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Sebastian Debes, Johannes Gareis,
Eric Mayer, and Sebastian Rüth[a]

[a]University of Würzburg

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University of Würzburg
Department of Economics
Chair VWL 1
Sanderring 2, D-97070 Würzburg
eric.mayer@uni-wuerzburg.de

Postal Address

Eric Mayer
University of Würzburg, Department of Economics, Sanderring 2,
97070 Würzburg, Germany
Email: eric.mayer@uni-wuerzburg.de

Towards a Consumer Sentiment Channel of Monetary Policy

Sebastian Debes, Johannes Gareis, Eric Mayer, and Sebastian Rüth*

Abstract

We investigate the role of consumer confidence in the transmission of monetary policy shocks from an empirical and theoretical perspective. Standard VAR based analysis suggests that an empirical measure of consumer confidence drops significantly after a monetary tightening and amplifies the impact of monetary policy on aggregate consumption. Using a behavioral DSGE model, we show that a *consumer sentiment channel* can account for the empirical findings. In an environment of heterogeneous expectations, which gives rise to the notion of *consumer sentiment*, innovations to the Federal Funds rate impact on consumer confidence and thereby the broader economy.

Keywords: Monetary policy, monetary transmission, consumer sentiment.
JEL codes: E32, E52, D83.

*University of Wuerzburg, Department of Economics, Sanderring 2, 97070 Wuerzburg, Germany.
Corresponding author: Eric Mayer; E-mail: eric.mayer@uni-wuerzburg.de, Tel.: +49-(0)931-3182948.

1 Introduction

In this paper, we investigate the role of consumer confidence in the transmission of monetary policy from an empirical and theoretical perspective. Loosely speaking, we raise the question whether monetary policy is operative - besides other well-known channels - via a *consumer sentiment channel* that determines aggregate demand? While, on the one hand, a large body of existing literature studies the effects of monetary policy shocks on the business cycle (e.g. Christiano, Eichenbaum and Evans, 2005, among others), on the other hand, a large strand of literature focuses on consumer confidence and its effects on the macroeconomy.[1] To the best of our knowledge, we are the first to look at both sides of the coin. Our empirical analysis reveals that consumer confidence drops significantly after a monetary tightening and amplifies the impact of monetary policy on aggregate consumption. Using a behavioral DSGE model, we argue that a *consumer sentiment channel* can account for the empirical findings.

Among politicians, central bankers, and in the media it is a well-established idea that consumer confidence is an important factor to understand the business cycle. In academics, a cautious consensus view is that consumer confidence indices, such as those from the *Michigan Survey of Consumers*, contain information, which is not already included in other macroeconomic variables (Acemoglu and Scott, 1994; Carroll, Fuhrer and Wilcox, 1994; Matsusaka and Sbordone, 1995). However, the empirical finding that confidence indices are informative in itself and exert a causal impact on the economy, has not led to a common structural interpretation.

Broadly speaking, there are at least two alternative structural views on the role of consumer confidence and its repercussions on the broader economy (see e.g. Bachmann and Sims, 2012). One approach may be labeled as "*news approach*". In this view, consumers are exposed to noisy information on future economic fundamentals, e.g. aggregate or idiosyncratic productivity. Therefore, surprise changes in consumer confidence simply reflect news on fundamentals far in the future that fully rational agents take into account and which tend to have long lasting effects on economic activity (see e.g. Barsky and Sims, 2012). A natural interpretation of this empirical finding is that persistent changes in output should reflect productivity, e.g. shocks to the expected growth rate, and not demand side factors. In this view, pure "*animal spirits*" shocks, e.g. noise shocks that

[1] See for instance Acemoglu and Scott (1994), Carroll, Fuhrer and Wilcox (1994), Matsusaka and Sbordone (1995), Ludvigson (2004), and Barsky and Sims (2012).

contaminate a signal about future growth, can only have transitory effects on economic activity. Closely related to this approach is the idea that consumers are exposed to news on e.g. future income, but due to financial frictions that prevent optimal intertemporal consumption smoothing, these news are not fully reflected in current income changes (see Mankiw, 1982; Carroll, Fuhrer and Wilcox, 1994). Therefore, consumer confidence contains information that is orthogonal to current fundamentals. Recently, the role of consumer confidence not only as an autonomous source of disturbances, but also as an important factor in the transmission of fiscal shocks has received a tremendous amount of interest. Bachmann and Sims (2012) report empirical evidence for fiscal shocks in recession regimes. They find that the effects of consumer confidence in the transmission on output are best characterized as slowly building up and long lasting. A reasonable interpretation of this evidence is that shifts in government spending towards investment items such as infrastructure or education signals future productivity gains, which improve future income.

