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Macroeconomic Dynamics under Bounded Rationality: On the Impact of Consumers' Forecast Heuristics

by Tae-Seok Jang and Stephen Sacht

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Macroeconomic Dynamics under Bounded Rationality: On the Impact of Consumers' Forecast Heuristics

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Abstract

In this study, we analyze the macroeconomic dynamics under various shocks in two competing frameworks. Given the baseline New-Keynesian model, we compare the impulse response functions that stem from the hybrid version under rational expectations with the ones obtained in the forward-looking version under bounded rationality. For the latter, we assume heterogeneous agents who may adopt various forecast heuristics. We seek to understand which framework mimics real-world adjustments well and is therefore most suitable to describe economic adjustments over the business cycle.

Keywords: Bounded Rationality; Consumer Expectations; Forecast Heuristics; Impulse Response Functions; New-Keynesian Model.

JEL classification: C53, D83, E12, E21, E32.

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1 Introduction

Since the outbreak of the financial crisis at the end of the last decade, the economic turmoil witnessed throughout the Great Recession period threw the *homo economicus* concept into question. In particular, how could the US housing bubble have emerged without being noticed by financial (non-) experts beforehand? An answer can be formulated according to the view that agents do not behave fully rationally. This view is not entirely new and is summarized by Akerlof and Shiller (2009), who claim that "the truly trusting person often discards or discounts certain information." Hence, even if agents process information in a rational way, they may not react to it accordingly. In the absence of the rational expectations (RE) paradigm, decision making and forecasting abilities might then become grounded on (but not limited to) emotional states.

This gives rise to model frameworks inhabited by heterogeneous agents who use simple forecast heuristics (i.e., rules-of-thumb procedures). Indeed, applying these turns out to be rational if the interactions of relevant variables such as output and inflation are barely understandable even though the structure of the economy is observable (Munier et al. 1999). Given the lack of full information, such bounded rational behavior in terms of proper forecasting ability rather focuses on habits, imitation, and/or procedural optimization (Day and Pingle 1991).

The most prominent use of heuristics in macroeconomic dynamic stochastic general equilibrium (DSGE) models in the literature is based on the discrete choice approach. This method allows for a switching mechanism in specific forecasting rules. In particular, agents sort themselves into different groups; each group is populated by individuals who believe in a certain expectation formation process. As a result, endogenous waves of economic beliefs such as optimism and pessimism are generated from period to period. This leads to fluctuations in the economic variables driven by reversals in the emotional state, which holds even in the absence of autocorrelated exogenous shocks.

Over the past two decades, the discrete choice approach has been widely used in financial economics. Seminal contributions have been made by Brock and Hommes (1997) and Gaunersdorfer et al. (2008) among others. The study by De Grauwe (2011) is acknowledged as the most influential early theoretical contribution in behavioral macroeconomics. Jang and Sacht (2016) were among the first to adopt such a behavioral DSGE model. Forecast heuristics do not necessarily rely on the emotional state; a heuristic process may include technical procedures. As an example of the latter, consider the well-known existence of so-called chartists and fundamentalists. For an in-depth overview on the corresponding literature, see the surveys of Assenza et al. (2014) and Franke and Westerhoff (2018).

To build on Jang and Sacht (2018), we examine the role of consumer confidence for the determination of private household expenditure and its influence on the

business cycle. One of the main stylized facts is given by the high correlation between confidence and consumption as well as GDP for the US economy and the Euro Area. Under the consideration of cross-correlation patterns, strong and contemporaneous co-movements in the time series are observed. This fact suggests that consumer confidence plays a crucial role in the determination of household expenditure and the pass through to GDP fluctuations. In addition, high persistence in consumer confidence can be modeled by using the discrete choice switching mechanism in expectations. As confidence affects heterogeneous consumers' decision-making processes, the question of how confidence influences macroeconomic dynamics as certain shocks occur then arises.

We primarily evaluate different forecast heuristics that connect consumer confidence and private household expenditure. The set of heuristics considered are chosen from the contributions by Gaunersdorfer et al. (2008) and Jang and Sacht (2016). Our empirical results suggest that expectations in the US economy are grounded on consumers' emotional state, while for the Euro Area, they are purely technical. Based on these observations, in this study we go a step further and analyze the impulse response functions (IRFs) to various shocks. Therefore, we choose the heuristics that lead to the best description of the hybrid version of a standard DSGE model to the empirical data following the findings of Jang and Sacht (2018).

More generally, we compare the IRFs stemming from the behavioral model framework with the ones obtained from the framework in which RE are assumed. Both types of IRFs are confronted with the outcome of a vector autoregressive (VAR) model. In doing so, we attempt to find an appropriate modeling approach that is ready to use for policy analysis. While there exists a large body of this kind of analysis with respect to DSGE models with RE (see Smets and Wouters 2003, 2005, 2007 among others), previous studies of bounded rational macroeconomic models are rare (see Lengnick and Wohltmann 2016 as an example). Such analysis is, however, of high interest, for instance in the case of the output/inflation trade-off the central bank will face when conducting an (optimal) monetary policy intervention. As a novel feature of our contribution, this study considers the parameter estimates obtained from the work in Jang and Sacht (2018) rather than applying a straightforward calibration approach.

The remainder of this paper is structured as follows. Section 2 discusses the general representation of the model frameworks under RE and bounded rationality (BR). The latter includes the forecast heuristics applied under the consideration of the discrete choice switching mechanism. Detailed descriptions can be found in Appendices A1 and A2. Section 3 presents the methodology and data used in this study. Section 4 presents a simulation study in which we compare the IRFs obtained from both model frameworks with a VAR model in the case of a demand, cost-push, and nominal interest shock, respectively. Finally, Section 5 concludes.

2 Model Frameworks

The core structure of the New-Keynesian model (NKM) in its hybrid variant with leads and lags is given implicitly as follows:

$$c_t = c_t(\tilde{E}_t^j c_{t+1}, c_{t-1}, r_t, \tilde{E}_t^j \pi_{t+1}, \varepsilon_{c,t}) \quad (1)$$

$$\pi_t = \pi_t(\tilde{E}_t^j \pi_{t+1}, \pi_{t-1}, c_t, \varepsilon_{\pi,t}) \quad (2)$$

$$r_t = r_t(r_{t-1}, \pi_t, c_t, \varepsilon_{r,t}). \quad (3)$$

The variables c_t , π_t , and r_t refer to private consumption (i.e., household expenditure), the inflation rate, and the nominal interest rate, respectively. All the variables are expressed in gap notation. According to the DSGE methodology, $c_t = y_t$ holds, where the latter denotes the output gap. Idiosyncratic shocks are denoted by $\varepsilon_{s,t}$ for $s = \{c, \pi, i\}$. These one-off disturbances can be interpreted as a demand shock to the dynamic IS equation (1), a cost-push shock to the New-Keynesian Phillips curve (NKPC) (2) and a nominal interest rate shock to the Taylor rule (3), respectively. Appendix A1 explicitly describes this well-known standard representation of the New-Keynesian workhorse model as well as interprets the parameters.

