to illustrate that the anticipation of the provision of forward guidance in the future can already be conducive to mitigating risks to price stability even though the interest rate has not yet fully reached the zero lower bound. This is arguably the situation in the euro area over our evaluation period. The potency of the mere *possibility* of forward guidance reflects the fact that private-sector expectations incorporate the knowledge that the scope for *future* cuts in nominal interest rates is limited once they are close to zero, without having necessarily reached the zero lower bound today.

4.1 Time-Based Forward Guidance

Table 5 provides an illustration of the possible effects of providing forward guidance concerning the path of future short-term nominal interest rates against the background of the economic conditions that prevailed in December 2011.[22] First, we recall as a point of reference the results of the NAWM-based real-time assessment of risks to price stability. When comparing the deflation and excess inflation risks for this forecast vintage with those obtained from the model's steady-state distribution, it can be seen that the deflation risk exceeds the steady-state value by about 5 percentage points, while the excess inflation risk stays below the steady-state value to a somewhat smaller extent. The (benchmark) risk-balance measure is tilted to the downside and stands at −0.7.

An important factor in explaining the negative risk balance is the heightened value of the lower-bound incidence which amounts to 29.0 percent, compared with 0.3 percent for the model's steady-state distribution. This record-high value of the lower-bound incidence reflects the historically low level of short-term nominal interest rates

[21] For a discussion of possible limitations on the effectiveness of forward guidance following severe recessions, see Levin et al. (2010).

[22] While the ECB had refrained from providing forward guidance during the period evaluated in this paper, it implemented a number of other non-standard measures; see footnote 3. In our analysis we do not explicitly consider those measures, or anticipations thereof, but rather assume that they are reflected in the baseline forecast path around which we conduct the model-based simulations.

Table 5. Gauging Risks to Price Stability under a Time-Based Conditional Commitment to Keep Nominal Interest Rates Low for Longer, December 2011

	Risks to Price Stability			
	Deflation	**Excess Inflation**	**Risk Balance**	**Lower-Bound Incidence**
December 2011	6.8	24.6	−0.7	29.0
Interest Rate Kept at Lower Bound for:				
One Additional Quarter	6.1	25.0	−0.6	28.9
Two Additional Quarters	3.4	27.1	−0.3	28.3
Three Additional Quarters	0.1	41.2	0.9	26.2
Steady State	1.5	28.7	0.0	0.3

Notes: The time-based conditional commitment foresees to keep the short-term nominal interest rate at the lower bound for a certain number of additional quarters, over and above the number of quarters in the absence of the conditional commitment, whenever the interest rate is constrained by the lower bound. The latter is imposed at an interest rate level of 60 basis points, reflecting the average spread between the Euribor and the Eonia over the horizon of the December 2011 forecast vintage. See tables 1 and 3 for details on the measures reported in the table.

that markets expected to prevail over the horizon of the December 2011 forecast vintage. It implies that monetary policy is likely to be increasingly often constrained in its ability to offset any further recessionary and deflationary shocks that may occur over the forecast horizon by adjusting its standard interest rate instrument.

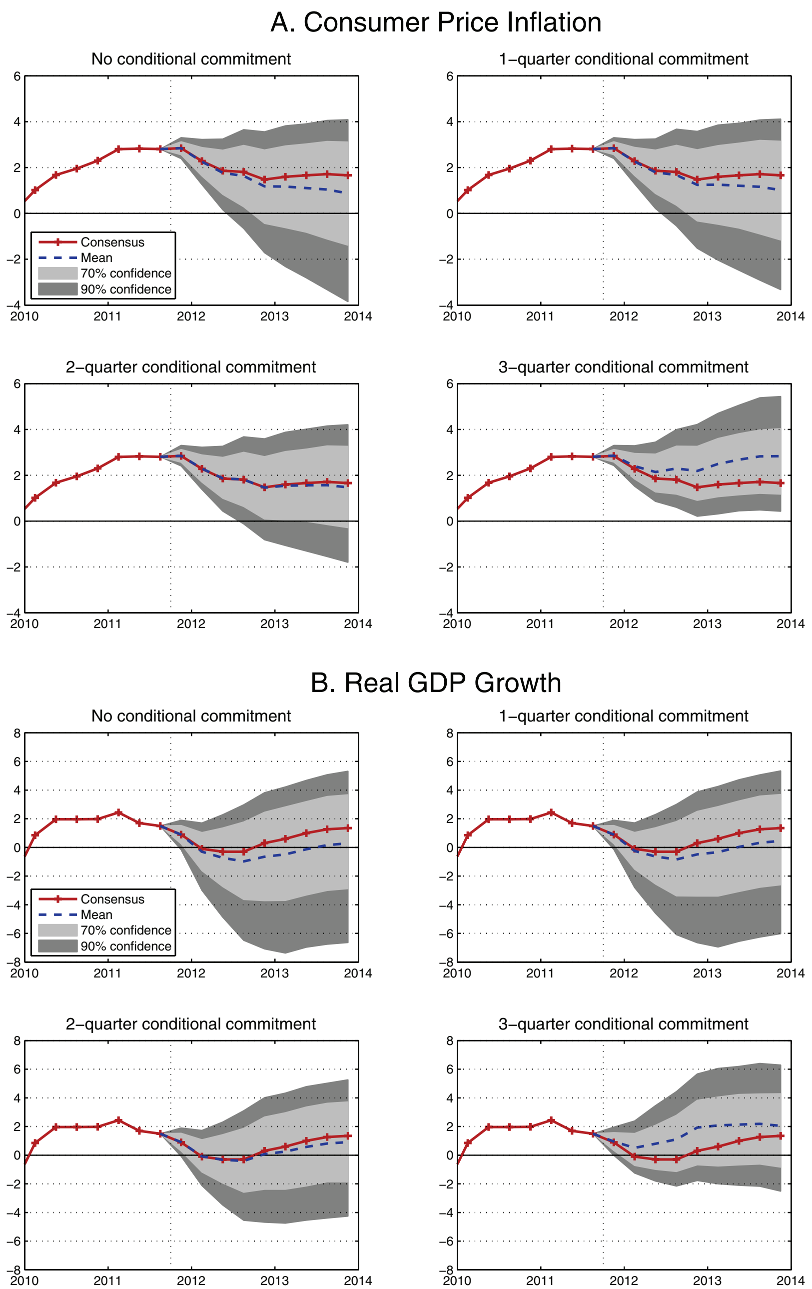
In the stochastic simulations underlying the results in table 5, forward guidance is implemented as a *conditional commitment* by the monetary policymaker to keep the short-term nominal interest rate low for longer than prescribed by the NAWM's estimated policy rule in situations where the interest rate is constrained by the zero lower bound. Specifically, the conditional commitment is *time based* and foresees to keep the short-term nominal interest rate at the lower bound for a certain number of additional quarters, over and above the number of quarters for which the interest rate is constrained in the absence of the conditional commitment, whenever the lower-bound constraint is binding. This commitment is revisited each quarter upon the arrival of new shocks.[23]