An alternative to the *news approach* is the idea popularized by Pigou (1927) and Keynes (1936) that contagious outbreaks of optimism or pessimism that may even be, at least to a certain extent, autonomous and disconnected from future fundamentals amplify the business cycle. This concept may be labeled as *pure sentiment* or *animal spirits* view. According to this view, Blanchard (1993) characterizes the pronounced drop in consumption, which in his view caused the 1990/91 recession, as not justified by obvious fundamentals and a result of *animal spirits*. In particular, Akerlof and Shiller (2008) recently revitalized this popular idea. Emphasizing the policy relevance of *animal spirits*, they coined the punchline: "*there are limits to the effectiveness of (...) monetary policy when there is a loss in confidence*" (see Akerlof and Shiller, 2008, p.74). Furthermore, empirical contributions provide evidence that *animal spirits*, also labeled as "*consumer misperceptions noise shocks*" (see Hürtgen, 2014, p.279) may be quantitatively important for business cycle fluctuations if prices and wages are highly sticky and the response of monetary authorities to inflation is low. In particular, these studies assign a prominent role of *pure noise shocks* to variations in consumption as these shocks help to explain between 25 percent (Hürtgen, 2014) and 75 percent (Blanchard, L'Huillier and Lorenzoni, 2013) of consumption fluctuations in the short run. In addition, Lorenzoni (2009) and Angeletos and La'O (2013) propose different theoretical frameworks, which both give rise to the notion of *pure noise shocks* as a source of short run fluctuations.

Overall, the structural interpretation of the time series evidence in this paper is closer to the idea of Keynes (1936), as our theoretical model builds on concepts of bounded rationality and cognitive limitations that support the notion of contagious outbreaks of optimism and pessimism. These waves in *sentiment* have repercussions on the macroeconomy that are not related to news on future fundamentals. Our motivation to deviate from the *news approach* of modeling confidence in DSGE models (see e.g. Barsky and Sims, 2012) is twofold. First, in contrast to the empirical evidence for fiscal shocks (Bachmann and Sims, 2012), our findings suggest that other mechanisms dominate in the face of monetary policy shocks, as we find quantitatively important, but short lived responses of consumption. That is, we report that consumer confidence quickly kicks in after a monetary shock and amplifies aggregate demand for approximately two years, but has no long lived effects. This empirical pattern does not signal that monetary policy shocks foreshadow changes in future productivity growth.[2] Additionally, DSGE models commonly used for monetary policy analysis offer no clear link between monetary policy and productivity growth far in the future. Second, from a modeling perspective, standard DSGE models rely on rational expectations and thus homogeneous beliefs among consumers (e.g. Smets and Wouters, 2007). In contrast, behavioral models can easily deal with heterogeneous beliefs, where consumers disagree on the future evolution of the economy. Thereby, we easily succeed to classify consumers into optimists and pessimists, which gives rise to an endogenous macroeconomic variable for consumer confidence. This feature is absent in standard DSGE models that usually define consumer confidence as a transformation of exogenous shocks (Barsky and Sims, 2012).

We proceed as follows. In a first step, we estimate a standard Vector-Auto-Regressive (VAR) system including consumer confidence as measured by the *Michigan Survey of Consumers*, and identify a monetary policy shock by the workhorse Cholesky decomposition. Based on impulse response analysis and variance decompositions, our empirical evidence suggests that consumer confidence reacts in a statistically significant and economically meaningful fashion to monetary policy shocks. Concretely, in response to a 100 basis point shock to the Federal Funds rate, consumer confidence drops significantly by 2 index points. Additionally, consumer confidence is important to understand the transmission of monetary disturbances. Based on counter-factual exercises, we isolate the marginal impact of confidence on aggregate consumption by shutting down the confidence response (see e.g.

[2] Our *pure sentiment* interpretation is in line with Blanchard (1993, p.274), who states that it is a "*plausible assumption that animal spirits have little or no long-run effect on output*".

Bachmann and Sims, 2012). Our estimates indicate that confidence adds up to one third of the total drop in consumption. Variance decompositions reveal that monetary policy shocks explain up to 7 percent of the variation in confidence at an eight quarter horizon.

