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Deflationary vs. Inflationary Expectations – A New-Keynesian Perspective with Heterogeneous Agents and Monetary Believes

by

Felix Geiger and Oliver Sauter

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Universität Hohenheim, 70593 Stuttgart

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Deflationary vs. Inflationary Expectations - A New-Keynesian Perspective with Heterogeneous Agents and Monetary Believes

Felix Geiger* Oliver Sauter†

University of Hohenheim University of Hohenheim

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Abstract

We expand a standard New-Keynesian model by allowing for a special role of money in the inflation and expectations building process. Motivated by the two-pillar Phillips curve, we introduce heterogeneous expectations. Thereby a fraction of agents forms inflation expectations by observing trend money growth. We show that in the presence of these monetary believers, contractive shocks to the economy produce smoother dynamics for inflation and output. We also find that monetary policy should follow a conventional Taylor rule with contemporaneous inflation and output data, if it is uncertain about the fraction of monetary believers.

Keywords: New-Keynesian model, monetary policy, two-pillar Phillips curve, heterogenous expectations, monetary believes.

JEL classification: E31, E41, E47, E52.

*Department of Economics, esp. Economic Policy. Email: geigerf@uni-hohenheim.de

†Department of Economics, esp. Economic Policy. Email: oliver.sauter@uni-hohenheim.de

1 Introduction

Within the last months there has been a lively discussion about the consequences of the recent turmoil on financial markets. Especially since the Lehman Brothers bankruptcy in August 2008 central banks around the world serve the market with almost as much liquidity as possible. Additional government spending has been injected into the financial system as well as in other industries. Despite this, the slowdown of the economy in real terms seems to be non stoppable, leading to declining output and rising unemployment rates. The US have experienced a drop in real GDP of nearly 5% turning highly negative this year. A development which is unique during the last decades.

This rather bad outlook gives rise to alerting statements by noble prize winner Paul Krugman about deflationary risks. To him, it could be the beginning of a vicious debt-deflation cycle à la Fisher, typically starting with falling collateral values, de-levering balance sheets on an economy-wide level and falling wages (Krugman, 2009). Against this background, there is a sensible argument that this worst-case scenario is unlikely to happen due to the widely applied instruments of national monetary authorities in order to stabilize the economy (Mishkin, 2009). Even with close-to-zero interest rates, central banks can use traditional open-market operations both to provide liquidity and to affect the various set of interest rates and risk premia on financial markets. This is exactly how the major institutions across the globe proceed in recent months in order to minimize the likelihood of deflation (Gerlach, 2009).

The counterpart of such operations in central banks' balance sheets is a massive blow-up of monetary figures, in particular base money and monetary aggregates consisting of near-monetary assets. For that reason, some authors already see the opposite of deflation for the medium-term future. An upcoming surge of inflation is predicted for example by Allan Meltzer (2009). In a NY Times article, he is concerned about the rather weak independence of the Federal Reserve System compared to earlier decades which could lead to an inflationary development in the light of the extraordinary amount of money held by market participants for liquidity-preference motives. If the central banks are not willing to withdraw these funds in times of a rebounding economy, global liquidity may flood goods and financial markets. The result could manifest itself in soaring prices on an aggregated level.

On the set of this twofold point of departure, where on the one hand deflationary expectations arising from the ruinous real data, and on the other hand inflationary expectations are immanent due to massive liquidity provisions, different expectations on the inflation outlook may give rise to two main inflation groups - deflation pessimists and inflation hawks. In this setting, we can evaluate how macroeconomic dynamics may alter. In particular, we can ask what is the exact role of heterogeneous expectations during the adjustment horizon when the economy is hit by a shock. The literature on heterogeneous expectations comes to the result that the outcome in terms of stability and dynamics depends on how these expectations are modeled. Branch and McGough (2009) find that the solution of the economy's law of motion is indeterminate when allowing for some degree of extrapolative expectations.

The modern monetary-policy process can be described as 'inflation forecast targeting' meaning to set the policy instrument such that the forecast of the target is in line with the desired central bank target. Such a strategy gives rise to two main interest-rate reaction function specifications, i.e. (i) a conventional Taylor rule according to which the central bank reacts to current inflation and (ii) a forward-looking version in which monetary policy responds to expected inflation. The implementation of one of the two rules depends on selected criteria about model views and monetary policy strategies as well as the degree of backward-looking and forward-looking behaviour of the private sector and the commitment or discretionary policy on part of the monetary authority (Svensson, 1997; Svensson and Woodford, 2005; Leitemo, 2008). In an environment of disagreement about the inflation outlook, a relevant policy issue emerges; how should a central bank deal with these heterogeneous expectations if it knows about their existence?

On a modeling level, inflation beliefs derived form monetary data must find consideration in the working of our economy. For this purpose, we set up a New-Keynesian model with heterogeneous agents differing in their perception and expectations about future price developments. The model is designed to allow for a special role of money in the New-Keynesian framework. We address monetary expectations in terms of agents which we call 'co-integration observers'. They form inflation expectations by observing the past money growth trend. A hybrid character of the model is added since we also introduce rational agents into the core equations who understand the model and know the structural parameters to make consistent forecasts of the state variables.

According to our model, we find that monetary beliefs *help* to stabilize macroeconomic dynamics. If the economy is hit by an aggregate demand shock and/or an interest rate shock, the dynamics back to the steady state are smoother and less severe than in the benchmark case with fully rational private sector expectations. This is in particular true if deflationary pressure is produced by contractive shocks. However, a fully accommodated money demand shock is translated into higher temporary trend money growth which induces *both* rational agents and co-integration observers to increase inflation expectations. This happens because monetary believers either do not know that the evolution of the money supply is endogenous to the state of the economy or they do not trust the monetary authority to let the money supply shrink as soon as the money demand shock evaporates. Being faced with heterogeneous expectations, monetary policy operates best under a conventional Taylor reaction function with contemporaneous inflation and output data rather than in a forward-looking manner. The results are robust to varying fractions of co-integration observers.

The paper is structured as follows: Chapter 2 presents common concepts of inflation forecasts. We show that dispersion measures of individual forecasts give support to the view that market participants are split into two camps, deflation-pessimists and inflation-hawks; this holds independently of the data source we work with. Chapter 3 derives the basic model set-up of the New-Keynesian model with heterogeneous agents. Although there are many ways of expanding the basic model to give money an explicit role in the transmission process, we follow the approach of modelling heterogeneous agents. Afterwards, the model is calibrated within an empirical New-Keynesian specification and both standard and forward-looking policy rules are evaluated. Chapter 4 concludes.

2 Dispersion of forecasts

During the last months, we have seen a dip in global economic figures hitting even negative values in world GDP growth. Not enough, many economic indicators and business sentiment surveys still signal warning evidence of a continuing economic slowdown. Against this background, the dip has been accomplished by falling prices for major industrialized countries, in particular in the US and the euro zone. Facing this development, voices have been raised comparing recent developments with the Great Depression of the 1930s and the fear of deflation (see for instance Eichengreen, 2009). Although the link between depression and deflation is not stable[1], financial market commentators and economists are concerned that this may be the beginning of the classical debt-deflation cycle in the spirit of Fisher (1933). This situation is characterized by cleaning balance sheets on part of financial and non-financial institutions and is followed by distressed selling and falling prices causing a greater fall of net worth (Fisher, 1933). Such a period keeps the economy down and may end in a dangerous vicious cycle (Krugman, 2009). What seems to be unanimous is a temporary decline in prices, especially for food and oil. This has been already observed in recent months. But only an economy-wide fall in the price level can be interpreted as *deflation*. This could be the case, if future expectations are characterized by falling prices for a sufficient long period of time with increasing real debt burdens for households, firms and government due to soaring real interest rates (Gerlach, 2009; Meltzer, 2009). As can be read from the Minutes of the FOMC, the deflationary scenario is the top agenda for practical policy making (FOMC, 2009).