The superscript $j = \{\text{RE}, \text{BR}\}$ denotes the RE and BR model frameworks, respectively. The corresponding expectations operator is \tilde{E}_t^j , which has to be specified for both frameworks in quarterly magnitudes.

Under RE the forward-looking terms are described by expectations with respect to consumption and inflation at time $t + 1$ in equations (1) and (2):

$$\tilde{E}_t^{RE} z_{t+1} = E_t z_{t+1} + E_t \tilde{\varepsilon}_{z,t} \quad (4)$$

with $z = \{c, \pi\}$ and where E_t denotes the statistical expectation operator conditional on information at time t . In a stochastic environment, we consider a random error term $\tilde{\varepsilon}_{z,t}$. The latter is independent of the future realizations in z and has an expected value of zero, namely $E_t \tilde{\varepsilon}_{z,t} = 0$ holds. According to the RE hypothesis, it is therefore assumed that expectations are not systematically biased and that those agents process all the available information in an optimal way.

In the BR model, we distinguish between the expectation formation with respect to consumption and inflation. Under BR, we apply the specific heuristics first adopted by Gaunersdorfer et al. (2008) and De Grauwe (2011). Regarding consumption expectations, agents can sort themselves into four groups of forecasters expressed through the following heuristics:

$$E_t^F c_{t+1} = \bar{c} + \psi_c (c_{t-1} - \bar{c}) \quad (5)$$

$$E_t^C c_{t+1} = c_{t-1} + \xi_c (c_{t-1} - c_{t-2}) \quad (6)$$

$$E_t^O c_{t+1} = \frac{1}{2} \cdot [\beta + \delta \lambda_{c,t}] \quad (7)$$

$$E_t^P c_{t+1} = -\frac{1}{2} \cdot [\beta + \delta \lambda_{c,t}] \quad (8)$$

where the general steady-state assumption suggests $\bar{c} = 0$. Here, equations (5) to (8) reflect consumers' forecast heuristics in the absence of the RE hypothesis.

We refer to heuristics (5) and (6) as displaying direct rule-of-thumb behavior since they consist of backward-looking elements. For simplicity, we assume that *fundamentalists* (F) and *chartists* (C) account for professional forecast behavior (i.e., there is an absence of emotional states with limited information). Fundamentalists believe in a convergence of the future value(s) towards the steady-state value \bar{c} with the speed of convergence given by $0 \leq \psi_c \leq 1$. Quick (slow) movement is observed when ψ_c is close to 0 (1). Chartists form their expectations based on historic patterns in the time series. Under the consideration of the past realization and relation between the first and second lags, this type of agent either extrapolates the last change in c ($\xi_c > 0$) or expects a reversal instead ($\xi_c < 0$). Hence, these heuristics are *technical* in nature.

In addition, with respect to heuristics (7) and (8), we directly follow the specifications proposed by Jang and Sacht (2016, 2018) to quantify the divergence in beliefs. Here, we assume that agents may adopt either an *optimistic* (O) or a *pessimistic* (P) attitude towards movements in future consumption. Hence, both types of agents are uncertain about the future dynamics of consumption and therefore predict a subjective mean value of c_{t+1} measured by $\beta \geq 0$. However, this kind of subjective forecast is generally biased and therefore depends on the volatility in consumption (i.e., given by the unconditional standard deviation $\lambda_{c,t} \geq 0$). The corresponding parameter $\delta \geq 0$ measures the degree of divergence in the movement of economic activity. We consider symmetry with respect to behavioral specifications (β and δ): optimists expect consumption to differ positively from the steady-state value \bar{c} given by the value of $\beta/2$, while pessimists expect a negative deviation of the same magnitude. We refer to these heuristics as the *emotional* ones.

By following different approaches in the literature, we consider a "purely" bounded rational approach (i.e., we incorporate non-RE formation with respect to inflation). The central bank seeks to stabilize inflation via the interest channel of monetary policy. In particular, the monetary authority anchors expectations by announcing an inflation target given by $\bar{\pi}$. Fundamentalists consider this pre-commitment strategy to be fully credible. The corresponding forecasting rule then becomes

$$E_t^F \pi_{t+1} = \bar{\pi} \quad (9)$$

with a target rate for the inflation gap of $\bar{\pi} = 0$ for simplicity (cf. Jang and Sacht 2016). Chartists expect the future value of the inflation gap to be given by

$$E_t^C \pi_{t+1} = \pi_{t-1}. \quad (10)$$

Hence, we adopt the same heuristics with respect to fundamentalists and chartists as before (see equations (5) and (6)) but with $\psi_\pi = 1$ and $\xi_\pi = 0$ instead.

We place these constraints on the heuristics to consider the impact of consumer confidence in isolation while following the description of the so-called inflation targeters and extrapolators imposed by De Grauwe (2011). Under BR, switching from one group to the other is based on discrete choice theory. Appendix A2 describes this approach in the context of the core structure of the model.

3 Methodology and Data

Jang and Sacht (2018) estimate both the RE and the BR models by using the Simulated Method of Moment (SMM) approach (cf. Franke et al. 2015 and Jang and Sacht 2016). In the BR framework, we consider different combinations of the forecast heuristics (5) to (8), while the rules-of-thumb (9) and (10) hold in general for inflation.

The findings show that two specific sets of combinations (which we call "blocks") are selected. These provide the best possible fit of this type of BR model framework to the data compared with other sets of heuristics. For the US economy, the so-called emotional-fundamental block (EFB) is the most promising choice. This consists on the forecast heuristics of optimists (7), pessimists (8), and fundamentalists (5) only. In the Euro Area, the highest degree of fitness is observed in the absence of any heuristics linked to an emotional state. Hence, only the expectation formation scheme of fundamentalists (5) and chartists (6) is important. Both heuristics combined stand for the so-called *pure-technical block* (PTB). Table 1 reports the estimation results.

Based on the overall conclusion of Jang and Sacht (2018), we therefore state that expectations in the US economy are grounded on consumers' emotional state, while for the Euro Area, they are technical in nature. According to the value of the objective function J , which displays the measure of fitness within the SMM approach, the BR model framework exhibits a (slightly) better fit to the data in the (US) Euro Area case than the RE one. Therefore, lower values of J indicate a better fit to the data. The results for the RE model framework highlight the importance of backward-looking behavior for the empirical application to both the US economy and the Euro Area. This can be seen by the estimates for the habit formation and price indexation parameters in the RE cases, which are both close (for γ) or even at their boundary value of unity (for χ). Hence, our previous observation questions the need for a hybrid model variant under RE.