In a second step, we offer a structural interpretation by building a DSGE model that incorporates confidence in a behavioral fashion in the spirit of De Grauwe (2010*a*,*b*, 2011). Given the empirical evidence both at the micro and macro level in favor of heterogeneous and biased expectations, behavioral mechanisms that allow for cognitive limitations provide a natural way to explain why confidence may influence the behavior of agents in an environment of bounded rationality.[3] By allowing for heterogeneous expectations, we succeed to model consumer confidence directly by computing the overhang of optimistic versus pessimistic consumers, which form their expectations based on simple heuristics.[4] With these fractions at hand, our model provides an endogenous variable that can directly be related to standard definitions of consumer confidence. Our theoretical analysis provides evidence that the permanent evolutionary competition and switches between alternative heuristics are of macroeconomic relevance when agents start to choose the same heuristic simultaneously. We show that monetary policy can trigger such a contagion in beliefs. The associated swing in consumer confidence initiates fluctuations in consumption in a self-fulfilling fashion, which amplifies the consumption reaction after a monetary policy shock beyond the well-known channels.[5] To flesh out the marginal effect of this *pure sentiment channel*, we perform counter-factual experiments, where we keep the level of consumer confidence fixed when the monetary policy shock hits the economy. Our findings suggest that the theoretical model is able to replicate the qualitative results of the empirical VAR analysis. When the *sentiment channel* is shut off, monetary policy is less effective in terms of affecting consumption than in an environment, where monetary policy triggers a reaction in consumer confidence.

[3]See e.g. Branch and Evans (2006); Hommes (2006); Brazier et al. (2008); Branch and McGough (2009); Branch and Evans (2010); De Grauwe (2010*a*,*b*); Guse (2010); De Grauwe (2011); Anufriev et al. (2012), and Massaro (2013).

[4]As standard in the rational choice theory, agents are not dumb. Agents' behavior is rational to the extend that they continuously evaluate subjective forecasts against actual outcomes. Based on the forecast performance, people may change their mind and switch, e.g. from optimists to pessimists, when they learn that their beliefs were wrong (see Anderson, De Palma and Thisse, 1992; Brock and Hommes, 1997).

[5]Our interpretation of consumer confidence as an important factor in the transmission of monetary policy into consumption is also related to the idea of expectation driven business cycles as beliefs are self-fulfilling, if a sufficient fraction of agents follows a particular forecasting rule. See e.g. Benhabib and Farmer (1994) and Farmer and Guo (1994) for the idea that expectation driven cycles with multiple equilibria exist, and "*sunspots*" are driven by non-fundamental shocks. These contributions show that monetary policy may be an important factor in stabilizing aggregate expectations and guide the economy to superior equilibrium outcomes.

The paper is structured as follows. In the next section, we report our empirical findings, based on VAR evidence. Our structural model, which explains how consumer confidence influences the transmission of monetary policy shocks, is presented in Section 3. In Section 4, we map our empirical findings into our theoretical model. Section 5 presents the results from our behavioral model and discusses the economic importance of a *consumer sentiment channel* in monetary policy transmission from a theoretical perspective. Section 6 concludes the paper.

2 Empirical Methodology

In this section, we present the econometric strategy and our main empirical findings.

2.1 Estimation, Data, and Identification

Since Sims (1980), it is well established to use Vector-Auto-Regressions (VAR) to analyze the process of monetary transmission over the business cycle.[6] In particular, we specify the following reduced form VAR model for the US economy as

$$\boldsymbol{Y_t} = \boldsymbol{c} + \boldsymbol{\Phi_1} \boldsymbol{Y_{t-1}} + ... + \boldsymbol{\Phi_p} \boldsymbol{Y_{t-p}} + \boldsymbol{\varepsilon_t}, \text{ with } \mathbb{E}[\boldsymbol{\varepsilon_t}] = 0 \text{ and } \mathbb{E}[\boldsymbol{\varepsilon_t} \boldsymbol{\varepsilon_t}'] = \boldsymbol{\Sigma_\varepsilon}. \tag{1}$$

$\boldsymbol{Y_t}$ is a vector comprising m endogenous variables measured at time $t = 1, ..., T$, and $\boldsymbol{c}$ represents a $m \times 1$ vector including constants. The $m \times m$ matrix $\boldsymbol{\Phi_i}$ contains auto-regressive polynomials at horizon $i = 1, ..., p$, and $\boldsymbol{\varepsilon_t}$ represents the one step ahead forecast errors. We employ Bayesian methods for inference and estimation. Following the footsteps of Koop and Korobilis (2010), we implement an independent Normal-Wishart prior and take $100,000$ draws from the posterior simulator, where we discard the first $20,000$ draws.[7] The Bayesian treatment of the VAR coefficients allows for parameter uncertainty and is widespread in the literature (see e.g. Uhlig, 2005, among others). We estimate the model with four lags.[8]

[6] See e.g. Bernanke and Blinder (1992), Leeper, Sims and Zha (1996), and Christiano, Eichenbaum and Evans (1999), among others.

[7] See also Koop and Korobilis (2010) for the implementation of this prior, which enables us to do restricted estimations by allowing the explanatory variables to differ across regression equations.