[1] An empirical analysis about the links between deflation and depression has been undertaken by Atkeson and Kehoe (2004)

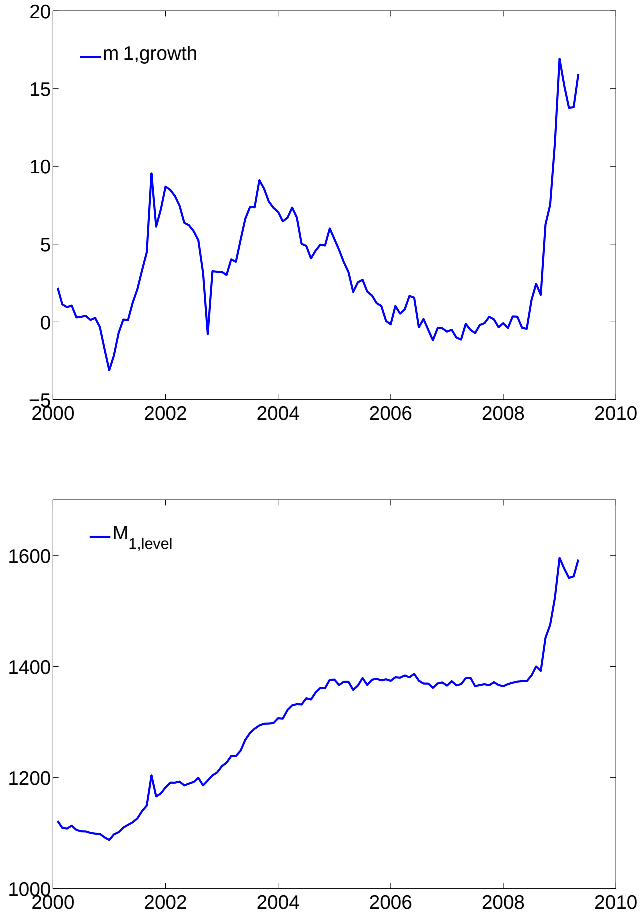
On the other hand, Allan Meltzer (2009) is not only convinced by a non-deflationary environment, but rather a highly inflationary process in the medium run, arising from expansionary policy of the monetary system, especially the Federal Reserve System. Central banks around the world fight the disastrous financial crisis by providing liquidity on an extensive scale. They have been operating under a massive easing of monetary policy in terms of low interest rates as well as quantitative measures in the aftermath of the financial turmoil. Monetary authorities have been heavily engaged in expanding their balance sheets by means of new operating instruments in order to provide enough credit lines to stimulate the dry money market and to promote medium- and long-term credit granting. The balance sheet reflex can be documented in a ballooning rise of monetary figures, especially of monetary aggregates like M1. Since the new operating instruments have a maturity structure that does not allow to quickly withdraw excess reserves on part of financial institution, it might be at least questionable to what extend central banks can reduce the amount of money in the economy as soon as the economy is rebounding. To Meltzer, there is a time consistency mismatch since central banks are mostly concerned in fighting the economic depression rather than considering the medium-term side effects of their policies. Moreover, he doubts the commitment of the administration and the autonomy of the FED as it has sacrificed its independence and has become the "monetary arm of the Treasury."

In Figure (1) the basic message of the 'inflation hawks' can be summarized: in the US, the monetary aggregate M1 has accelerated tremendously beginning in the third quarter 2008. If a correlation between money growth an inflation can be presumed, especially in the long run, inflationary tendencies seem to be appropriate.[2]

Hence, the situation for central banks is twofold: on the one hand, massive liquidity injections into the economy fuel expectations of soaring price developments and on the other hand, the ongoing drop in real economic indicators give rise to a low inflationary

[2] A brief literature overview about the connection of money (growth) and inflation and the information content of money can be found for instance in Berger et al. (2008).

Figure 1: US M1 Growth and Level



Source: FED FRED II

and even deflationary environment. Central banks exactly need to deal with these two sorts of expectations. Managing expectations seems to be the most important task for monetary policy these days.[3]

Assuming a Phillips-curve relation with current inflation partly determined by inflation expectations, the kind of expectations formation is critical for the current inflation outcome. If agents make their expectations mainly dependent from past inflation rates, expectations move together with realized inflation and a deflationary spiral becomes possible as falling prices are reinforcing. Williams (2009) calls this set-up an *unanchored*

[3] See for an excellent review of the role of expectations for the conduct of monetary policy ECB (2009)

Phillips-curve model.[4] At an early stage of the recession, the emergence of a slack induces inflation to fall which at the same time brings about declining inflation expectations on part of market participants. In contrast, if expectations in this terminology are *well anchored* even in a severe recession, inflation expectations remain positive due to the trust in the monetary authority in achieving their communicated inflation target.

To give a clearer picture on current inflation outlooks, there are various ways to obtain measures for private sector's inflation expectations. Either information can be extracted indirectly from asset prices or survey data allow for a direct observation (ECB, 2004). Both concepts enable to get mean/average expectations of inflation. The recent dynamics of inflation expectations derived from a comparison of nominal bonds and inflation-indexed bonds account for both appraisals where deflationary pressure has been reflected mainly until February 2009. Recently, nominal bond yields are picking up catering for rising inflation expectations.[5]

In what follows we focus on surveys conducted for the US and the euro zone, i.e. the *Survey of Professional Forecasters* for the US (henceforth SPFUS) and the *Survey of Professional Forecasters* for the euro zone (henceforth SPFEU), respectively.[6] They give a more complete view for two reasons: First they do not suffer from measurement errors that are immanent in asset prices due to various term premia concepts and second disaggregated survey data allow to display the degree of *dispersion* among market partic-

[4] Here, the term 'unanchored' does not reflect the question whether a state variable is predetermined or forward-looking.

[5] It is for that reason why the FED has decided to buy long-term US treasuries to keep bond yields down. Usually, a steep yield curve precedes a period of decent growth since short-term interest rates decline. However, the recent widening of the spread is triggered by rising long-term yields due to (i) higher inflation expectations and (ii) an increased Treasury issuance to finance the government budget deficit. Though the spread is at record levels, the current environment worsen incentives to lend long which is a big challenge for the FED to keep mortgage rates low. Moreover, the control over long-term bond yields may weaken if inflation expectations are partly determined endogenously. This holds in a situation in which market participants interpret the FED purchases of US treasuries as a 'printing-money' device. Then, open market operations work exactly in opposite direction to market dynamics and aggravate the problem.

[6] The complete SPFUS for mean and individual forecasts can be downloaded from www.phil.frb.org. The SPFEU is provided by the ECB and is available for mean data on their web page www.ecb.int. We thank the Survey of Professional Forecasters team for kindly providing us the individual data set; the latter is available on request directly from the ECB.

ipants about the inflation outlook. By analyzing the composition of the mean forecasts, we may find evidence in favor of heterogeneous expectations, i.e. the presence of deflation pessimists and inflation hawks. For this purpose, we express the heterogeneity in terms of standard deviation and maximum-minimum forecasts.