As shown in table 5, incrementally increasing the number of additional quarters over which the interest rate is expected to remain at the lower bound—from the reference case with no commitment to the cases with a one- and a two-quarter conditional commitment—succeeds in tilting the risk balance upwards to –0.6 and –0.3, respectively. Interestingly, if the commitment is extended further to three quarters, the risk balance turns positive by a sizable amount. In particular, lengthening the duration of the commitment beyond two quarters has such a strong impact on the economy that inflationary pressures emerge, with the probability of excess inflation exceeding 40 percent. This value is significantly higher than the steady-state probability of around 29 percent. Notice that for all three cases of the time-based conditional commitment, the incidence of the short-term interest rate hitting the lower bound turns out to be somewhat lower ex post.

Figure 3 shows the mean and the 70 percent and 90 percent confidence bands of the NAWM-based predictive distributions of consumer price inflation and real GDP growth for the December 2011 forecast vintage, both for the reference case with no conditional commitment and for the three cases with the one-, two-, and three-quarter conditional commitment. In the case with no conditional commitment, the distributions are markedly skewed to the downside from the middle of 2012 onwards. Accordingly, their means depart from the baseline paths and lie increasingly below the latter over the outer years of the forecast horizon. As already anticipated above, this is due to the fact that the reaction of monetary policy

[23] On the whole, the proposed conditional commitment to keep the interest rate low for a certain number of additional quarters seems easier to implement in practice than a proposal by Reifschneider and Williams (2000), which features a conditional commitment to undo the (unobservable) *interest rate gap* corresponding to the cumulated shortfall of the notional interest rate prescribed by an interest rate rule without having imposed the lower-bound constraint from the interest rate which respects the constraint.

Figure 3. Predictive Distributions for Consumer Price Inflation and Real GDP Growth under a Time-Based Conditional Commitment, December 2011



Note: See figure 1 and table 5.

to new recessionary and deflationary shocks over the forecast horizon is more and more often constrained by the zero lower bound. By contrast, in the cases with the one-, two-, and three-quarter conditional commitment, the distributions for consumer price inflation and real GDP growth are progressively shifted upward, with their means broadly aligned with the baseline forecast under the two-quarter commitment and increasingly exceeding the baseline under the three-quarter commitment. As regards the predictive distribution for the short-term nominal interest rate, the differences between the no-commitment case and the one-, two-, and three-quarter commitment cases are hardly discernible, and therefore the respective distributions are not displayed.

Table 6 reports the mean effects of making a conditional commitment to keep the interest rate low for longer. They are computed as the deviation from the mean of the predictive distributions for the December 2011 baseline forecast with no commitment. It can be seen that the effect of the conditional commitment to keep the interest rate at the lower bound for longer is increasing non-linearly with the duration of the commitment. For example, the incremental effect of lengthening the duration of the commitment from two to three quarters on the mean of inflation in 2013 amounts to 1.2 percentage points, compared with a 0.4-percentage-point effect of extending the commitment from one to two quarters.[24] The key factor behind this result is the acceleration in the buildup of (excess) inflation expectations, measured here by the model-based forecast of the annualized average inflation rate two years ahead. By contrast, nominal interest rate expectations, computed on the basis of a term-structure relationship extending two years into the future, are virtually unaffected. The reason is that current as well as expected future short-term interest rates are endogenous variables which adjust to the improved outlook, including for inflation, that results from the provision of forward guidance. In equilibrium, the endogenous adjustment of interest rates offsets, on average, the ex ante

[24]Relevant to this finding, Carlstrom, Fuerst, and Paustian (2012) show that in prototype New Keynesian models, pegging the short-term nominal interest rate—tantamount to credibly announcing that it will remain at the zero lower bound for longer—can result in responses of macroeconomic variables that are surprisingly large if the horizon of the peg is extended beyond a few quarters.