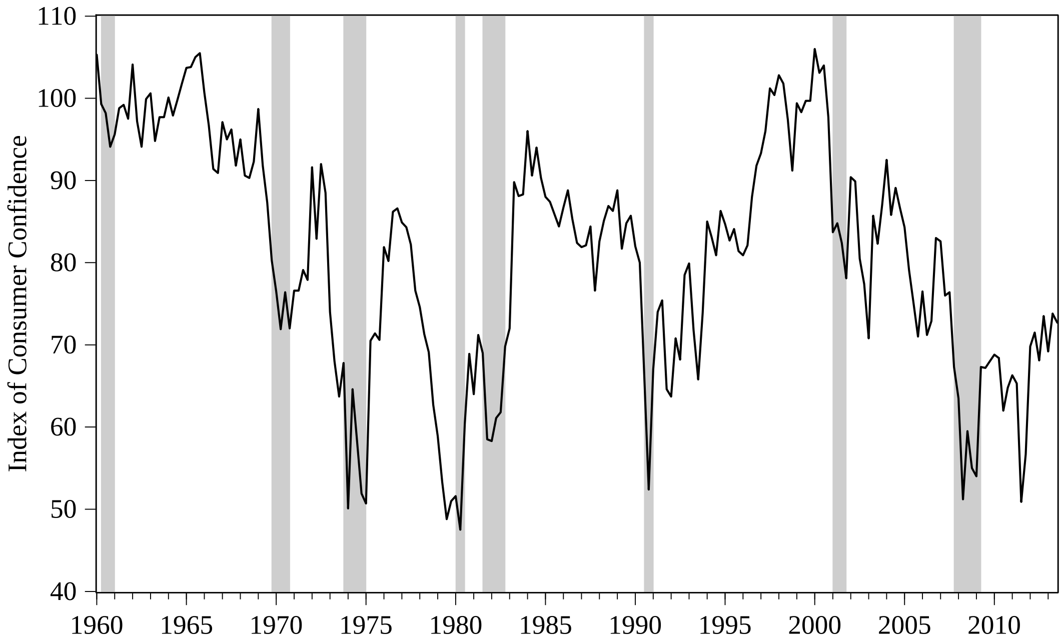
[8] This lag order seems to sufficiently capture the dynamics of the system, as it assures that squared regression residuals dismiss evidence for conditional heteroscedasticity as well as for auto-correlation. In particular, this large number of lags proved useful to mitigate the price puzzle (Eichenbaum, 1992). However, different lag lengths yield qualitative very similar results.

In our baseline estimation four data series of quarterly frequency enter the VAR:

$$\boldsymbol{Y_t} = [\ \texttt{CONS}_t\ \texttt{INFL}_t\ \texttt{FFR}_t\ \texttt{CONF}_t\ ]' . \tag{2}$$

Price inflation, $\texttt{INFL}_t$, is the annualized log difference of the seasonally-adjusted GDP deflator, $\texttt{DEFL}_t$. $\texttt{CONS}_t$ represents seasonally-adjusted personal consumption expenditures, which we deflate with $\texttt{DEFL}_t$ and normalize by the civilian non-institutional population, $\texttt{POP}_t$. $\texttt{FFR}_t$ stands for the annualized Federal Funds rate.[9] As in Bachmann and Sims (2012), our measure of primary interest, i.e. the consumer confidence series, $\texttt{CONF}_t$, is the *Index of Consumer Expectations*, which we obtain from the *Survey of Consumers* conducted by the *University of Michigan* (see Figure 1).[10]

Figure 1: Consumer Confidence Index



Notes: The solid line depicts the evolution of the *Index of Consumer Expectations* in quarterly frequency. Shaded areas display NBER defined recession periods.

$\texttt{CONF}_t$ represents a normalized average of three (sub-)indices, which are calculated as the difference of optimistic and pessimistic outlooks of respondents: The first index comprises an assessment about the expected financial situation of the own family 12 months ahead. The second question asks for expectations about the financial environment for the whole

[9] All these data are downloaded from the *St. Louis FED's* database.

[10] See Appendix A for a detailed description of this time series.

economy over the same horizon and the last question extends the "forecast" horizon of the second component to 5 years. Figure 1 indicates that $\texttt{CONF}_t$ is a pro-cyclical time series; the correlation with the growth rate of our consumption measure, $\texttt{CONS}_t$, is 46 percent. Furthermore, it is evident that once confidence starts to revert, the turnaround occurs sharply and sustainably, i.e. confidence appears to be a jumpy time series (see also Bachmann and Sims, 2012). $\texttt{CONF}_t$ enters the VAR in levels. Our data sample covers the time interval from $1960Q1$ to $2007Q4$.[11]