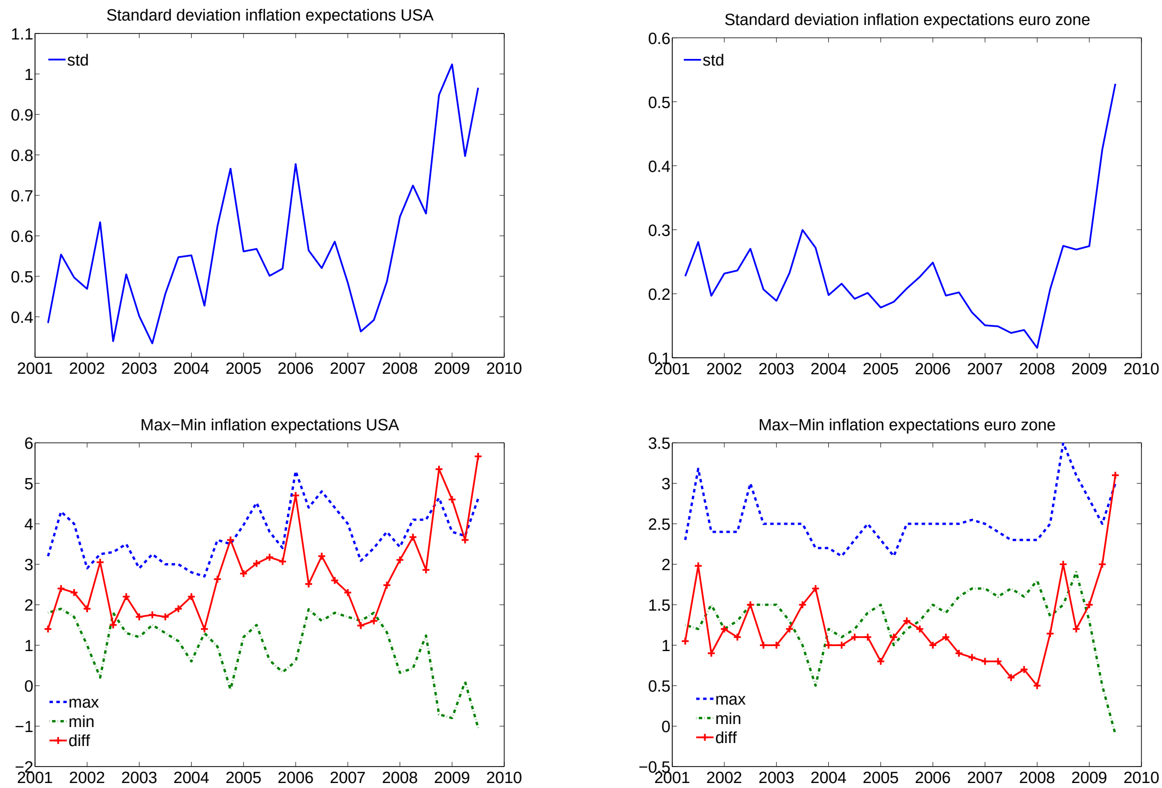
Figure (2) plots the measures for US and euro area quarterly forecasts of average annualized inflation over the next year.[7] Looking at the upper left and right graphics of the panel, the standard deviation of individual forecasts shows a clear upward trend, beginning for the USA in the second quarter of 2007 and for the euro area in the first quarter 2008. For both currency regions, the dispersion measure nearly doubled as the financial crisis in 2007/08 sent its first waves on financial markets. The values look even more dramatic compared to their lows in 2007 and respectively 2008. This clearly speaks in favor of a high amount of uncertainty and disagreement concerning future inflation. If we compare the one-year ahead dispersion measures for both countries, the standard deviation in the US is always higher than in the euro area since 2000 and the recent peak in the US also exceeds the value for the euro area. Beechey et al. (2008) come to similar results when analyzing disagreement on long-term inflation expectations. They find that long-run inflation expectations are not as firmly anchored in the US as in the euro area.

In order to grasp the idea of deflation pessimists and inflation hawks, we look at the point forecasts of the respondents in more detail. The lower left and right figures of the panel display the maximum and minimum forecasts among the survey participants. They confirm the findings of the standard deviation analysis. During the last quarters the rise in the spread between the max/min forecasts is evident. Whilst the maximum forecasts do not outperform the upper ceiling of previous projections, the minimum forecasts are on a historical low, never been observed during the last decade. At the same time, some observes even forecast negative inflation rates for the coming year. This holds for both the US and the euro area. Our analysis of inflation surveys for the US and the euro area

[7] For technical notes on the number of survey participants and details on questionnaires the reader might be referred to the source of the SPFUSA and SPFEU directly.

motivates to translate the findings into a theoretical model that allows for heterogeneous expectations on part of market participants.

Figure 2: Standard Deviation and Max/Min Forecasts



Notes: Own calculations based on ECB data and Philadelphia FED data.

3 Review of Theoretical Literature

There is an ongoing highly theoretical debate about the role of money in monetary theory and policy. At the center of monetary models with no explicit role for money is the New-Keynesian benchmark model that has become the 'workhorse' for academics. It is a modified, somehow micro-founded IS-LM representation of private sector's behavior that can be approximated by aggregate demand and supply. Due to advances in modeling techniques and estimation methods, they are as well increasingly applied by practitioners as professional forecasters. In particular many central banks apply them for their overall assessment of policy and economic outlook.[8] At the heart of these models, inflation is determined by the inflation target of the central bank and by current and expected future deviations of the equilibrium rate of interest and the intercept adjustment made to a central bank's reaction function (Woodford, 2008). The structural role of money in the more traditional IS-LM style models is apparently replaced in favor of an interest-rate reaction function to stabilize output and inflation.

It can be demonstrated that there are various ways to re-introduce money into the basic structure without changing its core mechanism. Indeed, the most simple way is to acknowledge that even in the underlying benchmark model, money is not absent at all. It relates real money demand to aggregate real expenditures and the opportunity cost of holding money. The money demand equation is superfluous from the perspective of explaining the dynamics of macro variables since a central bank that implements policy by means of an interest-rate reaction function fully commits to supply money in line with its operating procedures. Money evolves endogenously according to changes in money demand; trend money growth is still co-integrated with trend inflation, though there is no causal relationship running from money to prices (McCallum, 2008).

A causal and structural role for money in the economy can be obtained by including non-separability and financial frictions into the model set-up. Andres et al. (2004) and Ireland (2004) both build a model in which the utility function is not separable so that changes in the real quantity of money alter marginal utility of consumption. With non-separability, real money balances enter both the aggregate demand curve and the New-Keynesian Phillips curve. Evidence shows that the effects of money originating from separability are if anything rather small.

Recently, the New-Keynesian model has been augmented by a 'financial/banking sector' with the effect of adding further propagation mechanisms running from monetary policy to output and inflation. Within the bank-lending channel, money matters because loan supplies depend to a large degree on the bank's ability to draw deposits. The lat-

[8] See Smets and Wouters (2003), Christiano et al. (2006).

ter in turn is affected by the supply of money.[9] The financial accelerator has also an important role to play when central-bank induced interest-rate changes lead to rising or falling values of collaterals, thereby changing the external finance premium demanded by financial intermediaries to make loans. In this respect, a large body of literature is emerging to bridge this gap within in DSGE-models.[10] In particular, what these models actually do, is to introduce a banking sector that is exposed to credit frictions. This makes it possible not to work with one unique short-term interest rate but to determine a set of interest rates for various assets, loans as well as saving contracts. Depending on the model specification, spreads between these rates alter the transmission process in the economy.

A different starting point has been taken up by Gerlach (2004) and Assenmacher-Wesche and Gerlach (2006) to give money an explicit role in the conduct of monetary policy. The authors introduce money in a 'eclectic' way and decompose inflation into high- and low frequency components that are positively correlated with the output gap and (trend) money growth, respectively. Against this background, they justify the inclusion of money growth trend as a shift variable in a 'two-pillar' Phillips curve equation if money growth trend helps forecasting inflation in the medium run. Such existence of monetarist expectations can be hardly defended given the modern New Keynesian model set-up. This holds because a representative household and a representative firm form expectations about the future state variables in a homogeneous and rational - model consistent - way. Moreover, Woodford (2007) shows that the standard model approach is capable to produce the same long-run empirical link between money and inflation while rejecting the causality of money for inflation.