Table 6. Assessing the Mean Effects of a Time-Based Conditional Commitment to Keep Nominal Interest Rates Low for Longer, December 2011

	Consumer Price Inflation			Real GDP Growth		
	2011	**2012**	**2013**	**2011**	**2012**	**2013**
Interest Rate Kept at Lower Bound for:						
One Additional Quarter	0.0	0.0	0.1	0.0	0.1	0.2
Two Additional Quarters	0.0	0.1	0.5	0.0	0.5	0.7
Three Additional Quarters	0.0	0.5	1.7	0.0	1.7	2.1

	Two-Year Nominal Interest Rate			Two-Year Inflation Expectations		
	2011	**2012**	**2013**	**2011**	**2012**	**2013**
Interest Rate Kept at Lower Bound for:						
One Additional Quarter	−0.0	−0.0	−0.0	0.0	0.1	0.1
Two Additional Quarters	−0.0	−0.0	−0.0	0.0	0.2	0.4
Three Additional Quarters	−0.0	−0.0	0.0	0.0	0.9	1.4

Notes: See table 5. The mean effects represent the deviations from the means of the distributions for the December 2011 forecast vintage, expressed in percentage points.

effect from the conditional commitment to keep interest rates low for longer.[25] In fact, with an improved outlook there may actually

[25]By contrast, using deterministic simulations with an estimated medium-size New Keynesian model like the NAWM, Del Negro, Giannoni, and Patterson (2012) explain the extreme sensitivity of the simulation outcomes to keeping the

be shorter spells with the interest rate being at the lower bound, or even fewer instances where the policymaker needs to commit to keep interest rates at the lower bound for longer.[26] This is consistent with the observation that the lower-bound incidence under the conditional commitment moderately falls and that the shape of the predictive distribution of the short-term interest rate is hardly affected.

4.2 Time-cum-Threshold-Based Forward Guidance

The above findings suggest that, for practical policymaking purposes, it will be important to carefully calibrate the length of the horizon over which forward guidance is provided. Indeed, if mechanically applied, forward guidance in the form of a purely time-based commitment to keep interest rates low over an extended horizon may—through its impact on inflation expectations—create higher inflationary momentum than desired, eventually leading to upside risk to price stability over the medium term.

By way of illustration, table 7 shows the results of model-based stochastic simulations that have been designed so as to prevent the materialization of such upside risk. Specifically, in these simulations the pure time-based conditional commitment is augmented with a threshold condition of 2 percent for the average two-year-ahead inflation forecast generated by the model in each quarter. This *time-cum-threshold-based* conditional commitment foresees to keep the short-term nominal interest rate at the lower bound for a certain number of additional quarters, over and above the number of quarters in the absence of the conditional commitment, whenever the interest rate is constrained by the lower bound *and* the current inflation forecast does not exceed the threshold value of

short-term nominal interest rate at the lower bound for longer by the model's tendency to predict an excessive response of the *long-term* nominal interest rate, compared to what has been measured in the data following, e.g., statements on forward guidance by the Federal Reserve's Federal Open Market Committee. In a deterministic setting, this feature is also observed for the NAWM.

[26]For the cases with the one-, two-, and three-quarter conditional commitment, the expected average length of the zero-lower-bound spells—including the number of additional quarters over which the interest rate is expected to remain at the lower bound—equals 5.2, 6.2, and 6.8 quarters, respectively.

Table 7. Gauging Risks to Price Stability under a Time-cum-Threshold-Based Conditional Commitment to Keep Nominal Interest Rates Low for Longer, December 2011

	Risks to Price Stability			
	Deflation	**Excess Inflation**	**Risk Balance**	**Lower-Bound Incidence**
December 2011	6.8	24.6	−0.7	29.0
Interest Rate Kept at Lower Bound for Maximum Period of:				
One Additional Quarter	6.2	24.9	−0.6	28.9
Two Additional Quarters	3.6	26.8	−0.3	28.4
Three Additional Quarters	1.1	31.0	−0.0	28.0
Steady State	1.5	28.7	0.0	0.3

Notes: The time-cum-threshold-based conditional commitment foresees to keep the short-term nominal interest rate at the lower bound for a certain number of additional quarters, over and above the number of quarters in the absence of the conditional commitment, whenever the interest rate is constrained by the lower bound and the threshold of 2 percent for the annualized average two-year-ahead inflation forecast is not exceeded. In case the threshold value is exceeded, the number of additional quarters over which the interest rate is kept at the lower bound is successively reduced until the threshold is met. The lower bound is imposed at an interest rate level of 60 basis points, reflecting the average spread between the Euribor and the Eonia over the horizon of the December 2011 forecast vintage. See tables 1 and 3 for details on the measures reported in the table.

2 percent. In case the inflation threshold is crossed, the number of additional quarters over which the interest rate is kept at the lower bound is successively reduced until the threshold condition is met.

Whereas the results under the threshold-augmented conditional commitment in table 7 do not differ materially from the results under the pure time-based conditional commitment in table 5 when the interest rate remains at the lower bound for one or two additional quarters, the results change significantly for the three-quarter conditional commitment case. For the time-cum-threshold-based commitment, the increase in the (excess) inflation risk is now contained and exceeds its steady-state value of around 29 percent by merely a small amount, whereas the deflation risk is significantly reduced, even slightly below the steady-state value of about 1.5 percent.[27] The risk balance turns out to be virtually zero.[28]