As our previous investigation is not entirely conclusive, it is fruitful to study the model dynamics in response to different shocks: a demand shock (via the impulse $\varepsilon_{c,t}$ in equation (1)), a cost-push shock (via the impulse $\varepsilon_{\pi,t}$ in equation (1)), and a nominal interest shock (via the impulse $\varepsilon_{\pi,t}$ in equation (1)). This is crucial as one would like to study the adjustments in the economy over time for the purpose of a policy analysis. Therefore, we compare the IRFs of both frameworks for the US economy and Euro Area. To show this, we choose the

Table 1: Estimation results for the hybrid RE and BR models

Label	US Economy		Euro Area	
	Hybrid RE	EFB	Hybrid RE	PTB
χ	1.000 -	-	1.000 -	-
τ	0.032 0.015 - 0.048	0.371 0.222 - 0.520	0.079 0.022 - 0.136	0.144 0.005 - 0.284
σ_c	0.554 0.394 - 0.714	0.543 0.267 - 0.818	0.561 0.430 - 0.693	0.413 0.206 - 0.619
γ	0.914 0.803 - 1.0	-	0.765 0.630 - 0.900	-
κ	0.030 0.019 - 0.040	0.213 0.175 - 0.252	0.035 0.021 - 0.049	0.152 0.125 - 0.178
σ_π	0.293 0.153 - 0.434	0.240 0.018 - 0.461	0.275 0.159 - 0.390	0.360 0.213 - 0.507
ϕ_π	1.573 1.000 - 2.228	1.914 1.080 - 2.747	1.288 1.0 - 1.918	1.593 1.056 - 2.129
ϕ_c	0.785 0.253 - 1.317	0.709 0.011 - 1.407	0.497 0.124 - 0.870	0.325 0.039 - 0.611
ϕ_r	0.831 0.766 - 0.895	0.808 0.660 - 0.956	0.604 0.479 - 0.729	0.426 0.229 - 0.623
σ_r	0.464 0.133 - 0.796	0.151 0.000 - 0.417	0.421 0.072 - 0.769	0.444 0.078 - 0.809
β	-	3.282 1.598 - 4.967	-	-
δ	-	0.531 0.000 - 1.550	-	-
ψ_c	-	0.951 0.657 - 1.244	-	0.762 0.526 - 0.998
ξ_c	-	-	-	1.010 0.574 - 1.447
J	47.33	43.29	56.30	37.96
p	0.973	0.989	0.844	0.999

Note: We use 78 moments (two years), based on the SMM approach. The 95% confidence intervals are given with a smaller size. The value of the objective function and the p-value are denoted by J and p , respectively. For the hybrid RE, the degrees of freedom for the χ^2 distribution amount to 68. The 5% critical value for 68 degrees of freedom is 88.25. No memory is assumed in the BR scenarios ($\rho = 0$). The discount factor ν is calibrated to 0.99. We set ϖ equal to 1800. For a detailed description of the SMM approach, see Jang and Sacht (2016, 2018).

associated estimated mean values of the parameter sets taken from Table 1 for the calibration. For a robustness check, we compare the simulated IRFs with the empirical ones that stem from a VAR model. Before we interpret the results, in the following we briefly discuss the methodology and data.

3.1 Methodology

To compute the IRFs, we display the deviation of the simulated time series from the same time series induced by an increase in $\varepsilon_{s,\tilde{t}}$ with $s = \{c, \pi, r\}$ by one unit at time \tilde{t} being considered. The underlying simulations are both caused by the same series of otherwise random shocks. We focus on consumption (cf. equation (1)) and consumer confidence. For the latter, the displayed IRFs are defined as a *measure of dominance* for the heuristics being considered.

The baseline model of RE and BR can be expressed in reduced form as follows:

$$X_t = F(X_{t-1}, \dots, X_{t-p}) + V_t, \quad (11)$$

where $F(\cdot)$ is a function of the dynamic IS, the NKPC and the Taylor rule. $X_t = \{c_t, \pi_t, r_t\}$ is a 3×1 vector and $V_t = \{\varepsilon_{c,t}, \varepsilon_{\pi,t}, \varepsilon_{r,t}\}$ is a 3×1 IID random disturbances.

Then the IRF is defined as:

$$I_X = E_t[X_{t+1}|\nu_t, \omega_{t-1}] - E_t[X_{t+1}|\omega_{t-1}], \quad (12)$$

where ν_t is an arbitrary current shock and ω_{t-1} refers to history. Note that ω_{t-1} is a particular realization of Ω_{t-1} , namely the set containing the information used to forecast X_t .

In particular, the IRF of the BR models shows that the response depends on both the persistence of the current shock and the history. In addition, the simulated trajectory is based on a multivariate non-linear system. This suggests that the shocks ($\varepsilon_{c,t}, \varepsilon_{\pi,t}, \varepsilon_{r,t}$) have contemporaneous effects on the corresponding variables (c_t, π_t, r_t) as well as the other macroeconomic variables.

Based on equation (12), the following statements regarding the interpretation of the different IRFs with respect to consumer confidence should be considered. For the US economy, according to the EFB scenario, we first consider two fractions of groups for two different cases: optimists relative to pessimists *and* fundamentalists versus fundamentalists relative to, say, emotional consumers (optimists *and* pessimists). Both specific fractions are computed in response to the shock. In the second step, we calculate the same configuration in the absence of the shock. In the third and final step, the IRFs are given by the deviation of the relations without the shock from the one where the shock occurs at time $\tilde{t} = 10$. The same computations are applied for the Euro Area, where we consider the change in the fraction of fundamentalists relative to chartists according to the PTB scenario.

In the US economy, we consider two IRFs for consumer confidence in one graph. The IRF labeled "Optimists" indicates the dominance of this group relative to fundamentalists and pessimists if positive realizations above zero are observed. According to the group behavior, fundamentalists and pessimists dominate confidence over optimists as negative realizations below zero occur. The same kind of interpretation holds with respect to the fraction of fundamentalists relative to emotional consumers (i.e. optimists and pessimists). The corresponding IRF is simply labeled "Fundamentalists". In the Euro Area, we consider fundamentalists and chartists only. The trajectory above zero then indicates the dominance of fundamentalists over chartists and vice versa. The corresponding IRF is also labeled "Fundamentalists" in this case.

The IRFs that stem from real-life data are based on a VAR model. We choose VAR(8) as a two-year lag based on quarterly data, which is consistent with the moment conditions for the estimation of the BR and RE model frameworks in Jang and Sacht (2018). Including additional lags might improve the fit of the model to the data, but it does lead to over-parametrization in which many parameters are not significant. Hence, we consider eight lags to be an appropriate choice for the VAR model. For a clear arrangement, we omit the graphical representation of the ± 2 standard deviations from the mean value in all figures. As the standard deviation describes the uncertainty about the IRFs, it is commonly known that the former has a large impact for several periods afterwards but reduces gradually to zero as the non-autocorrelated shocks vanish in later periods.

3.2 Data

The data used to compute the IRFs from the VAR model are described as follows. The US data set is taken from the webpage of the Federal Reserve Bank of St. Louis (<https://fred.stlouisfed.org>). The sample spans 1975:Q1 to 2009:Q4. Inflation is measured by using the seasonally adjusted consumer price index with 2009 as the base year. Output is obtained from seasonally adjusted real GDP based on billions of chained 2009 dollars. The effective federal funds rate is used to measure the short-term nominal interest rate in the United States.