The difficulty of including monetarist expectations in such a standard monetary economy can be overcome by the introduction of heterogeneous expectations on part of agents.

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9 This argumentation demands that at least to some degree there is a quantity restriction to create bank deposits. reserve requirements or an explicit quantity tightening in the business cycle may play this role.

10 See Cúrdia and Woodford (2008); Goodfriend and McCallum (2007); Canzoneri et al. (2008).

The general idea of different expectations has been followed and pioneered by the adaptive learning literature. It has parted with the rationality dogma and has analyzed under what assumptions learning agents can consider temporary errors in their forecasts. The consequences of learning agents can be summarized as a state of imperfect knowledge about the reduced-form parameters of the model when forming expectations about the future. Evans and Honkapohja (2003, 2006) show that an expectations-based monetary policy is able to ensure that the economy has a unique stable equilibrium and that the equilibrium is learnable by agents. Still, the idea of homogeneous expectations and learning rules are immanent in modeling the economy (*structural homogeneity*).

Starting point for imbedding some degree of heterogeneity may be that the basic characteristics of learning differs across agents. Honkapohja and Mitra (2006) describe such an economy as *structural heterogeneous*. Agents use different recursive updating algorithms to forecast a common vector of aggregated variables, though information is symmetric between agents. Alternatively, we may explicitly allow for heterogeneous agents who posses different information sets across time. Carroll (2001) modifies the basic New-Keynesian Phillips curve in a way consistent with epidemiology inflation expectations. According to this idea, information generally diffuses slowly through the economy by the presence of different agents processing information. Mankiw et al. (2003) find empirical support in data on inflation expectations; they diverge on part of consumer and professional forecast survey. If so, heterogeneous expectation formation may lead to different results in terms of the dynamics of a monetary economy.

On theoretical grounds, Branch and McGough (2009) recently introduced heterogeneous agents into a New-Keynesian model. They develop aggregate demand and supply functions that are both derived from a micro-founded sticky price model whereas the model fulfils the restrictions of heterogeneous and possible boundedly rational expectations. This is achieved by applying a class of admissible boundedly expectations operators for the private agents derived from specific axioms. Among linearity and the law of iterated expectations, the latter includes restrictions so as to ensure analytic aggregation of individual first-order conditions for consumption and price-setting. Then, a proportion γ of agents forecast future variables using the expectations operator E^1 and the remaining agents use E^2. Conditional expectations in the usual IS-curve are replaced with the convex combination of the heterogeneous expectations operators.

In their paper, Branch and McGough (2009) focus on rational vs. simple adaptive expectations.[11] Accordingly, agents of type 1 make optimal forecasts in the form of rational expectations, and agents of type 2 are adaptive on the macro variables output and inflation. They find that the impact on indeterminacy of the proportion of adaptive learners is ambiguous. If type 2 agents form expectations in the conventional adaptive way, the regions of determinacy expands indicating a stabilizing force of non-rational expectations. If, however, only a small set of agents are trend-chasing via extrapolative expectations, they may destabilize the economy and force monetary policy to react on inflation expectations much more aggressively.

Putting monetary expectations into a Phillips curve as a shift variable comes from permitting heterogeneous market participants. A proportion of agents form expectations with the help of monetary figures because they see a regularity between money and inflation. That does not mean that they do regard the New-Keynesian standard model as not true. They rather rely on empirical regularities since they suffer from deep cognitive problems of the model limiting their capacity to understand and to process the complexity of their received information. They then rely on simple empirically-based forecasting rules rather than on the identification of structural parameters of the true model. This does not mean that these agents behave in an irrational way; it is just a 'rational' response to the complexity of the model (DeGrauwe, 2008). We call such agents 'co-integration believers'; they use an underparameterized forecasting equation to extract conditional expectations about inflation from observable variables.

[11] For a more general solution see Beradi (2009).

4 A NK-Model with co-integration observers

4.1 Model Set-up

Our strategy of modeling heterogeneous expectations follows closely the work of Branch and McGough (2009). We assume that there are two type of agents a_i with expectations denoted E^i indexed by $i = \{1, 2\}$ differing in their forecasting mechanism. Agent a_1 represents the rational agent who fully understands the structure of the underlying model to make reasonable forecasts for the state variables of the economy. The proportion of agent 1 to all agents is denoted as γ and expectations are denoted as E^1. We introduce a second kind of agent a_2 who uses a simple, heuristic rule to forecast future variables with the expectations operator E^2.

On an aggregated level, the heterogeneous expectations operator $\hat{E}$ is a linear combination of the two operators E^1 and E^2. It holds that

$$\hat{E} = \gamma E^1 + (1 - \gamma) E^2. \tag{1}$$

Branch and McGough (2009) impose necessary restrictions on the expectations operator to allow for representing aggregate supply and demand in the well-known log-linearized version. Especially they make the assumption that agents of type 1 expectations on the future expectations of agent 2 coincides with the expectations of agent 1. Thus, they rule out high-order beliefs.[12] Although agent 1 understands the basic logic of the underlying macro model, she is eager of considering the forecasting rule of agent 2. She knows that a proportion of agents form expectations of the form E^2 that will alter the dynamics of the law of motion.

Our economy is described by the 'workhorse' New-Keynesian model with standard aggregate demand and supply equations augmented by a monetary policy rule in the spirit of Taylor (1993), together with an endogenous money supply process. The state

[12] More formally it must hold that $E_t^1 E_{t+1}^2(x_{t+1}) = E_t^1(x_{t+1})$. This allows for the law of iterated expectations on an aggregated level.

variables are deviations from their respective steady-state values which are assumed to be zero. Since we try to capture at least some basic moments of U.S. data, we modify the core equations so as to present them on a quarterly basis. This allows us to produce 'realistic' quantitative dynamic properties of the state variables (Ellingsen and Söderström, 2004; Söderström et al., 2005).[13] The empirical New-Keynesian model can be captured by the following system of equations:

$$\pi_t = \mu_\pi \hat{E}_{t-1}\bar{\pi}_{t+3} + (1-\mu_\pi)\sum_{j=1}^{4}\alpha_\pi \pi_{t-j} + \kappa y_{t-1} + g_t \qquad (2)$$

$$y_t = \mu_y E_{t-1}y_{t+1} + (1-\mu_y)\sum_{j=1}^{2}\beta_{yj}y_{t-j} - \sigma\left(i_{t-1} - \hat{E}_{t-1}\bar{\pi}_{t+3}]\right) + u_t \qquad (3)$$

The New-Keynesian Phillips curve is an empirical version where $\bar{\pi}_t = 1/4\sum_{j=0}^{3}\pi_{t-j}$ is the average four-quarter inflation rate; quarterly inflation depends on expected and lagged inflation, the lagged output gap and a shock term g_t. Aggregate demand as well is driven by its own expectations and past realizations, the real ex-ante short-term interest rate and a demand shock u_t. The interest rate i_t is the quarterly annualized federal funds rate. The interest-rate reaction function, expressed as deviation from the steady-state interest rate, is in the spirit of Taylor (1993) where the central bank reacts to inflation and the output gap. As discussed later, we work with three versions of reaction functions, one in which the central bank responds to current inflation and output (MR 1), the second (MR 2) describes the 'expectations-based' rule according to which the central use its own optimal forecasts, and a third (MR 3) allows the central bank to react to private-sector's expectations. MR 3 differs from MR 2 in the choice of the inflation forecast. MR 2 embeds the optimal forecast based on the structural model of the central bank; whereas MR 3 considers private expectations formed as a combination of heterogeneous beliefs on the outlook of inflation. It also has the property to be a monetary targeting rule since heterogenous expectations imbed the money growth trend. A central bank following the

[13] The authors use the model to re-examine the key stylized facts of the model. Instead of using simple Taylor-style monetary policy rules, they work with an optimal discretionary monetary policy.