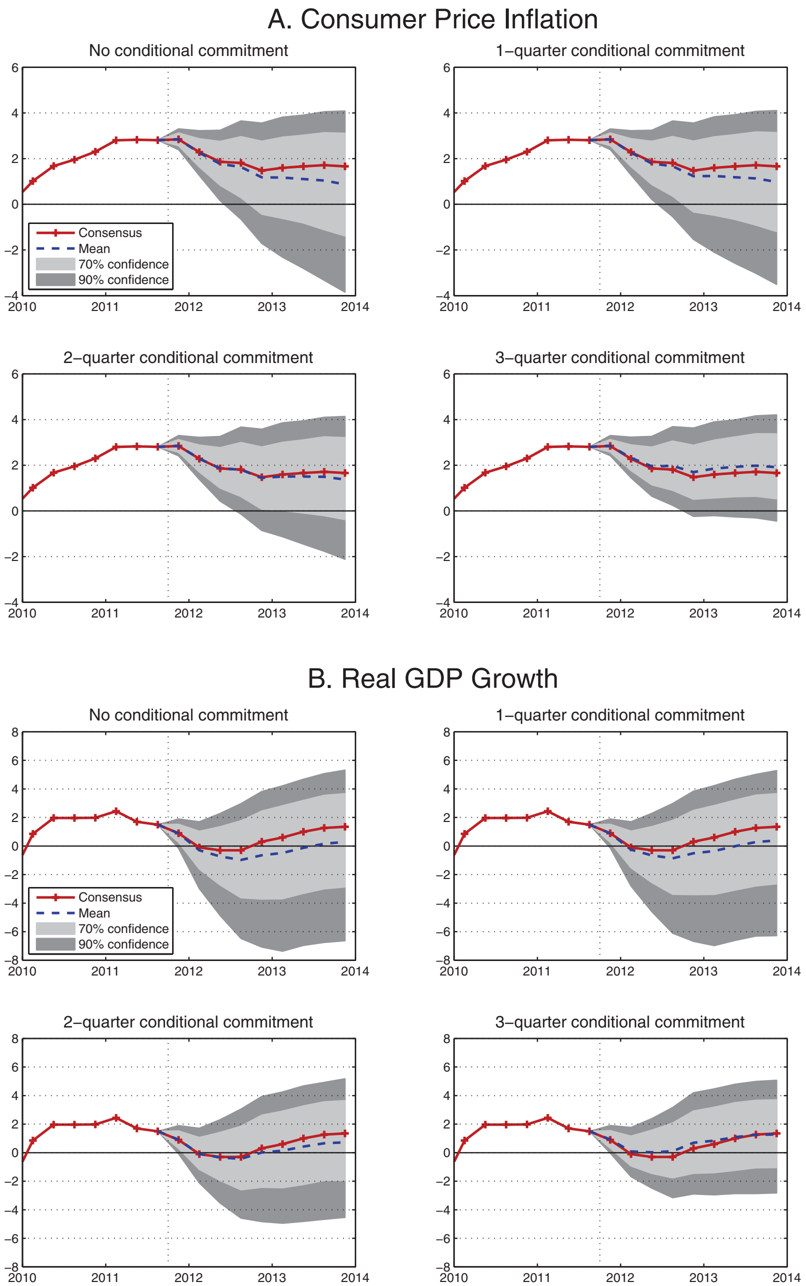
These striking findings are also evident from the shape of the predictive distributions for consumer price inflation under the two types of conditional commitment, which are depicted in the upper panels of figure 3 and figure 4, respectively. In particular, for the three-quarter conditional commitment cum threshold, the mean of the distribution lies just slightly above the Consensus baseline, with the sizable upward bias under the pure time-based commitment having virtually disappeared. This in turn reflects a much more benign impact on medium-term inflation expectations.

All in all, our analysis of the effectiveness of forward guidance shows that imparting additional monetary stimulus through forward guidance in a situation where short-term nominal interest rates have reached or are close to the zero lower bound affects the entire distribution of macroeconomic outcomes. Indeed, according to our analysis, a conditional commitment to keep short-term nominal interests low for longer not only offsets the effects of the lower-bound constraint on the mean outcomes for inflation and real GDP growth, but it also comes close to restoring symmetry in the distribution of outcomes—in particular, if it is complemented with a threshold

[27]For the three-quarter commitment case, out of the total number of instances where the lower-bound constraint is binding and the monetary policymaker considers providing forward guidance, the horizon of the commitment to keep the interest rate at the lower bound is reduced to two quarters in 31.7 percent of all instances, and to one quarter in 1.6 percent of all instances. In 0.6 percent of the instances no forward guidance is offered. For the two- and one-quarter commitment cases, the fraction of instances with reduced commitment horizon is disproportionately smaller.

[28]The risk balance does not turn positive, as the mean of the deflation event is still more negative than for the steady-state distribution.

Figure 4. Predictive Distributions for Consumer Price Inflation and Real GDP Growth under a Time-cum-Threshold-Based Conditional Commitment, December 2011



Note: See figure 1 and table 7.

condition concerning tolerable future inflation which helps to contain the impact on medium-term inflation expectations.

5. Summary and Conclusions

In this paper, we have studied the evolution of the risks to price stability in the euro area during the recent financial crisis. To this end, we have employed model-based stochastic simulations to characterize the profound uncertainties and risks that surrounded the outlook for inflation in the euro area in real time. A formal measure of the balance of risks, which is based on policymakers' preferences about inflation outcomes and takes the severity of the prevailing risks into account, suggests that downside risks to price stability were considerably greater than upside risks during the first half of 2009. After a drawn-out rebalancing of risks, the risk balance started to turn negative again in the second half of 2011 due to the reintensification of the crisis on account of elevated tensions in euro-area sovereign debt markets. Our analysis demonstrates that the lower bound on nominal interest rates has induced a noticeable downward bias in the risk balance throughout the crisis period because of the implied amplification of deflation risks.