We retrieve the Euro Area data set from the 10th update of the Area-Wide Model quarterly database (<http://www.eabcn.org/page/area-wide-model>; see Fagan et al. (2001)). To be consistent with the time span for the US economy, the sample covers 1975:Q1 to 2009:Q4. The consumption deflator is used to measure inflation in the Euro Area. The short-term nominal interest rate and real GDP are used to measure the gaps in the nominal interest rate and output in the Euro Area. The time series in the Area-Wide Model database have the following abbreviations: PCD, consumption deflation; STN, short-term nominal interest rate; and YER, real GDP. According to the equilibrium condition $c_t = y_t$, we consider the output gap time series to be a proxy for the private consumption gap (due to the limited data availability of the latter) within our

analysis. A standard smoothing parameter of $\lambda = 1600$ is used to estimate the trend of the observed data from the Hodrick-Prescott filter for output, inflation, and the nominal interest rate.

4 Simulations and Analysis of IRFs

4.1 Demand Shock

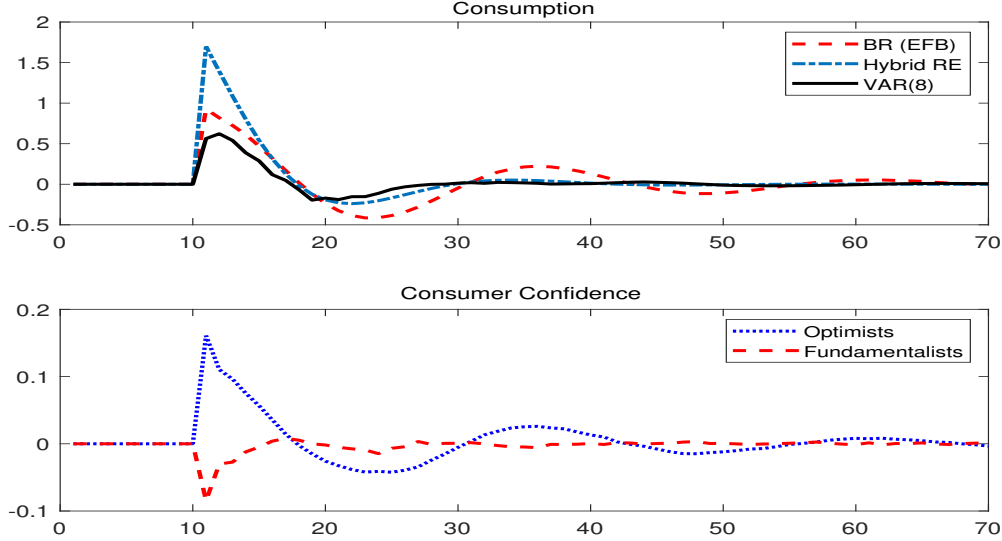
Figure 1 shows the dynamics of consumption (upper panel) and consumer confidence (lower panel) in the US case. The results support the prediction of the model when the economy is hit by a positive demand shock, namely an exogenous increase in consumption where $\varepsilon_{c,\tilde{t}} > 0$ holds in period $\tilde{t} = 10$. A rise in government expenditure or an increase in demand for investment goods serve as examples in this case. According to the NKM, an increase in consumption (and, hence, in output) leads to an increase in inflation. The central bank reacts to the shock by increasing the nominal interest rate according to the Taylor rule. Based on the concept of intertemporal consumption smoothing, household expenditure drops as the real interest rate increases. We consider a one-off impulse, where the shock-induced dynamics die out after several periods (around period $t = 70$).

To interpret our observations, throughout our analysis we consider two subperiods: the *impact* phase (from period $t = 10$ to $t = 20$) and the *convergence* phase (from period $t = 20$ onward). The IRFs from the VAR model exhibit almost no persistence after the impact phase. The disturbance by the shock only has a strong impact over a short period, while it vanishes soon after the shock occurs. As we consider the VAR model's IRF to be a benchmark, we interpret the IRFs from the BR and RE frameworks in a qualitative and quantitative way for both phases separately.

In the impact phase, the demand shock leads quantitatively to a stronger effect on consumption obtained in the RE than in the BR model framework. The IRFs of the latter therefore mimic the ones from the VAR. The less pronounced effect on impact under BR is caused by the dominance of optimists, who expect a subjected mean value of plus $\beta/2 = 1.621$ according to Table 1. The realized increase in consumption is less than the subjected mean value owing to the existence of pessimists, who consider a negative value of minus 1.621 because of the symmetry in the structure of both forecast heuristics. Fundamentalists are clearly dominated in the impact phase since this group simply expects the (unaltered) previous consumption level to be realized.

In the convergence phase, we observe more wiggles and fluctuations under BR. Hence, the economy becomes more unstable, which is not in line with the VAR model's IRF. As the consumption trend over time is closely linked to the change in consumer confidence, we observe the following. While the realization of consumption relies on the dominance of the optimistic group, the volatility in consumption depends on the dominance of the fundamentalists. The latter ob-

Figure 1: IRFs: positive demand shock (US)



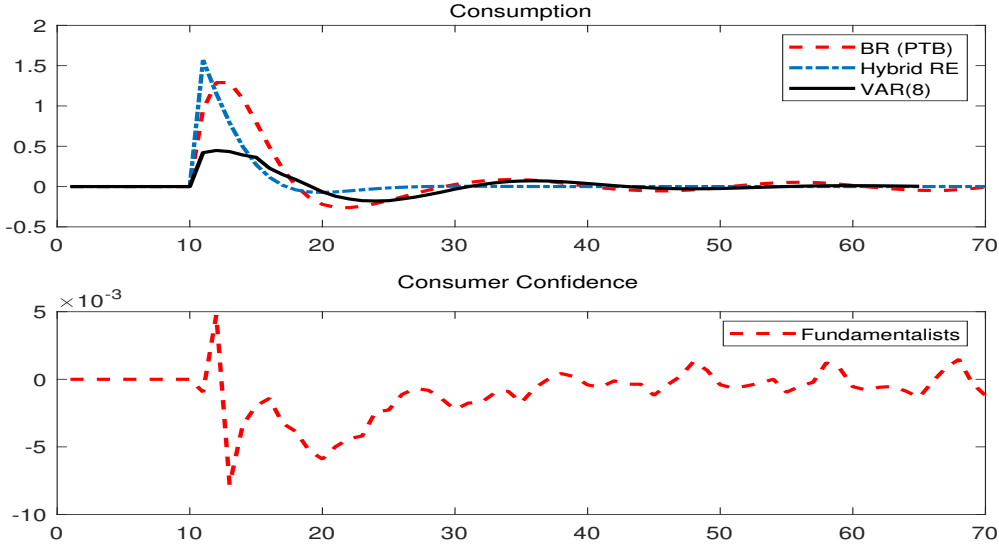
Note: The upper and lower panels display the IRFs with respect to consumption and consumer confidence, respectively. The latter shows the dominance of one group over the other group(s) of consumers. The deviations from the steady state in percentage terms are shown on the vertical axes. The periods in quarterly magnitudes are displayed on the horizontal axes. The shock hits the economy in period $t = 10$. Both model specifications are calibrated according to the parameter estimates in Table 1.

servations suggest that over time the dominance of one group over the other alternates: since agents switch from a technical to a more emotional grounded expectation formation scheme and vice versa, the impact of the shock prevails. This is indeed characterized by a high degree of autocorrelation in consumer confidence, as discussed by Jang and Sacht (2018). The persistence effect is dampened in the RE case without switching. Hence, the BR model is a good approximation of the consumption dynamics in the impact phase, while the opposite is true for the RE model. This resembles our empirical result regarding the fitting of both models to the data, where both values of J are, in fact, indistinguishable (see Table 1).