MR 3 rule, thus, targets trend money growth. To this end, monetary policy smoothes the evolution of interest rate dynamics.

$$\text{MR 1:} \quad i_t = \rho_i i_{t-1} + (1-\rho_i)(\tau_\pi \bar{\pi}_t + \tau_y y_t) + v_t \tag{4}$$

$$\text{MR 2:} \quad i_t = \rho_i i_{t-1} + (1-\rho_i)(\tau_\pi E_{t-1}[\bar{\pi}_{t+3}] + \tau_y E_t[y_{t+1}]) + v_t \tag{5}$$

$$\text{MR 3:} \quad i_t = \rho_i i_{t-1} + (1-\rho_i)(\tau_\pi \hat{E}_{t-1}[\bar{\pi}_{t+3}] + \tau_y E_t[y_{t+1}]) + v_t \tag{6}$$

The money demand equation relates real money holdings to output and the interest rate. It can be derived from a simple optimization problem of a household who values real money holdings in its utility function that is consumption and real money balances (Woodford, 2003). Note, that we work in first-difference, i.e. $\Delta m_t = m_t - m_{t-1}$. Correspondingly, what determines the money demand growth is the change in output and the interest rate, together with changes of money demand shocks. Following Gerlach (2004), we define filtered money growth Δm_t^T to be a linear combination of past filtered growth and current money growth. The parameter ζ is the smoothing parameter where $\log(2)/\zeta$ captures the time it takes for a one-unit change of Δm_t to lead to a 0.5 unit change in Δm_t^T.[14]

$$\Delta m_t = \pi_t + \eta_y \Delta y_t - \eta_i \Delta i_t + \Delta l_t \tag{7}$$

$$\Delta m_t^T = (1-\zeta)\Delta m_{t-1}^T + \zeta \Delta m_t. \tag{8}$$

The shocks g_t, u_t and l_t are assumed to be observable and follow $e_{j,t} \sim iid(0, \sigma_j^2)$ with $j = \pi, y, i, \Delta m$.

In order to present results concerning determinacy and dynamic properties of the model, we need to make specific assumptions about $\hat{E}$. Since the purpose of the paper is to introduce monetary expectations into the structure model, we process the following way. Firstly, we assume that agents of type 1 have 'rational expectations' of the form

[14] See Gerlach (2004).

consistent with the structural model. They make one-step ahead forecasts given the known parameters for the law of motion. This at the same time implies that the economy follows the logic of the New-Keynesian standard model.

Agents of type 2 are ‘co-integration observers’ who base their forecasting rule on the empirical co-integration of filtered money growth and trend inflation. Since our model is quarterly, agent 2 regards the arithmetic average over the last 4 quarters for filtered money growth as a ‘good’ proxy in her forecasting rule. Together, heterogeneous expectations for inflation follow

$$\begin{aligned}\hat{E}_{t-1}[\bar{\pi}_{t+3}] &= \gamma E^1_{t-1}[\bar{\pi}_{t+3}] + \gamma E^2_{t-1}[\bar{\pi}_{t+3}] \\ &= \gamma E_{t-1}[\bar{\pi}_{t+3}] + (1-\gamma)\frac{1}{4}\sum_{i=0}^{3}\Delta m^T_{t-i}. \end{aligned} \tag{9}$$

Note the timing of expectations formation. Private agents' expectations are taken in $t-1$ on future inflation in $t+1$. This implies that agent 1 makes her best forecast on $\bar{\pi}_{t+3}$ in $t-1$. While such an assumption seems realistic for a rational agent, co-integration believers are said to follow simple heuristic forecasting rules with no need of estimating the whole set of structural parameters. If, however, the timing of expectations is the same for agent 2, then she would need to make a forecast for trend money growth Δm_t in $t-1$. This would make it hard, to justify a simple rule mechanism on part of agents of type 2 because the model structure would command the same sophisticated hands-on procedure in forming expectations of trend money growth than taking type-1 agent's expectations for inflation. We, thus, assume that co-integration believers rely on an adaptive approach without forecasting current money growth; they just consider average money growth over the last 4 quarters.

Finally, the model can be simplified to its structural form representation

$$A_0 \begin{bmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{bmatrix} = A_1 \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + B_1 u_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0_{n2\times 1} \end{bmatrix} \tag{10}$$

to obtain the state space formulation in reduced form

$$\begin{bmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{bmatrix} = A \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + Bu_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0_{n2\times 1} \end{bmatrix} \tag{11}$$

with $A = A_0^{-1}A_1$, $B = A_0^{-1}B_1$ and $cov(\varepsilon_t; 0_{n2\times 1}) = A^{-1}cov(\varepsilon_t; 0_{n2\times 1})A^{-1\top}$. The variable x_{1t} is an $n_1 \times 1$ vector of predetermined variables (backward looking) with x_{10} given, x_{2t} an $n_2 \times 1$ vector of non-predetermined (forward looking) variables, u_t a $k \times 1$ vector of policy instruments, and ε an $n_1 \times 1$ vector of innovations (Söderlind, 1999). Since the heterogenous expectations model has the same form as a standard rational expectations model, usual toolkits for checking determinacy and dynamic analysis can be applied.

To parameterize the model, there are many possible sources to work with. Depending on the inclusion of backward- and forward-looking behavior of agents, the numerical parameters differ considerably.[15] The basic core equations have been estimated by Rudebusch (2002) and numerical parameters for the money demand are from Woodford (2008). The value on lagged output is taken from Söderström et al. (2005). An overview of the parameters is given in Table (1).

4.2 Impulse-Response Analysis for the Heterogenous Expectations Model

In this section, we examine the effects on the economy, if we allow for a sufficiently large number of 'co-integration observers'. Since we try to give 'reasonable' scenarios what happened during the current financial crisis, we assume that the economy has been hit by three kinds of shocks; (i) a positive interest rate shock, (ii) a negative shock to aggregate demand and a positive shock to money demand (iii). Since model dynamics always start at their steady-state values, we must treat events separately. We therefore

[15] See for instance Woodford (2008), Söderström et al. (2005), Cho and Moreno (2006), McCallum (2001) and Gerlach (2004)

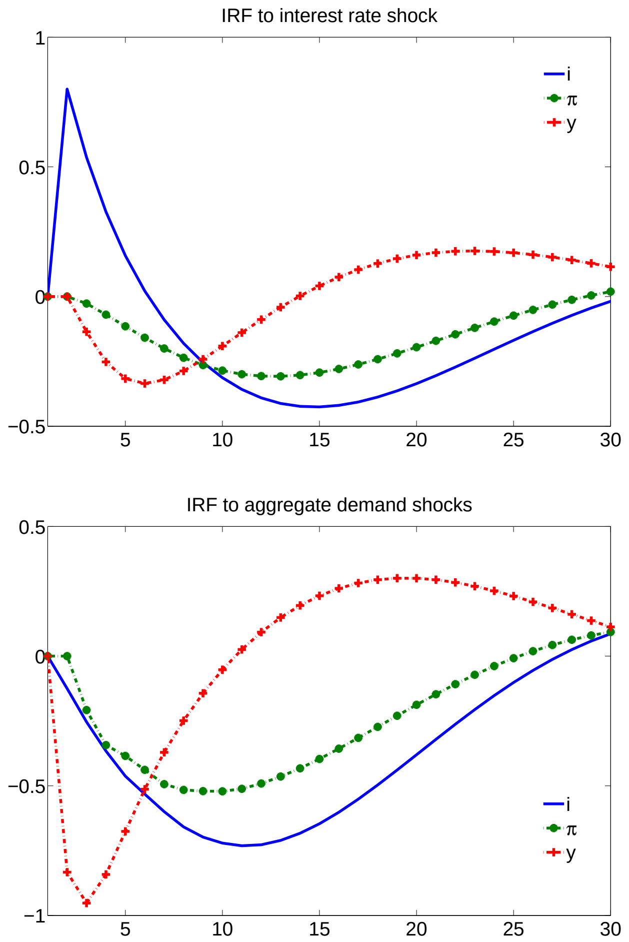
Table 1: Numerical Parameter Values for Calibration