While our analysis of the evolution of risks to price stability offers a narrative of the consequences of the financial crisis for the euro-area inflation outlook in real time, the employed methodology of stochastic simulations has also been used to illustrate the effects of counterfactual policy measures. In particular, we have examined the effectiveness of providing forward guidance concerning the path of future short-term nominal interest rates as a means of delivering additional stimulus in a situation where nominal interest rates are close to zero and where downside risks to price stability prevail. We show that a time-based form of forward guidance, which foresees to keep the interest rate at the zero lower bound for a certain number of additional quarters, imparts the intended stimulus and is successful in reducing the prevailing downside risks. Yet if extended too far into the future, it may, through its impact on inflation expectations, give rise to upside risks to price stability over the medium term. We demonstrate that complementing the time-based variant of forward guidance with a threshold condition concerning tolerable future inflation developments can provide insurance against the materialization of such upside risks.

We conclude by arguing that the model-based measure of the balance of risks to price stability studied in this paper is a valuable tool for characterizing the general uncertainties and risks surrounding any given baseline forecast, over and above the use of model-based scenario analyses that highlight the consequences of specific shocks and events over the forecast horizon. Moreover, to the extent that the balance-of-risk measure is derived from the preferences of policymakers that are concerned about inflation outcomes, it establishes a link between desirable levels of inflation from the policymakers' point of view and the balance of upside and downside risks to price stability. Accordingly, the risk measure itself may serve as a guidepost for policymaking, including in situations where short-term nominal interest rates are close to the zero lower bound.

Appendix 1. The New Area-Wide Model

The New Area-Wide Model (NAWM) is a microfounded open-economy model of the euro area designed for use in the ECB/Eurosystem staff projections and for policy analysis; see Christoffel, Coenen, and Warne (2008) for a detailed description. The development of the model has been guided by a principal consideration, namely to provide a comprehensive set of core projection variables, including a number of foreign variables, which, in the form of exogenous assumptions, play an important role in the staff projections. As a consequence, the size of the NAWM—compared with the well-known Smets and Wouters (2007) model—is rather large, and it is estimated on eighteen macroeconomic time series.

The NAWM features four classes of economic agents: households, firms, a fiscal authority, and a monetary authority. Households make optimal choices regarding their purchases of consumption and investment goods, the latter determining the economy-wide capital stock. They supply differentiated labor services in monopolistically competitive markets, they set wages as a markup over the marginal rate of substitution between consumption and leisure, and they trade in domestic and foreign bonds.

As regards firms, the NAWM distinguishes between domestic producers of tradable intermediate goods and domestic producers of three types of non-tradable final goods: a private consumption good, a private investment good, and a public consumption good. The intermediate goods firms use labor and capital services as inputs to produce differentiated goods, which are sold in monopolistically competitive markets domestically and abroad. Accordingly, they set different prices for domestic and foreign markets as a markup over their marginal costs. The final goods firms combine domestic and foreign intermediate goods in different proportions, acting as price takers in fully competitive markets. The foreign intermediate goods are imported from producers abroad, who set their prices in euros in monopolistically competitive markets, allowing for an incomplete exchange rate pass-through. A foreign retail firm in turn combines the exported domestic intermediate goods, where aggregate export demand depends on total foreign demand.

Both households and firms face nominal and real frictions, which have been identified as important in generating empirically plausible dynamics. Real frictions are introduced via external habit formation in consumption, through generalized adjustment costs in investment, imports, and exports, and through fixed cost in intermediate goods production. Nominal frictions arise from staggered price and wage setting à la Calvo (1983), along with (partial) dynamic indexation of price and wage contracts. In addition, there exist financial frictions in the form of domestic and external risk premia that enter the model as exogenous shocks. The domestic risk premium is interpretable as a financial intermediation premium.[29]

The fiscal authority purchases the public consumption good, issues domestic bonds, and levies different types of distortionary taxes. Nevertheless, Ricardian equivalence holds because of the simplifying assumption that the fiscal authority's budget is balanced

[29]The historical decomposition of the NAWM's observed variables into its structural shocks reveals that the domestic risk premium shock is amongst the most important shocks explaining the sharp drop in real GDP at the onset of the financial crisis. Moreover, the domestic risk premium shock is found to broadly capture the adverse economic consequences of the sovereign debt crisis in the years 2010 and 2011 that resulted in a surge in sovereign yields and private-sector financing costs.

each period by means of lump-sum taxes. The monetary authority sets the short-term nominal interest rate according to a simple log-linear rule,

$$\widehat{r}_t = \phi_R \widehat{r}_{t-1} + (1-\phi_R)\phi_\Pi \widehat{\pi}_{C,t-1} + \phi_{\Delta\Pi}\left(\widehat{\pi}_{C,t} - \widehat{\pi}_{C,t-1}\right) \\ + \phi_{\Delta Y}\left(\widehat{y}_t - \widehat{y}_{t-1}\right) + \widehat{\eta}_t^R,$$

where $\widehat{r}_t$ is the logarithmic deviation of the (gross) nominal interest rate from its steady-state value. Similarly, $\widehat{\pi}_{C,t}$ denotes the logarithmic deviation of (gross) quarter-on-quarter consumer price inflation $\Pi_{C,t}$ from the monetary authority's inflation objective $\bar{\Pi}$, while $\widehat{y}_t$ is the logarithmic deviation of aggregate output from the trend output level. $\widehat{\eta}_t^R$ is a serially uncorrelated shock to the nominal interest rate.

Finally, the NAWM is closed by a rest-of-the-world block, which is represented by an SVAR model determining a small set of foreign variables: foreign demand, foreign prices, the foreign interest rate, foreign competitors' export prices, and the price of oil. The SVAR model does not feature spillovers from the euro area, in line with the treatment of the foreign variables as exogenous assumptions in the staff projections.