To identify a monetary policy shock, we impose a recursive structure on the data. Therefore, we order $\texttt{CONS}_t$ first, $\texttt{INFL}_t$ second, and $\texttt{FFR}_t$ third to account for a monetary transmission lag. For confidence, $\texttt{CONF}_t$, the literature provides no indication why it should react to monetary policy with a time lag. Consequently, we allow $\texttt{CONF}_t$ to respond contemporaneously to monetary policy shocks and order it fourth in the system.[12]

2.2 Empirical Results

Figure 2 illustrates the reaction of macroeconomic variables in $\boldsymbol{Y_t}$ to a contractionary monetary policy shock of 100 basis points.[13]

In line with preceding studies (see e.g. Christiano, Eichenbaum and Evans, 1999), we detect a transitory rise in the central bank's policy instrument, $\texttt{FFR}_t$, which is significant for 6 quarters. For the reaction of price inflation, we observe the well known price puzzle (Eichenbaum, 1992), i.e. a temporary increase of inflation in the face of a contractionary monetary policy shock.[14] Though, after 12 quarters, price inflation is back to its neutral level and persistently turns negative. For consumer confidence, we can report a statistically significant and economically meaningful response in the face of a monetary tightening.[15] $\texttt{CONF}_t$ exhibits a pronounced drop of approximately -2 index points. From quarter 3 onwards, the temporary decline in confidence slowly decays and the impulse response reverts back to zero and becomes insignificant in quarter 9. Our consumption measure,

[11] The survey data start in $1960Q1$, which determines the begin of our sample. To avoid non-linearities caused by the Great Recession and induced zero lower bound episode, we restrict our sample to $2007Q4$ (Galí, Smets and Wouters, 2012). Prior to estimation, we regress our four time series on a linear trend.

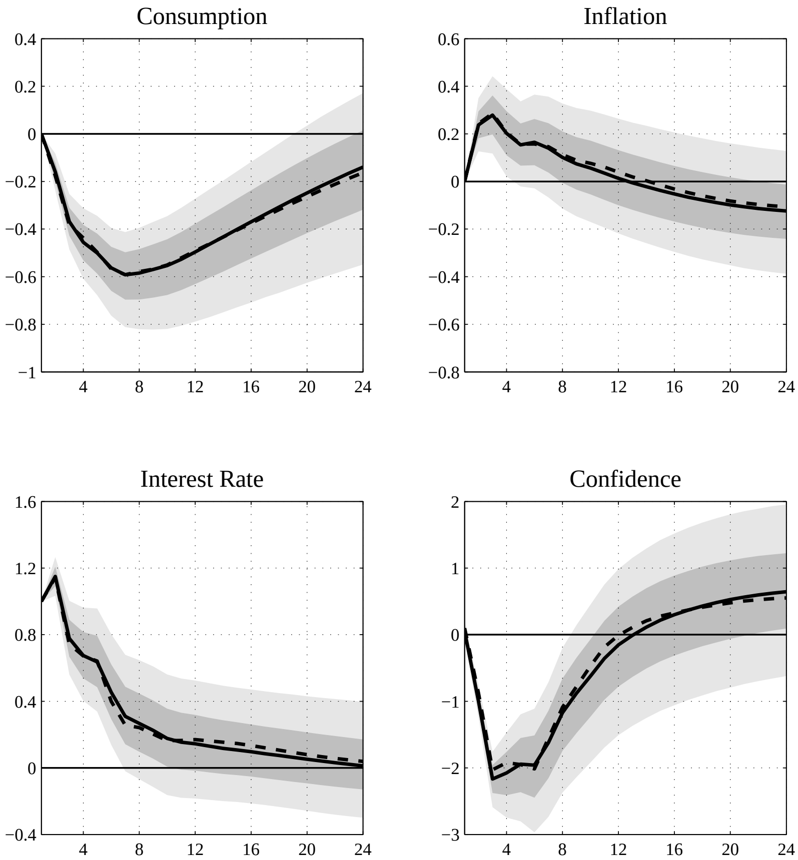
[12] Note that rearranging the position of confidence to prevent a reaction on impact yields even stronger effects compared to our baseline. These results are provided upon request.

[13] In addition to the median response (solid line), we report the median target solution (broken line) as the latter assures that all impulse responses are generated from the same structural model (Fry and Pagan, 2011). Though, there are no notable differences to detect.

[14] Additionally, controlling for commodity price inflation (Eichenbaum, 1992) only mildly attenuates the price puzzle in our case.

[15] Note that although we allow $\texttt{CONF}_t$ to react on impact to the monetary policy shock, the impulse response practically starts at zero.

Figure 2: Monetary Policy Shock with Confidence



Notes: The solid line depicts the median response. The dashed line represents the median target solution. Shaded areas display the 68% (dark gray) and 95% (light gray) quantiles obtained from the posterior distribution of the VAR.