Inflation		Output	
μ_{pi}	0.29	μ_y	0.22
$\alpha_{\pi 1}$	0.67	β_{y1}	1.15
$\alpha_{\pi 2}$	-0.14	β_{y2}	-0.27
$\alpha_{\pi 3}$	0.40	σ	0.09
$\alpha_{\pi 4}$	0.07	σ_y	0.833
κ	0.13		
σ_π	1.012		
Monetary Policy		**Money demand**	
τ_{pi}	1.5	η_y	1
τ_y	0.5	η_i	3
ρ_i	0.7	$\sigma_{\Delta m}$	0.80
σ_i	0.80		

assume that the final period of the restrictive federal funds cycle in 2007 can be identified as a positive interest-rate shock. Revealed expectations on investment opportunities and global re-balancing might be interpreted as a negative goods demand shock. Finally, the bankruptcy of Lehman Brothers and subsequent tightenings in money markets triggered a money demand shock with flight to liquidity and to quality (Taylor and Williams, 2009).

Starting point of our analysis is the New-Keynesian benchmark with fully rational agents ($\gamma = 1$) and a central bank following the reaction function MR 1. To illustrate the behavior of the estimated model, Figure (3) shows impulse responses to shocks to the interest rate and aggregate demand for selected state variables at $t = 1$. By construction, an interest-rate shock affects output from period $t = 2$ onwards, where output hits the ground after around 2-4 quarters. The effects on inflation are delayed reaching their maximum after 6-8 quarters. After shocks to the output gap, monetary policy has to gradually change the negative output gap to a positive one by interest-rate reductions in order to fight the deflationary impulse.[16] In the benchmark case, shocks to money demand have zero impact on the aggregate variables inflation and output, since money supply is adjusted endogenously without any effect to the interest rate.

Figure 3: Impulse Response Function Standard NK-Model



In what follows, we introduce heterogeneity by means of varying the proportion of rational agents and co-integrations observers via $\gamma \in [0, 1]$. In particular, we let the number of agents 1 to be equal to the number of agents of type 2. Starting with an interest-rate shock, the upper left panel of Figure (4) plots responses for the heterogeneous agent sce-

[16] The maxima effects in Söderström et al. (2005) are a little earlier timed. This might result from a different optimal monetary policy reacting in the aftermath of single shocks which is in line with their target variables of the loss function.

nario (denoted with a the subscript 'het'). While the dynamics of the aggregate state variables follow the same pattern as in the rational-expectations world for the first quarters, inflation, output and the necessary interest-rate moves show considerable smoother dynamics from the 4th quarter onwards; inflation seems to be much more anchored by deviating less from its steady state value. It is most evident in the upper-right panel in case of an aggregate demand shock. This comes not as a surprise since co-integration observers adjust inflation expectations sluggishly so that current deflationary pressure is less severe. The chosen numerical smoothing parameter ζ implies that a 1 percentage point increase in current money growth is translated into a 0.5 percentage points increase in trend money growth after 8 quarters. Output dynamics, instead, resemble each other in the rational-expectations and heterogeneous agent model.

In case of a shock to money demand, inflation slightly picks up triggering lower ex-ante real interest rates and pushing the output gap to positive values. A fully accommodated money demand shock is translated into higher trend money growth which induces *both* agents to increase inflation expectations. Agents of type 2 adjust their forecast in line with monetary figures; meanwhile agents of type 1 know that there are co-integration observers so that they likewise attribute inflationary expectations to a rising money stock, just because they realize that monetary developments lead to inflation in the presence of co-integration observers.

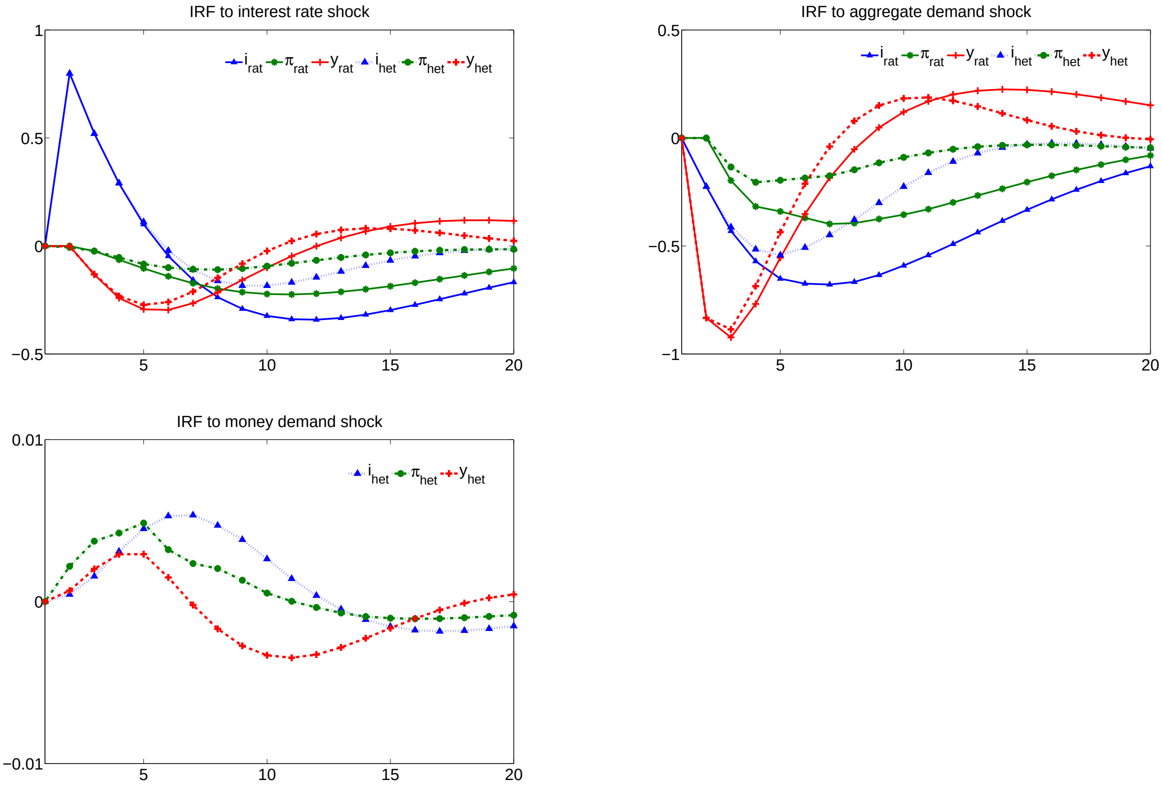
We might also ask whether building expectations by observing the money growth trend is in line with basic reasoning according to the quantity theory of price-level and inflation determination. Consider, for instance, a money demand shock. According to the equation $M \times V = P \times Y$, this shock induces the velocity of money V to fall. At the same time, the central bank provides sufficiently money supply in order to stabilize nominal expenditures $P \times Y$. As soon as the money demand shock cancels out, velocity reaches its initial level and the money stock should fall along the same lines. Within our model, this is exactly what happens. At least since Poole (1970) it is acknowledged under both academics and central bankers that the choice in favor of the interest rate as policy instrument is superior to the money supply, especially in case of money demand shocks. Fixing the interest rate and letting the money stock vary in accordance with public's money demand, avoids unfavorable macroeconomic outcomes in terms of inflation and output variability. Since the money supply evolves endogenously due to changes in money demand, shifts in the demand (up and down) are translated one-for-one in money supply dynamics.