The NAWM has been estimated with Bayesian methods and using time series for eighteen macroeconomic variables which feature prominently in the projections: real GDP, private consumption, total investment, government consumption, extra-euro-area exports and imports, the GDP deflator, the consumption deflator, the extra-euro-area import deflator, total employment, nominal wages per head, the short-term nominal interest rate, the nominal effective exchange rate, foreign demand, foreign prices, the foreign interest rate, competitors' export prices, and the price of oil. The estimation sample period ranges from 1985:Q1 to 2006:Q4 (using the period 1980:Q2 to 1984:Q4 as training sample). The estimation involves obtaining the posterior distribution of the model's parameters based on its state-space representation using the Kalman filter.[30]

[30] For the estimation of the NAWM, we have used YADA, a MATLAB program for Bayesian estimation and evaluation of DSGE models; see Warne (2013).

Appendix 2. Construction of Baseline Forecasts

The baseline forecast vintages are dated December 2008 until December 2011. They have been constructed by combining the quarterly Area-Wide Model (AWM) database maintained at the ECB with the quarterly Consensus Forecasts (CF) vintages released by Consensus Economics. The AWM database is updated annually with a cut-off date for a new update in early August each year. Each annual update contains euro-area data up to Q4 for the previous year. The CF vintages are updated quarterly.

The historical data for the constructed quarterly forecast vintages are all based on the AWM database updates. Therefore they only reflect annual revisions. The historical data in the CF vintages from September and December of a given year contain data for Q3 and Q4 of real GDP, real private consumption, and consumer prices for the previous year. Since these data are more recent than the AWM data available at the same point in time, the CF data are used in the September and December forecast vintages. For all CF vintages, further historical data and forecasts are provided for these variables up to a total of twelve quarters. This means that the September and December vintages have such data from Q3 of the previous year until Q2 two years ahead; e.g., for the December 2008 CF vintage the forecast data cover the sample 2008:Q3–2010:Q2. For the March and June vintages, the CF data cover Q1 for the previous year until Q4 for the next year.

The first quarter of the ECB/Eurosystem staff projections is given by the projection/vintage date (e.g., 2008:Q4 for the December 2008 projection exercise), while the final quarter of the projections is always Q4 two years ahead.[31] This means that there are twelve projection quarters for the March vintage, eleven for the June vintage, ten for the September vintage, and nine for the December vintage. The forecast vintages in this paper use the same horizon as the staff

[31] Even though the staff prepares quarterly projections until Q4 two years ahead, the ECB only publishes, in the form of ranges, annual projections of a restricted set of variables for the current year and one year ahead, except for the publication of the December projection exercises, which cover two-year-ahead projections.

projections. Compared with the end date for the ECB staff projections, this means that the March and June CF vintages have missing data in the last four quarters of the forecast sample, while the September and December vintages have missing data in the last two quarters of the forecast sample.

Furthermore, the AWM database series for the short-term nominal interest rate (corresponding to the Euribor) has been extended to the end of the forecast horizon by applying the methodology used by ECB/Eurosystem staff, with market expectations derived from futures rates (see, e.g., ECB 2012) and using a cut-off date aligned with the survey date of the CF vintage. The Eonia forecasts have likewise been calculated using a similar methodology based on swap rates.

For real GDP and real private consumption, quarterly growth rates are provided in the CF vintages and these rates have been applied to the levels data from the AWM database to obtain CF-consistent levels data for these two variables. The missing data for real GDP and private consumption have been estimated by applying an ARIMA(0,1,1) model with a constant to the log-levels of these variables. For consumer prices, the CF vintages provide only annual growth rates. These annual rates have been applied to the HICP variable of the AWM database. The resulting HICP series is likewise extended using an ARIMA(0,4,1,) model with a constant for the log-levels and accounting for seasonality. The resulting growth rates have been applied to extend the series for the private consumption deflator over the historical and the forecast sample.

For the remaining variables of the NAWM, there are historical data for each forecast vintage until the end of the year prior to the vintage date for the September and the December vintages, and until the end of two years prior to the vintage date for the March and June vintages. For example, for the December 2009 vintage, there are AWM data on wages until 2008:Q4. This means that there are missing data for the historical sample (up to 2009:Q3). Rather than treating these data points as missing in the assessments of risks to price stability, the missing data are replaced with estimates via the Kalman smoother based on the state-space representation of the NAWM and using only the historical sample of the forecast vintage.

Appendix 3. Solution and Simulation Methods

In preparation for the stochastic simulations, we first computed for each baseline forecast vintage the structural shocks and the state variables of the NAWM for the historical sample extended with the baseline forecast. Since the non-negativity constraint for nominal interest rates was never binding in the extended sample, we obtained the structural shocks and states by solving the NAWM for its reduced form using the AIM implementation (Anderson and Moore 1985 and Anderson 1987) of the Blanchard and Kahn (1980) method for solving linear rational expectations models and by applying the Kalman filter to its (log-)linear state-space representation.

Based on the population covariance matrix of the structural shocks and the conditional covariance matrix of the states at the origin of the baseline forecast horizon, we then generated for each forecast vintage 5,000 sequences of artificial normally distributed shocks with a sample length corresponding to the baseline forecast horizon and 5,000 realizations of the states.[32] We added the sequences of the artificial shocks (except for the shocks to the NAWM's interest rate rule, which we set to zero) to the sequence of shocks computed over the baseline forecast horizon and used the resulting sequences of shocks to conduct stochastic simulations, while imposing the zero-lower-bound constraint on nominal interest rates.[33] If it were not for this non-linearity, we could use the linear state-space representation of the NAWM to compute the predictive distributions of the

[32]That is, we restrict our analysis to a fixed set of parameters, namely the posterior mode estimates of the NAWM's structural parameters. Accounting for parameter uncertainty by drawing from the posterior distribution of the structural parameters would have been computationally too burdensome.