$\texttt{CONS}_t$, contracts by approximately -0.6 percent in a hump-shaped manner reaching its peak in period 7 after the shock. Thereafter, the response slowly unfolds and becomes insignificant after one and a half years. The transitory confidence reaction together with the short lived consumption response do not hint towards a productivity mechanism with long lived effects operative in the transmission of the monetary policy shock. Therefore, our structural model interpretation of the time series evidence in Section 3 takes the route towards the *pure sentiment* hypothesis, which is consistent with the temporary dynamics observed after the monetary tightening (see e.g. Blanchard, 1993).

Furthermore, the importance of monetary policy shocks for consumer confidence is strengthened by the forecast error variance decomposition from Table 1. While accounting for the largest portion of variation in $\texttt{FFR}_t$, the monetary policy shock is of less importance for the forecast error in price inflation (see e.g. Stock and Watson, 2001), but helps to explain up to 24 percent of fluctuations in consumption over the medium horizon. Most important for our purpose and as a novel finding in the literature, we can report that up to 6.6 percent of the variation in confidence is attributed to monetary policy shocks.

Table 1: Variance Decomposition for Monetary Policy Shock

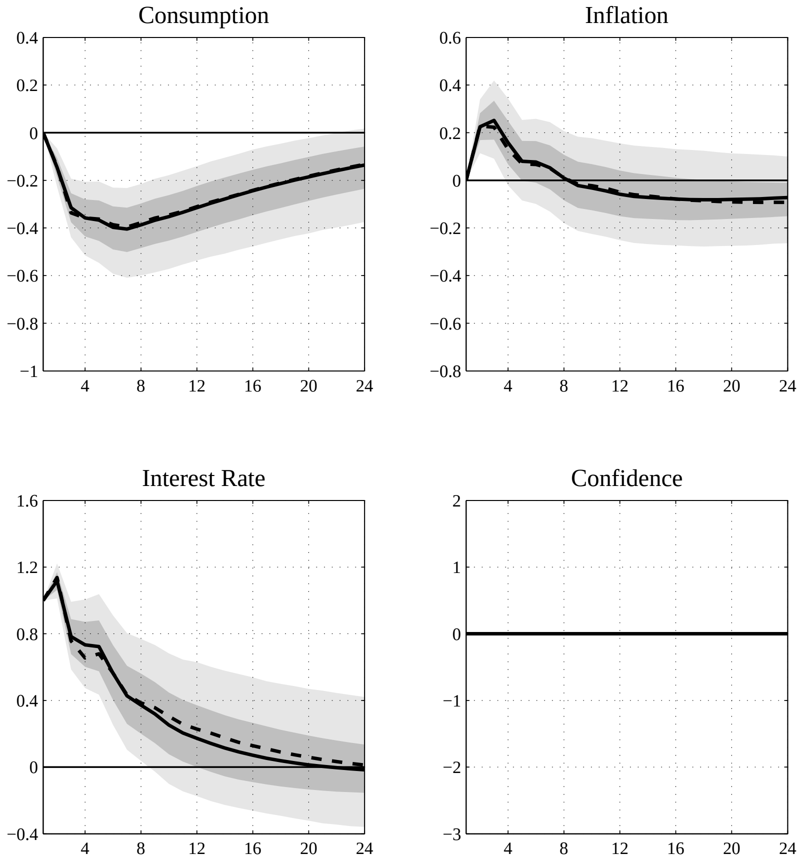
Forecast Horizon	$\texttt{CONS}_t$	$\texttt{INFL}_t$	$\texttt{FFR}_t$	$\texttt{CONF}_t$
1	0.0	0.0	92.9	0.9
4	10.9	3.9	60.4	3.8
8	20.3	2.8	47.5	6.6
12	23.5	2.5	44.7	6.1
24	21.9	4.8	41.8	6.6

Notes: Results are computed for the median target solution. The values in columns 2 to 5 denote the contribution of the monetary policy shock to the variation of the respective variable in percent.

Now, we take one step further and raise the question how our findings affect monetary transmission itself. To separate the extra effect of consumer confidence in the transmission process, we revert to a counter-factual experiment (see Bachmann and Sims, 2012, for an exercise close in spirit). By imposing appropriate restrictions, we re-estimate our VAR and force the response of confidence to the monetary policy shock to zero for the whole forecast horizon. Put differently, we analyze the reaction of variables in $\boldsymbol{Y_t}$ for an alternative scenario, where confidence does not affect monetary transmission. To create such an environment, we restrict the lag polynomials in the confidence equation (except for the own lag of confidence) to zero. This guarantees that confidence plays no role in the propagation of the monetary policy shock. Furthermore, a potential contemporaneous response of confidence is ruled out by imposing appropriate zero restrictions on the Cholesky factors of the Bayesian VAR.