A proponent of the quantity theory is aware of this fact and will *not* alter inflation expectations unless for the two subsequent reasons; (i) she does not regard money supply to be endogenous and, thus, does not understand the link between money demand and money supply (see for this line of argumentation Spahn, 2007); or (ii) we must impose some degree of distrust on part of agents of type 2 against the central bank in following the Poole principle. This means, that a money-demand shock driven rise in trend money growth leads to higher inflation expectations since agents of type 2 do not believe that the central bank will cut the initial money-supply increase proportionally as soon as the shock is evaporated. It is for the latter reason why Meltzer (2009) sees inflation rather than deflation at the horizon.

As can be seen from the analysis of impulse responses, the presence of heterogenous agents brings about smoother dynamics of inflation, output and the policy rate in case of demand and policy shocks compared to the rational-agent model. Taking the model implications to the real world, monetary believers support the central bank in achieving their targets of price and output stability. In particular, if we interpret recent developments since August 2008 as a combination of an aggregate demand and money demand shock, the deflationary pressure stemming from rational agents is likely hampered by co-integration observes. As it becomes evident in Figure (1), the data may speak for the monetary believers since the FED has been unwilling to fully netting out the money growth in the aftermath of 09/11. If it would have done so, we would have seen *negative* growth rate figures (unless we think of a sky-rocketing productivity growth).

Even though our heterogeneous agent model is not fully coherent with consistent expectations formation in a New-Keynesian and quantity-theoretic context, we can show

Figure 4: Impulse Response Function Heterogenous NK-Model



that such heuristic monetary beliefs stabilize rather than destabilize the economy in times of financial crisis and deflationary pressure; in principle, this constellation should support the central bank in achieving its inflation target.

4.3 Forward-Looking Monetary Policy Rules - The Role of Private Sector Expectations

One of the basic insights of the literature on learning in macroeconomics deals with determinacy of the rational expectations equilibrium if agents need to learn the true parameters of the model. Evans and Honkapohja (2008) give a review on E-stability with a monetary policy following the Taylor principle and an optimal rule. They point out that as long as the central bank at least reacts proportional to inflation and the reaction coefficient of the output gap is not large, the macro system is stable under learning.[17] However, a *fundamentals*-based monetary policy rule derived from an optimizing central bank can lead to parameter regions in which the underlying model can be indeterminant. Such a reaction function might consists of current observable shocks and lagged state variable terms. If private agents' expectations are observable, this lack can be overcome by reacting in part to conditional private expectations. The *expectations-based* reaction function as proposed by Evans and Honkapohja (2006) offers a solution where the central bank also responds to private expectations about inflation and output. This is more likely the case if current data are non available or heavily measured with noise.

It is straightforward to ask a related question within our model set-up: to what extend should a central bank be forward-looking? Among practical policy making, there seems to be a clear trend towards the inclusion of internal forecasts and private-sector expectations in the decision-making process owing to systematic time lags of the monetary transmission and the presence of the expectations channel of monetary policy.[18] We can test to what extend the simulation results vary if we allow for three different interest rate rule, a conventional Taylor rule, a forward-looking rule based on internal forecasts and a forward-looking rule based on private sector's expectations.

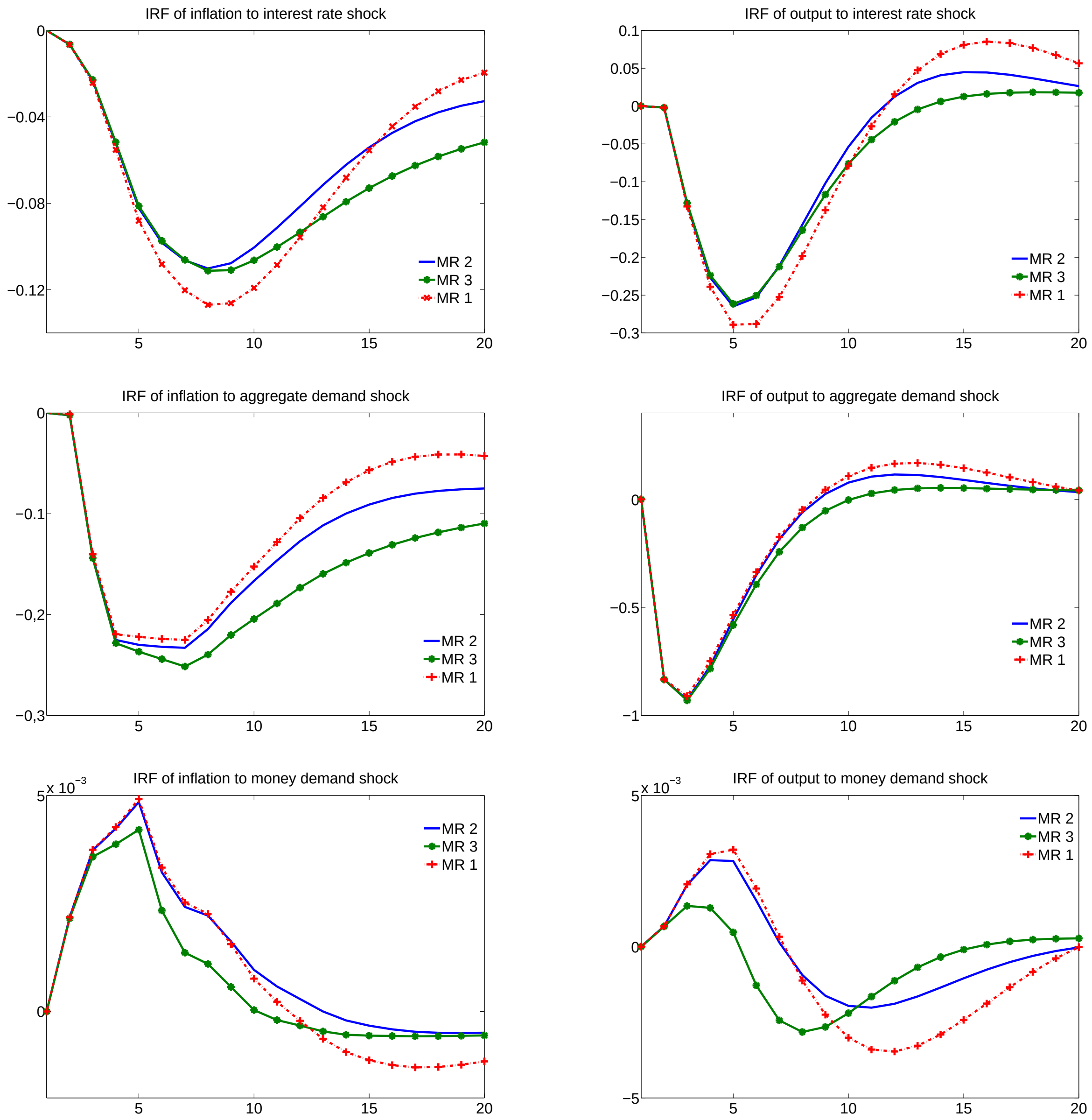
In our model, the first forward-looking monetary policy strategy coincides with the policy rule as specified in MR 2 of Equation (4); meanwhile the second strategy considers average inflation expectations of private agents in line with rule MR 3. The economy is characterized by equal proportions of rational agents and heterogeneous agents ($\gamma = 0.5$). Again, we concentrate on the relevant shocks, i.e. an interest rate shock, aggregate demand as well as money demand shock.