Figure 2 shows the outcome for the Euro Area. In the impact phase, we observe a rapid reversal in the dominance of fundamentalists over chartists. This leads to a quantitatively strong increase in consumption as in the RE case. Both IRFs show almost identical dynamics, which can be explained by the high weight on the backward-looking expectation formation in both model frameworks. To see this consider that $\chi = 1$, $\psi_c = 0.762$ and $\xi_c = 1.010$ hold according to Table 1.

However, consumer confidence becomes more volatile under BR, which holds

Figure 2: IRFs: positive demand shock (Euro Area)



Note: See Figure 1.

because of the dominance of chartists in the impact phase. Indeed, this group extrapolates into the future under the consideration of the past realization of consumption up to the second lag. This dominance translates into the highest peak (around period $t = 12$) and lowest trough (around period $t = 20$) in consumption, which coincide with the fact that fundamentalists are highly dominated in the corresponding periods. Therefore, in these time periods, the IRFs (to be shown in the lower panel) are below zero. The increase in the relative fraction of fundamentalists from the beginning of the convergence phase contributes to a decrease in volatility over time. However, in the absence of RE, volatility in consumption prevails in the BR model framework, while the opposite holds for the RE model.

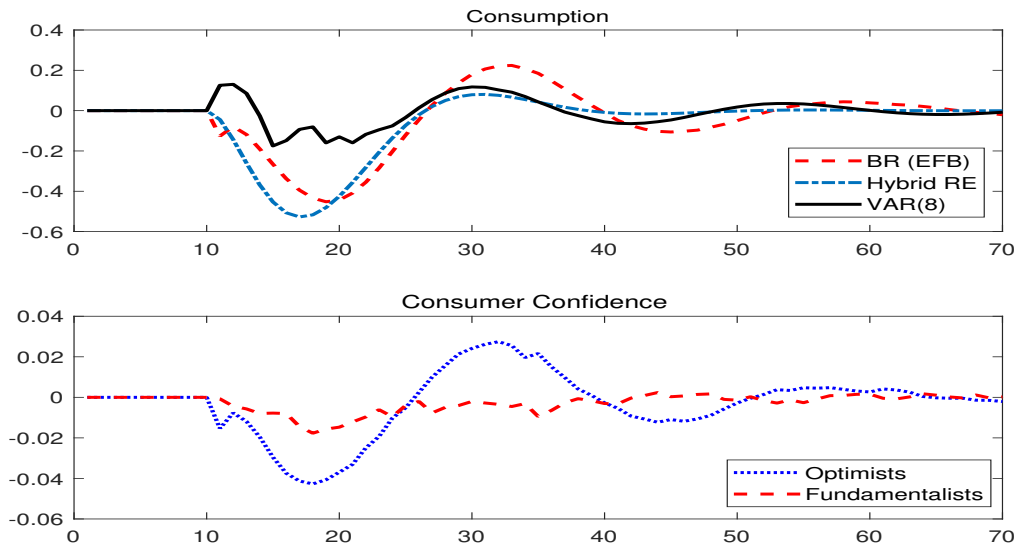
Overall, the IRF of the BR model matches the one from the VAR well, especially in the convergence phase. This observation is in line with the better empirical fit of this model type compared with the RE one judged by the different values for J (see, again, Table 1).

4.2 Cost-Push Shock

Figures 3 and 4 depict the adjustments in the macroeconomic variables in the case of a non-autocorrelated cost-push shock in the US and Euro Area. The latter leads to an increase in the price level induced by firms, which changes their prices periodically. As a result, the inflation rate increases on impact (i.e., $\varepsilon_{\pi, \tilde{t}} > 0$ holds at $\tilde{t} = 10$). Since the central bank can influence the inflation rate

only indirectly, it faces a trade-off between inflation and output stabilization. To dampen the boost in the inflation rate, the monetary authority must raise the nominal and (because of the Taylor principle) real interest rates. However, this leads to a decrease in the output gap on impact since now it is less attractive to consume more goods instead of purchasing bonds. In other words, households smooth their consumption because of the increase in their interest payments on bonds. The trade-off is now described by the fact that the output gap and inflation rate (not shown here) move in opposite directions.

Figure 3: IRFs: positive cost-push shock (US)



Note: See Figure 1.

Indeed, the oil crises in 1973 and 1979 serve as prominent examples of real-life disturbances in this manner. Again, in the case of a cost-push shock, to target a lower level of inflation after the shock occurs, the central bank must allow for a negative output gap on impact. Therefore, the analysis of such a supply shock is of high interest for conducting (optimal) monetary policy because of the output/inflation trade-off.

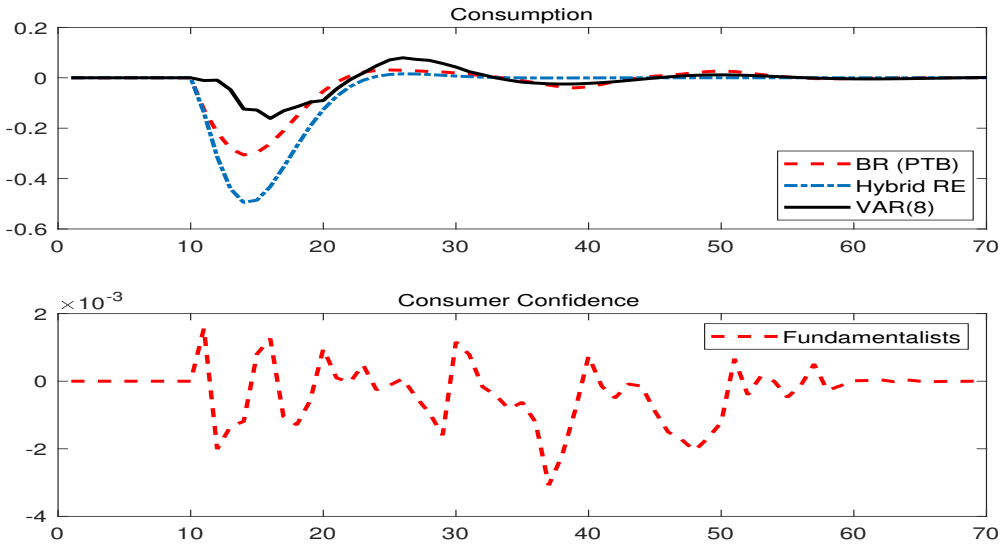
With respect to the BR model framework, the forecast strategy of pessimists dominates in the impact phase. Therefore, the IRFs for consumer confidence labeled "Optimists" and "Fundamentalists" *both* lie below zero. This indicates that pessimists represent the largest fraction among all groups of bonded rational agents. While fundamentalists become more dominated than optimists, the subjective mean value of (minus) 1.621 plays a larger part in anchoring the consumption expectation than the steady-state value. As a result, the deviation from the VAR model's IRF is less pronounced than the one under RE. In the

latter, future deviations are predicted by construction.