[33]To ensure stability of the model in the presence of the zero-lower-bound constraint, fiscal policy is assumed to boost aggregate demand to rescue the economy from falling into a deflationary spiral, if deflation becomes so severe that the lower bound restricts the real interest rate at a level high enough to induce a growing aggregate demand imbalance. An alternative approach to ensuring stability is to concentrate on other channels of the monetary transmission mechanism that may continue to operate even when the interest rate channel is ineffective. For example, Orphanides and Wieland (2000) concentrate on the aggressive expansion of the monetary base during episodes of zero interest rates to exploit direct quantity effects such as a portfolio-balance effect.

endogenous variables of interest without having to resort to stochastic simulations.

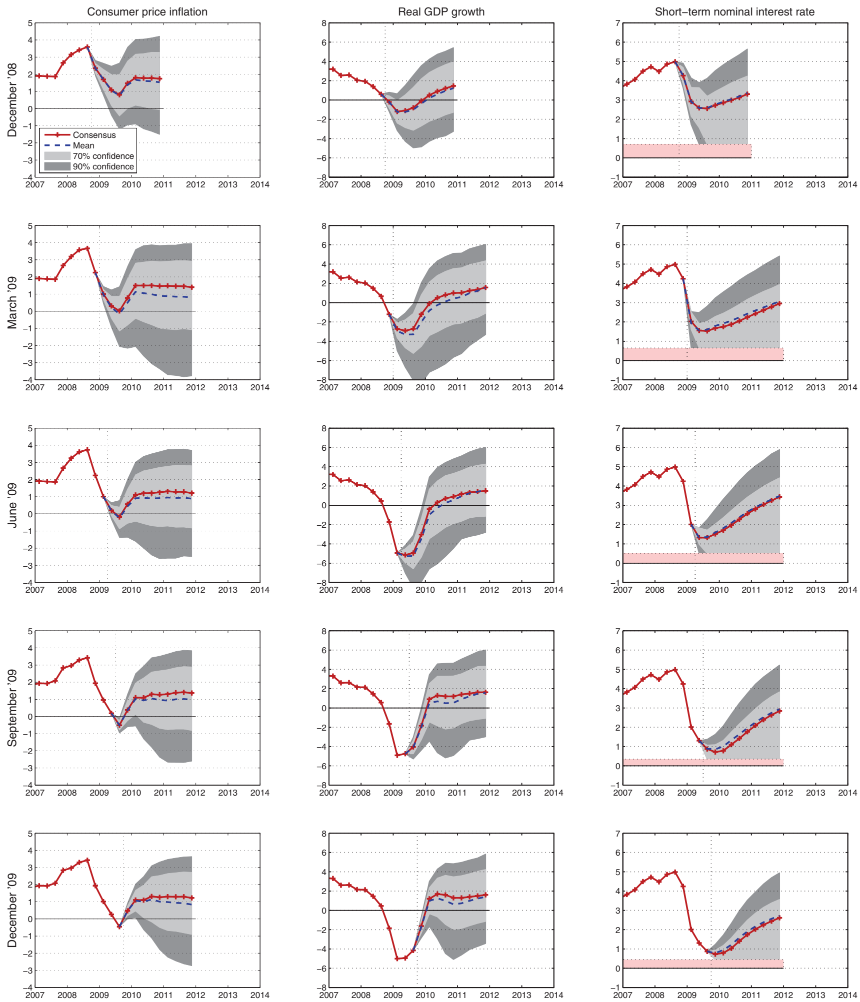
We simulate the non-linear model using a computationally efficient algorithm which is implemented in TROLL and based on work by Laffargue (1990), Juillard (1994), and Boucekkine (1995).[34] It is related to the Fair and Taylor (1983) extended-path algorithm. In the simulations, the lower-bound constraint also applies to the expectations of future interest rates. A limitation of the algorithm is that the expectations of economic agents are computed under the counterfactual assumption that *certainty equivalence* holds in the non-linear model being simulated. This means, when solving for the dynamic path of the endogenous variables from a given period onwards, the algorithm sets future shocks equal to their expected value of zero. Thus the variance of future shocks has no bearing on the formation of expectations and, hence, on current conditions. This would be correct in a linear model. However, once we introduce the zero lower bound on nominal interest rates into the model, the variance of future shocks introduces a small bias in the average levels of various variables, including interest rates. To be clear, we should emphasize that the variance of shocks has both a direct and an indirect effect on the results. The direct effect is that a greater variance of shocks implies that the zero lower bound on nominal interest rates binds with greater frequency; the indirect effect is that all agents should be taking this effect of the variance into account when they form their expectations. The simulation algorithm captures the direct effect but not the indirect one.

There are other solution algorithms for non-linear rational expectations models that do not impose certainty equivalence. But these alternative algorithms would be prohibitively costly to use with the NAWM, which has more than eighty state variables. Even with the algorithm we are using, stochastic analysis of non-linear rational expectations models with a large number of state variables remains fairly costly in terms of computational effort.

[34] TROLL is an integrated econometric modeling and time-series management tool used by many central banks and international organizations.