Compared to Figure 2, we detect no eye-catching differences in the responses of the Federal Funds rate and price inflation in Figure 3. Thus with respect to these two measures, consumer confidence does not appear to be operative in the transmission. However, evaluating the response of consumption reveals a prominent role of consumer confidence. The impulse response already peaks at -0.4 percent in quarter 7, which is remarkably less pronounced compared to the unrestricted case. Concretely, confidence adds up to one third of the consumption response. This difference is also statistically significant as the median response of the restricted estimation lies outside the 68 percent posterior intervals of the unrestricted estimation for allmost all quarters and even outside the 95 percent bands for some quarters.

Figure 3: Monetary Policy Shock with Restricted Confidence Response



Notes: The solid line depicts the median response. The dashed line represents the median target solution. Shaded areas display the 68% (dark gray) and 95% (light gray) quantiles obtained from the posterior distribution of the VAR.

To sum up, our empirical analysis provides evidence that a monetary tightening triggers a pronounced decline in consumer confidence, which itself strongly, albeit temporarily amplifies the effect on consumer spending.[16] This, together with the evidence from the variance decompositions, suggests that monetary policy exerts a powerful influence on consumer confidence - a channel that is widely ignored by existing literature. Due to the transitory character of this extra effect, we interpret it as being suggestive to a *consumer sentiment channel*, which is not necessarily linked to future fundamentals like productivity.

[16]Though, this channel seems to be of minor importance for inflation and the Federal Funds rate itself.

3 Consumer Confidence in a Behavioral DSGE Model

It is clear from our VAR analysis that the notion of *pure sentiment* is a prime candidate to drive consumer confidence in response to a monetary policy shock. Still, so far, we only reported time series evidence in favor of our story. To give some structure to the problem, we employ a variant of the Smets and Wouters (2007) DSGE model and augment it by behavioral features along the lines of Branch and Evans (2006), Hommes (2006), De Grauwe (2010*a*,*b*), and Massaro (2013). Based on the linearized version of the model, we substitute rational expectations operators for aggregate forecasts, which are rule-based as in De Grauwe (2010*a*, 2011).[17] Thus with the exception of expectations formation, our behavioral model has the identical underlying macroeconomic structure as the rational expectations counterpart.[18] The model has the usual real and nominal frictions. Consumers receive utility from consumption and disutility from labor supply. The production side is composed of a continuum of intermediate goods producers that set prices for imperfectly substitutable goods in a staggered fashion (Calvo, 1983). Firms in the final good sector are perfect competitors. Labor markets operate under monopolistic competition as in Erceg, Henderson and Levin (2000), and monetary policy implements a Taylor rule.[19]

3.1 Consumer Confidence and Expectations

Our empirical findings show that consumer confidence quickly kicks in after a monetary policy shock and amplifies aggregate demand temporarily. Thus our findings suggest that with respect to monetary policy shocks, other mechanisms seem to be at play than for fiscal shocks (Bachmann and Sims, 2012), as we find quantitatively important, but short lived responses. We interpret our empirical results as indication that contractionary monetary policy can depress aggregate *sentiment* and thereby weaken aggregate demand, which in turn decreases aggregate supply in equilibrium. To that extend, our modeling strategy is closely related to Akerlof and Shiller (2008), who asses that *animal spirits* are important

[17]This is consistent with the literature on statistical learning (see Evans and Honkapohja, 2001; Bullard and Mitra, 2002; Orphanides and Williams, 2004; Gaspar, Smets and Vestin, 2006; Milani, 2007; Branch and Evans, 2010, among others). However, we assume expectations that are systematically biased, whereas convergence to rational expectations (conditional on the statistical tools agents use for their forecasts) is often assumed in the learning literature.

[18]Of course, this is a strong assumption as the linearized model is derived under the hypothesis of fully rational agents implying that the law of iterated expectations holds. However, see Massaro (2013) for a micro-founded derivation of the New Keynesian Phillips curve in an environment of bounded rationality in a DSGE model.

[19]As the core DSGE model is standard, we leave the description to Appendix B, where we document the complete set of linearized equations.

to understand the business cycle.