In the convergence phase, we observe a better match of the IRF that stems from the RE model than from the BR model. The reason for this finding can be found in the calibration of the speed of convergence to be considered in fundamentalists' forecast heuristics. According to our estimates, $\phi_c = 0.951$ holds, which indicates a purely backward-looking expectation formation scheme applied by this group of agents (see heuristic (6)). Hence, the hump-shaped movement, while primarily caused by the dominance of chartists, is amplified by the forecasting behavior of fundamentalists.

Recall that the BR model mimics the real-world consumption dynamics better than the RE one does in the impact phase. The opposite holds for the convergence phase owing to the low degree of consumption volatility according to the IRF from the VAR model. However, both frameworks fail to replicate the increase in consumption over the first three periods after the shock occurs — with the slight exception of the BR model in which we observe a small upward movement of the corresponding IRF in period $t = 13$.

Figure 4: IRF: positive cost-push shock (Euro Area)



Note: See Figure 1.

For the Euro Area, the BR model is the most appropriate model for analyzing this kind of shock in this scenario. This basically holds, as we observe first a decline and then a reversal in the VAR model's IRF. In the impact and convergence phases, the IRFs under BR therefore come close those in the VAR one. This matching of IRFs is explained by the ongoing fluctuation in consumer con-

fidence. As fundamentalists and chartists dominate each other alternately over time, this leads to a moderate fluctuation in consumption around the steady state in the convergence phase, as seen by the rough oscillation of the IRF labeled "Fundamentalists" around zero.

In addition, the troughs in the dynamics of consumption match the periods of chartists' dominance (e.g., around $t = 13$ and $t = 37$). Therefore, the exploration parameter ξ_c is estimated to be unity. This indicates again a purely backward-looking expectation formation scheme according to chartists' forecast heuristic (6). By comparison, the speed of convergence in fundamentalists' rule-of-thumb (5) is high but unequal unity with $\phi_c = 0.762$ in the Euro Area. For the RE model framework, the discrepancy in the IRF is large in the impact phase, while the dynamics quickly fade in the convergence phase as no expectation formation switching mechanism is assumed.

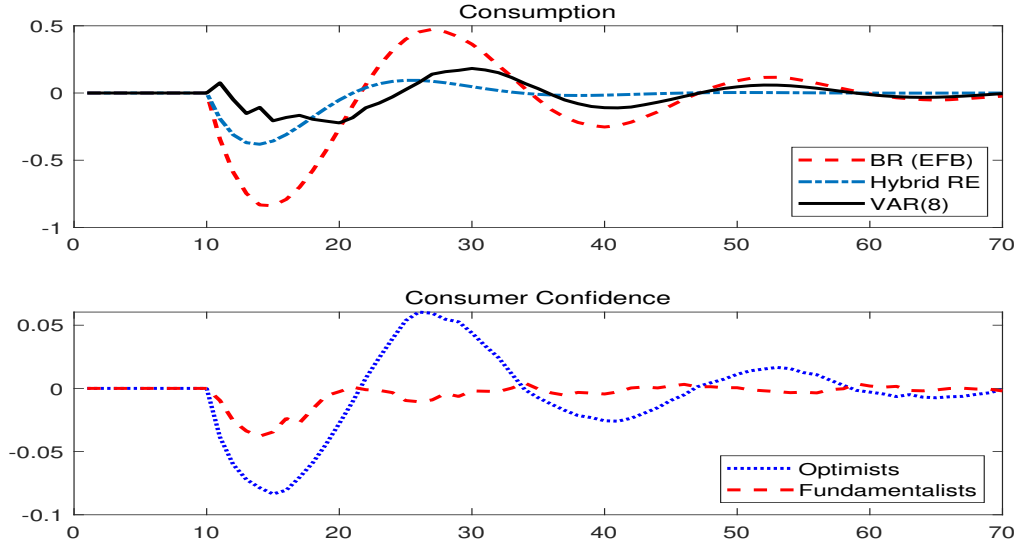
4.3 Monetary Policy Shock

An increase in the nominal interest rate by the central bank leads to an increase in the real interest rate because of the Taylor principle. Such a disturbance might represent the behavior of the Federal Reserve (FED) and European Central Bank (ECB) in the aftermath of the Great Recession. In particular, after a long period of low interest rates close to the zero-lower bound, an increase in the corresponding monetary policy instrument is expected (ECB) or has already been implemented (FED).

As an immediate outcome of the shock, the output gap declines on impact. The transmission channel can be briefly explained as follows. Since the household receives an interest payment when selling bonds in the next period, an increase in the corresponding real interest rate increases the attractiveness of holding bonds. Hence, demand for goods must decline at the same proportion as the amount of bonds increases. This effect is known as the intertemporal consumption smoothing effect, which is the cornerstone of the dynamic IS equation (1). As firms can set their prices, they decrease them as demand drops. The remaining firms, which face no price adjustment, then reduce the supply of goods. Hence, the goods market clears again after the shock occurs. Although $\varepsilon_{r,\tilde{t}} > 0$ in $\tilde{t} = 10$ is considered, we call this a negative shock since both output and inflation (again not shown here) decrease on impact.

Figure 5 shows the adjustments in consumption and consumer confidence over time for the US economy. The IRFs based on the VAR model exhibit a small degree of fluctuation and deviate significantly from the other two in the impact and convergence phases. In this scenario, the movement under RE comes close to the one predicted by the real data, especially in the impact phase. With respect to the latter, as in the case of a cost-push shock, the lower panel shows that the group of pessimists clearly dominates. This is not surprising since as a result of the negative shock, the forecast performance of pessimists (cf. equation (A2-2) in Appendix A2) seems to attain the highest value. Hence, a further

Figure 5: IRFs: negative monetary policy shock (US)