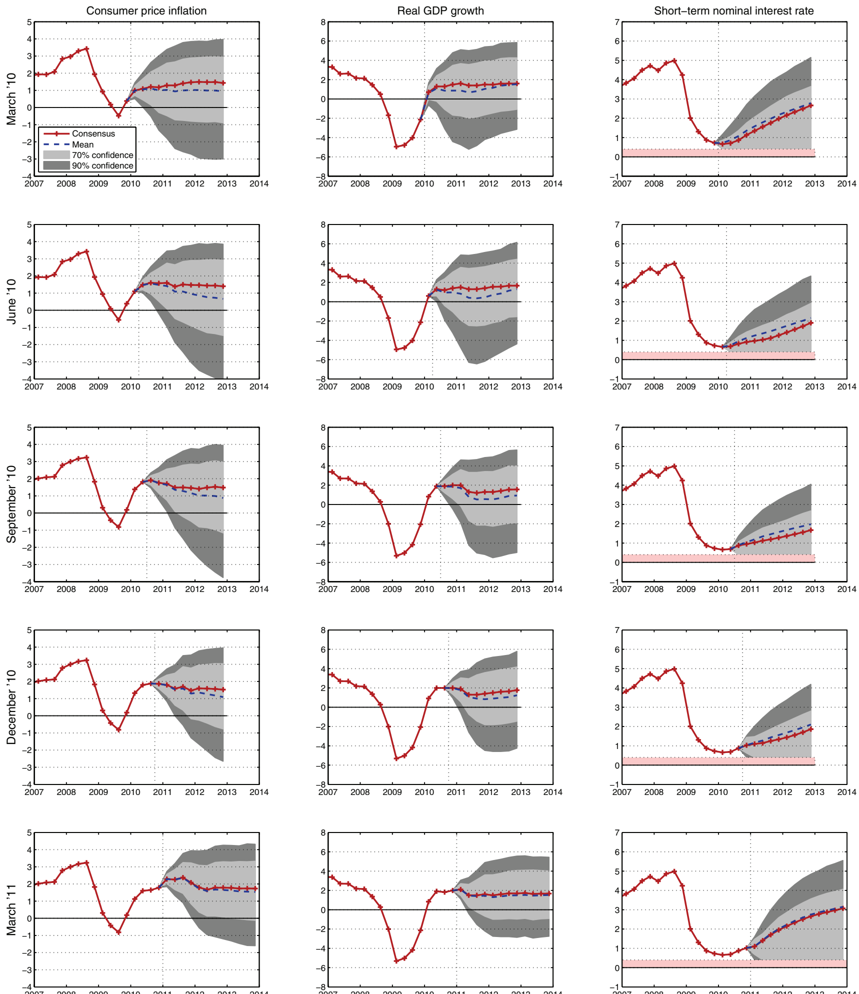
Appendix 4. Additional Results

Figure 5. Predictive Distributions for Consumer Price Inflation, Real GDP Growth, and the Short-Term Nominal Interest Rate, December 2008 to December 2011



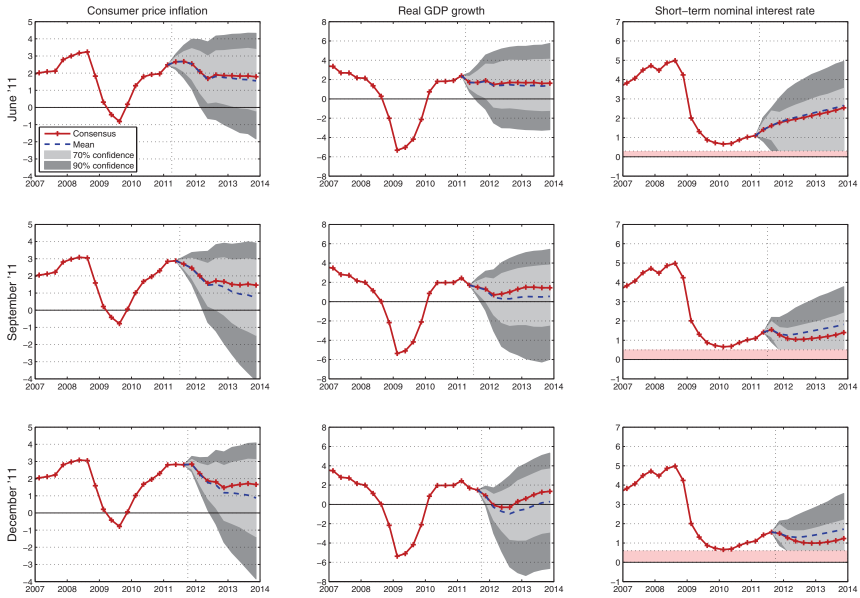
(continued)

Figure 5. (Continued)



(continued)

Figure 5. (Continued)



Notes: The predictive distributions are derived from stochastic simulations of the NAWM and are centered on the structural shocks that the model has identified for the respective Consensus forecast vintage. Consumer price inflation and real GDP growth are expressed in annual terms. The short-term nominal interest rate corresponds to the annualized three-month Euribor. The lower bound is imposed at interest rate levels between 30 and 70 basis points, reflecting the average spread between the Euribor and the Eonia over the horizon of the respective forecast vintage.

Table 8. Gauging Risks to Price Stability and the Lower-Bound Incidence over a Uniform Nine-Quarter Horizon

	Risks to Price Stability		
	Deflation	Excess Inflation	Lower-Bound Incidence
December 2008	4.4	15.3	6.0
March 2009	12.5	8.0	17.4
June 2009	14.8	7.6	12.2
September 2009	11.7	8.9	17.5
December 2009	9.2	9.3	17.7
March 2010	8.9	10.1	21.7
June 2010	7.9	14.8	26.0
September 2010	6.7	18.7	22.6
December 2010	5.6	19.8	19.0
March 2011	2.5	32.9	8.3
June 2011	2.3	35.1	9.0
September 2011	5.7	24.5	25.2
December 2011	6.8	24.6	29.0
Steady State	1.1	28.3	0.2

Notes: See table 1. The steady-state values are calculated from the predictive distributions for annual inflation and the short-term nominal interest rate initialized at the model's steady state and evaluated over a nine-quarter horizon.

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