Figure (5) plots impulse response functions of inflation and output for the three different rule concepts. The right column reveals that the output dynamics are similar for

[17] For different Taylor rules and the learnability criterium see Bullard and Mitra (2002).

[18] See the article on expectations and the conduct of monetary policy in the May 2009 issue of the ECB monthly bulletin and data from the monthly bulletin of the ECB in its June and December issues (2008) as well as the Inflation Reports of the Bank of England (2008).

Figure 5: Impulse Response Function Heterogenous NK-Model with Different Policy Rules



all three rules. In case of an interest-rate and aggregate demand shock, the MR 2 rule performs slightly better in maintaining the state variables at their respective steady state values whereas the amplitudes magnifies when the central bank applies a conventional Taylor rule. If the central bank reacts to heterogenous expectations in the aftermath of a money demand shock, the effects in the first quarter are smaller compared to MR 1 and MR 2 due to relatively higher ex-ante real interest rates; they aggravate after 4 quarters

Table 2: Moments of Simulated Variables

	MR 1	MR 2	MR 3
Σ_π	1.86	2.09	2.17
Σ_y	1.88	1.81	1.83
Σ_i	2.47	2.52	2.50

onwards as a results of the higher interest rates. The analysis of impulse responses leads to the assertion that there is no big difference in terms of output dynamics after a shock has hit the economy. When calculating the second moments for the simulated state variables, Table (2) reveals that a forward-looking central bank considering its own rational forecasts does best in reducing the variability of output, though the differences are quite small.[19]

The impulse response functions for inflation give a clearer picture about possible instructions how to cope with heterogenous expectations (Figure 5). If the economy is hit by an interest rate shock or an aggregate demand shock, the negative effects on both, output and inflation are smaller in case of the MR 2 rule compared to the MR 3 rule. Moreover, the conventional MR 1 rule achieves to get output to more favorable dynamics but at the cost of producing a much more severe deflationary environment. A money demand shock reflects itself in a temporary increase in inflation where the MR 3 rule generates the smoothest dynamics. However, the differences between the rules are rather negligible.[20] An inspection of the simulated second moments indicates to a preferred role for the Taylor rule MR 1, followed by the reaction function MR 2. If the central bank would respond to heterogenous expectations, the adjustment process to the steady state would be more costly in terms of volatility in inflation. This holds in particular vis-à-vis

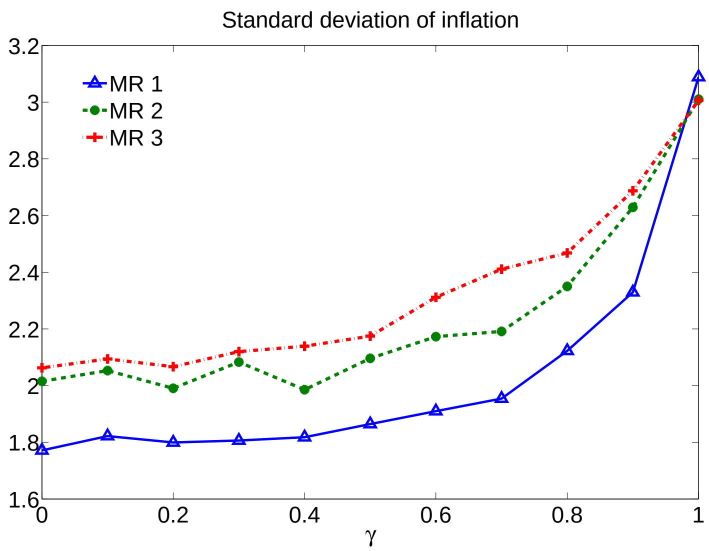
[19] We compute first and second moments for a total length of 100,000 periods to get a proxy for the unconditional moments.

[20] Note the scale of the y-axis.

the MR 1 rule in terms of inflation; for output dynamics, instead, its standard deviation is smaller.

To check for robustness, we vary the proportion of agents in the economy for different values of $\gamma \in [0, 1]$. The standard deviation of inflation serves as evaluation indicator what kind of reaction functions to follow in setting interest rates. The model is again simulated for a sample length of 100,000 periods. A graphical illustration of second moments is given in Figure (6). The x-axis covers the possible range for the fraction of rational agents. For $\gamma = 0$, the model consists solely of monetary believers; whereas the opposite holds in the $\gamma = 1$ case. The standard deviation of inflation for the MR 1 rule is represented by the line with triangles, the dotted line and the line with small crosses stands for the MR 2 and MR 3 rule, respectively. The results for the superior monetary policy strategy

Figure 6: Standard Deviation with Different Policy Rules and Varying Degree of Agents



with respect to robustness are (almost) unambiguous. The reaction to current economic variables produces standard deviations of inflation that are below the two forward-looking reaction functions independent of the fraction of co-integration observers. One exception is the limiting case in which co-integration observers do not exist so that the whole system is characterized by rational, forward-looking agents. This holds for the private sector as well as for the central bank. A policy recommendation of reacting in a forward-looking manner, thus, seems to be only appropriate in a rather 'unrealistic' world in which all expectations are built in accordance with the underlying structural model. If we allow for just a small amount of heuristic forecasters, in our case co-integration observers, the results show a picture in favor of a contemporaneous policy rule. This is in contrast to most academic work on instrument rules (see e.g. Svensson and Woodford, 2005); they usually propose forward-looking rules to make allowance of the typical lag structure between interest-rate impulses and its impact on the economy. Although the transmission argument might speak for a rule like those sketched out in MR 2 and MR 3, note that the model we choose is aware of this fact. For instance, the ex-ante real interest rate affects the economy with a lag of one quarter which sounds reasonable from an empirical point of view.[21]

An inspection of the forward-looking rules reveals that if a central bank is forward-looking, it can relatively reduce inflation volatility by using its own rational forecast of inflation expectation rather than reacting to perceived market expectations as documented in survey data. This does hold in the standard case with $\gamma = 0.5$ and for all remaining values of the parameter region. By no surprise, the standard deviation lines converge in the limit with $\gamma = 1$ with expectations only mirroring rational agents.

5 Concluding Remarks

The purpose of this paper has been to examine a standard New-Keynesian model extended by heterogenous expectations and monetary believes. Motivated by the empirical evidence on survey data, we can identify a group of deflation pessimists and inflation hawks. The root of this heterogeneity may be the outcome of ambiguous inflation signals on part of monetary policy. In order to keep the economy from falling into a deep deflationary environment, it promotes an immense quantitative easing cycle. The side effects express

[21] Still, there is a practical problem with the timing of observing inflation figures.

themselves in ballooning monetary figures that have caused proponents of the money-inflation nexus to lower their guards. They see inflation rather deflation in the medium term.

For monetary policy, the question is how to cope with these developments and how to conduct policy in an environment of expectational heterogeneity. We work with an empirical New-Keynesian standard economy with a complex lead and lag structure to reproduce stylized inflation and output dynamics. Moreover, we have modified the standard version by translating heterogenous expectations into the model setup; the two diverging groups are characterized as rational agents who fully understand the structure of the economy and heuristic co-integration observers where the latter observe past money growth trend to make inflation forecasts.

The presence of heterogenous expectations helps to stabilize the macroeconomy in terms of adjustments to the steady state after the economy is hit by one of the following disturbances: a negative demand shock, an interest-rate shock and a money demand shock. In particular, shocks that foster a deflationary environment are partly absorbed by monetary beliefs. This makes it easier for central banks to achieve their inflation target when nominal interest rates are near the zero-bound and their room for maneuver is limited. We also find that a conventional Taylor rule according to which a central bank reacts to current inflation and output does best in reducing the volatility of inflation. Forward-looking specifications are only the preferred choice if there are no heterogenous expectations and private agents are characterized by rational expectations.

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