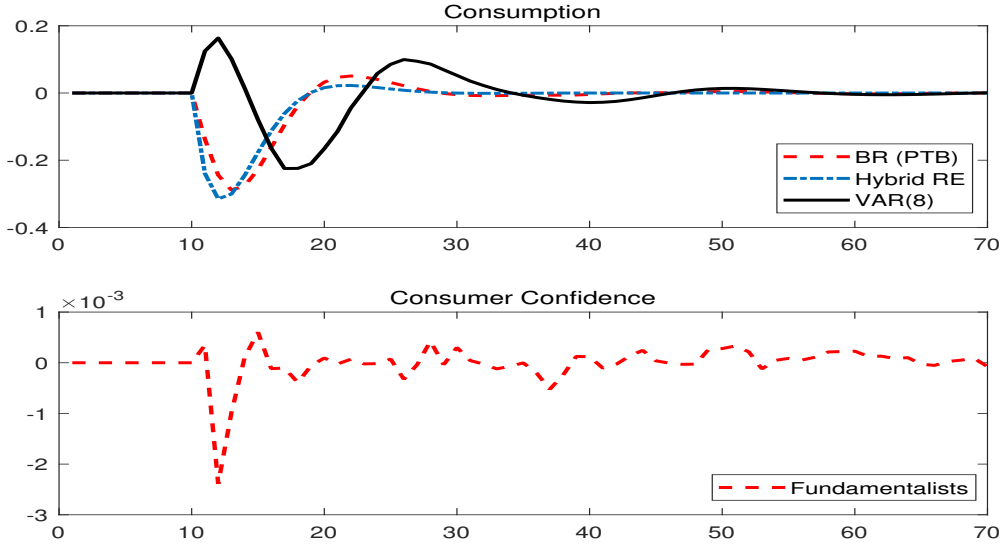
Note: See Figure 1.

negative deviation from the steady state is expected and members of the other two groups become pessimists. This translates into a strong negative reaction in consumption (to be seen in the upper panel) after the shock occurs.

The previous explanation ties into the behavior of optimists. The corresponding IRF, which displays the dominance of this group, alternates heavily over time. We observe a large trough and peak in the impact phase and at the beginning of the convergence phase, respectively. The upswing in consumer confidence after period 20 is grounded on the fact that the negative monetary policy impulse vanishes gradually. As a consequence, the forecast performance of optimists improves. The strong increase in confidence induced by a large amount of switching to the optimistic group leads to a boom period as consumption recovers after periods of high interest rates in the impact phase.

The high degree of fluctuation in the IRF under BR is linked to the moderate degree of dominance by fundamentalists, who apply a purely backward-looking expectation formation scheme (note, again, that $\phi_c = 0.951$ holds). As consumption equals its steady-state value around period $t = 21$, no group of bonded rational agents dominates the other, as shown by the intersection of the IRFs that resemble the dominance of optimists and fundamentalists at the exact point in time. Overall, monetary policy in the US economy creates high fluctuations over the business cycle in the absence of RE. This, however, is at odds with the observed development based on the real data.

Figure 6: IRFs: negative monetary policy shock (Euro Area)



Note: See Figure 1.

The IRF of the VAR model in Figure 6 shows an increase in consumption in the impact phase for the Euro Area scenario. While, as theoretically expected by the core structure of the NKM, household expenditure drops under BR and RE, we observe a peak around period $t = 15$ given the real data. As a result, the IRFs that stem from both models are the direct opposite to the VAR. Further, the VAR model's IRF also exhibits a higher degree of hump-shaped behavior, which leads to a longer convergence time back to the steady state. These differences could be explained by missing structural components in both model frameworks (e.g., investment decisions or the influence of financial markets). The higher rate of convergence under BR and RE can be explained by the purely backward-looking expectation schemes applied in both models. The strong dominance of chartists in the impact phase therefore translates into the trough around period $t = 12$ for consumption. As consumer confidence fluctuates around zero from the beginning of the convergence phase onwards, the corresponding fluctuations in consumption are mitigated.

The analysis of the IRFs for the Euro Area reveals that both model frameworks fail to capture real economic development. This raises the question of potential misspecification in the underlying model structure. However, this study deals with a stylized version of the baseline NKM and thus more elaborate specifications of the model under RE in terms of additional structural equations to be considered might solve the mismatch of the IRFs. The same may be true for the BR model in which introducing forecast heuristics different to those discussed in this study should also be considered.

5 Conclusion

The discussion of the kind of economic model that is most suitable for describing the adjustment over the business cycle has become more crucial since the period of worldwide distress after 2008. Hence, macroeconomic model frameworks built on a heterogeneous agent structure together with bounded rational expectation formation have gained in importance. Indeed, all the specific types of forecast heuristics have led to a variety of stylized models being used for policy analysis in the absence of RE.

In this study, we calibrate two versions of the baseline NKM based on the parameter estimates reported by Jang and Sacht (2018). We then analyze the IRFs for the model under RE and BR with a focus on the US economy and Euro Area. For the latter, we assume that rules-of-thumb are applied in the expectation formation. Our analysis highlights the importance of relevant policies during the transition period because a central bank faces different dynamic consumption patterns based on the degree of rationality. To check the plausibility of our results, we compare the different IRFs to the one obtained from a VAR model based on real data.

Indeed, our results address the challenges that policymakers face, especially when stimulating the economy via fiscal and/or monetary policy in the presence of animal spirits. For example, few studies have investigated (optimal) monetary and fiscal policy under BR (cf. Caprioli 2015, De Grauwe and Macchiarelli 2015, Hollmayr and Matthes 2015, Lengnick and Wohltmann 2016). Cornea-Madeira et al. (2017) state that owing to the existence of multiple equilibria in a complex system under BR, valid empirical evidence for behavioral heterogeneity is questioning the formulation of the optimal policy design under the RE paradigm. They show that heterogeneity varies over time, concluding that inflation dynamics can be dominated by either forward-looking or backward-looking behavior.

In particular, the focus of this study is on the development of consumption over time. Our observations reveal that the BR model framework is qualitatively and quantitatively more capable of capturing real-life dynamics. This holds in terms of the smaller deviations of the corresponding IRFs to the one from the VAR model compared with the framework under RE. The fluctuations in consumer confidence, as a measure of the dominance of one group of bounded rational agents over others, mainly explain the degree of persistence in consumption. This is also confirmed by the robustness exercise applied in Jang and Sacht (2018) under consideration of different US monetary policy regimes. Without any kind of switching in the expectation formation, the hybrid version of the model under RE with lead and lags fails to describe the hump-shaped behavior of household expenditure.

While the previous statement is true for a positive demand and a cost-push shock, both models generate IRFs that are at odds with that predicted for the

development of consumption in the case of a negative monetary policy shock – at least in the Euro Area scenario. This raises the question of severe model mis-specification for both theoretical frameworks. This issue can be overcome by allowing a more elaborate model structure combined with different forecast heuristics being considered in the BR model framework. Our results indicate that further research on the impact of the different kinds of shocks under the incorporation of rule-of-thumb behavior into macroeconomic dynamics is needed. We leave this to future research and claim that our analysis of IRFs stands out as a point of departure in this regard.

Appendix

A1: The Core Structure of the Hybrid NKM

The baseline NKM in its hybrid variant is as follows:

$$c_t = \frac{1}{1 + \chi} \tilde{E}_t^j c_{t+1} + \frac{\chi}{1 + \chi} c_{t-1} - \tau(r_t - \tilde{E}_t^j \pi_{t+1}) + \varepsilon_{c,t} \quad (\text{A1-1})$$

$$\pi_t = \frac{\nu}{1 + \alpha\nu} \tilde{E}_t^j \pi_{t+1} + \frac{\alpha}{1 + \alpha\nu} \pi_{t-1} + \kappa c_t + \varepsilon_{\pi,t} \quad (\text{A1-2})$$

$$r_t = \phi_r r_{t-1} + (1 - \phi_r)(\phi_\pi \pi_t + \phi_c c_t) + \varepsilon_{r,t} \quad (\text{A1-3})$$

$$c_t = y_t \quad (\text{A1-4})$$

with $j = \{RE, BR\}$. Here, we consider a stylized version of the well-known Smets and Wouters (2003, 2005) model. All the variables are given in gap notation (i.e., $s_t = \hat{s}_t - \bar{s}$ holds), where we consider the deviation of the contemporaneous realization of this variable from its constant steady-state value denoted by $\hat{s} = \{\hat{c}, \hat{\pi}, \hat{i}\}$ and $\bar{s} = \{\bar{c}, \bar{\pi}, \bar{i}\}$, respectively. In the main text, we omit the expression "gap" to ensure a clear arrangement if it is not necessary.

In equation (A1-1), private consumption expenditure stems from the intertemporal optimization of consumption and saving, which leads to consumption smoothing (based on the realizations of the real interest rate gap denoted by $r_t - \tilde{E}_t^j \pi_{t+1}$). The parameter $\tau \geq 0$ denotes the inverse of the intertemporal elasticity of substitution in consumption behavior. Equation (A1-2) represents the NKPC, where aggregate consumption (c_t) acts as the driving force of inflation (π_t) dynamics under monopolistic competition and the Calvo-type sticky price setting scheme. The slope of the NKPC is given by the parameter $\kappa \geq 0$. ν measures the discount factor ($0 < \nu < 1$). Hybridity is incorporated into the demand and supply framework by using the parameters for habit formation $0 \leq \chi \leq 1$ and price indexation $0 \leq \alpha \leq 1$, respectively.

According to the ad-hoc Taylor rule with interest rate smoothing (A1-3), the nominal interest rate gap (r_t) is a predetermined variable with the corresponding persistence parameter $0 \leq \phi_r \leq 1$. The monetary authority reacts directly to contemporaneous movements in the gaps of consumption ($\phi_c \geq 0$) and inflation ($\phi_\pi \geq 0$). We assume that the exogenous driving forces follow idiosyncratic

shocks $\varepsilon_{s,t}$, which are independent and identically distributed around mean zero and variance σ_s^2 with variables $s = \{c, \pi, r\}$. As mentioned above, as a main characteristic of linearized DSGE models, the dynamics are described by the deviations from the steady state, where consumption expenditure equals output in the equilibrium. Hence, equation (A1-4) implies that equation (A1-1) expresses only the standard dynamic IS curve. That becomes even more apparent as equation (A1-4) stands for the national income identity in the absence of private investment, the trade balance, and government expenditure, as assumed in our prototype model here. The appearance of c_t in the NKPC (A1-2) and the Taylor rule (A1-3) can be justified from a theoretical point of view given the equilibrium condition (A1-4); see Galí (2015) for more details.

A2: Switching in the BR Framework

Now, we consider the description of the forecast heuristics (5) to (10) and the core structure of the model found in Section 2 and Appendix A1, respectively. The expression for the market forecast regarding consumption across the four groups is given by

$$\tilde{E}_t^{BR} c_{t+1} = \sum_{i=1}^4 (\alpha_{c,t}^{k\{i\}} \cdot E_t^{k\{i\}} c_{t+1}) \quad (\text{A2-1})$$

with $k = \{O, P, F, C\}$. The probability $\alpha_{c,t}^k$ indicates the stochastic behavior of agents who adopt a particular forecasting rule (i.e., out of the equations (5) to (8)). More precisely, $\alpha_{c,t}^k$ can be interpreted as the probability of being an optimist, pessimist, fundamentalist or chartist with respect to the development of consumption in period t . The selection of the forecasting rules (5) to (8) depends on the forecast performances of each group given by the mean squared forecasting error U_t^k . The utility for the forecast performances can be simply updated in every period as (cf. Brock and Hommes 1997)

$$U_{c,t}^k = \rho U_{t-1}^k - (1 - \rho)(E_{t-2}^k c_{t-1} - c_{t-1})^2, \quad (\text{A2-2})$$

where the parameter ρ is used to measure symmetrically the memory of the four types of agents ($0 \leq \rho \leq 1$). Here $\rho = 0$ suggests that agents have no memory of past observations, while $\rho = 1$ means that they have infinite memory. Agents can revise their expectations by applying the discrete choice approach given their forecast performances. The different types of performance measures can be utilized for $\alpha_{c,t}^k$ as follows:

$$\alpha_{c,t}^{\tilde{k}} = \frac{\exp(\gamma U_t^{\tilde{k}})}{\sum_{i=1}^4 \exp(\gamma U_t^{k\{i\}})}; \quad (\text{A2-3})$$

$$\alpha_{c,t}^C = \frac{\exp(\gamma U_t^C)}{\sum_{i=1}^4 \exp(\gamma U_t^{k\{i\}})} \cdot \exp\left[-\frac{(c_{t-1} - \bar{c})^2}{\varpi}\right], \quad (\text{A2-4})$$

with $\varpi > 0$ being the correction term. The parameter $\gamma \geq 0$ denotes the intensity of choice. Equations (A2-1) to (A2-4) have to be adjusted conditional on

any expectation formation scenario considered.

We distinguish the probabilities of the subgroups $\tilde{k} = \{O, P\}$ in (A2-3) from the one regarding chartists in (A2-4). Compared with the groups of optimists, pessimists, and fundamentalists, according to the forecast heuristics of chartists given by equation (6), they react to the historical pattern of consumption for up to two lags but not at the steady state. It follows that as this group exhibits the best performance among all groups, this forecasting strategy becomes the dominant one. The expected deviation of past realizations in consumption over two lags then contributes heavily to the volatility of economic dynamics if market sentiment is associated with higher chartist weights. As a result, an ongoing deviation of consumption from its steady-state value is observed, which leads to divergent adjustment paths and, hence, instability. Since we are interested in a convergent solution in favor of future policy analysis, we account for this kind of penalty term in equation (A2-4) with the value of ϖ as imposed by Gaunersdorfer et al. (2008). The latter can be seen as the transversality condition in the model with heterogeneous agents (Hommes 2011), which ensures that "speculative bubbles" cannot last forever (cf. Gaunersdorfer et al. 2008).

The probability of being a fundamentalist is then given by

$$\alpha_{c,t}^F = 1 - \sum_{i=1}^3 \alpha_{c,t}^{\tilde{k}\{i\}} \quad (\text{A2-5})$$

with $\tilde{k} = \{O, P, C\}$. Again, according to the different scenarios considered, the specification in equation (A2-5) must differ accordingly. Equations (A2-1) to (A2-5) have to be adjusted in the case of the inflation expectation formation process. The memory parameter given by ρ remains the same for consumption and also for inflation. Further, while we consider different heuristics with respect to consumption expectations, the ones for inflation remain the same; these are given by (9) and (10) under BR.

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