In line with the empirical *Index of Consumer Expectations* from Section 2, we construct an index of consumer expectations, $\mathtt{ICE}_t$, as the overhang of optimistic versus pessimistic consumers in our behavioral model:

$$\mathtt{ICE}_t = 1 + \alpha^c_{\text{opt},t} - \alpha^c_{\text{pes},t}, \tag{3}$$

where $\alpha^c_{\text{opt},t}$ is the fraction of optimistic and $\alpha^c_{\text{pes},t}$ the fraction of pessimistic households with respect to future consumption. Thus our behavioral model provides an endogenous variable for consumer confidence, $\mathtt{CONF}_t$, which is a re-scaled version of $\mathtt{ICE}_t$.[20] This feature is absent in standard DSGE models that usually define confidence as a transformation of exogenous shocks (Barsky and Sims, 2012). Within our modeling approach, an optimist is defined as an agent who expects future consumption above the zero steady-state (see e.g. De Grauwe, 2011). A pessimist is defined to forecast consumption below the "fundamental" value of zero. Agents use simple, but systematically biased rules for forecasting. The underlying hypothesis is that due to cognitive limitations agents are not able to form their expectations based on the true data generating process, i.e. the complete structural model. In contrast, they employ the following simple rules:

$$\mathbb{E}^{\text{opt}}_t\{\hat{c}_{t+1}\} = \frac{d^c_t}{2} \quad \text{and} \quad \mathbb{E}^{\text{pes}}_t\{\hat{c}_{t+1}\} = -\frac{d^c_t}{2}. \tag{4}$$

Expectations in our model are heterogeneous, where we specify the absolute divergence in beliefs, $d^c_t > 0$:

$$d^c_t = \beta^c_d + \delta^c_d \sigma(\hat{c}_t). \tag{5}$$

$\beta^c_d > 0$ represents a time-invariant part of the heterogeneity in expectations. Furthermore, $\delta^c_d > 0$ scales the sensitivity of the divergence in beliefs with respect to the unconditional standard deviation in consumption, $\sigma(\hat{c}_t)$. Agents evaluate the latter for a period of z past realizations of consumption (see De Grauwe, 2011).

Following the literature on behavioral models for financial markets (see e.g. Brock and Hommes, 1997), we furthermore allow for a third rule to form expectations on consumption, which may be labeled as a fundamental rule. This forecasting rule is assumed to be

[20] We normalize our consumer confidence measure, $\mathtt{CONF}_t$, to be consistent with the empirical counterpart. See Appendix A for a closer description of the empirical series.

unconditionally unbiased, as it forecasts consumption to the long run steady-state:[21]

$$\mathbb{E}_t^{\text{fun}}\{\hat{c}_{t+1}\} = 0. \tag{6}$$

Once agents use this rule predominantly, i.e. the shares of optimists and pessimists are negligible, self-fulfilling *pure sentiment* driven fluctuations in consumption become less likely.[22]

The three forecasting rules stand in permanent evolutionary competition. Along the lines of the discrete choice literature (see Anderson, De Palma and Thisse, 1992; Brock and Hommes, 1997), agents tend to choose the rule, which proved to perform best in recent periods. This requires a permanent evaluation of rules, which is based on

$$U_{\text{opt},t}^c = \sum_{k=1}^{\infty} \omega_k \left[\hat{c}_{t-k} - \mathbb{E}_{t-k-1}^{\text{opt}}\{\hat{c}_{t-k}\}\right]^2, \tag{7}$$

$$U_{\text{pes},t}^c = \sum_{k=1}^{\infty} \omega_k \left[\hat{c}_{t-k} - \mathbb{E}_{t-k-1}^{\text{pes}}\{\hat{c}_{t-k}\}\right]^2, \text{ and} \tag{8}$$

$$U_{\text{fun},t}^c = \sum_{k=1}^{\infty} \omega_k \left[\hat{c}_{t-k} - \mathbb{E}_{t-k-1}^{\text{fun}}\{\hat{c}_{t-k}\}\right]^2, \tag{9}$$

where $U_{\text{opt},t}^c$, $U_{\text{pes},t}^c$, and $U_{\text{fun},t}^c$ denote the mean squared forecasting errors (MSFE) of the respective forecasting rule. Agents attach to past forecasting errors less weight than to current. ω_k scales this effect and is specified as $w_k = (1-\rho)\rho^k$. Thus ρ can be interpreted as a memory parameter. Based on this evaluation, the shares or relative attractiveness of rules can be obtained as

$$\alpha_{\text{opt},t}^c = \frac{\exp(-\gamma^c U_{\text{opt},t}^c)}{\exp(-\gamma^c U_{\text{opt},t}^c) + \exp(-\gamma^c U_{\text{pes},t}^c) + \exp(-\gamma^c U_{\text{fun},t}^c)}, \tag{10}$$

$$\alpha_{\text{pes},t}^c = \frac{\exp(-\gamma^c U_{\text{pes},t}^c)}{\exp(-\gamma^c U_{\text{opt},t}^c) + \exp(-\gamma^c U_{\text{pes},t}^c) + \exp(-\gamma^c U_{\text{fun},t}^c)}, \text{ and} \tag{11}$$

$$\alpha_{\text{fun},t}^c = \frac{\exp(-\gamma^c U_{\text{fun},t}^c)}{\exp(-\gamma^c U_{\text{opt},t}^c) + \exp(-\gamma^c U_{\text{pes},t}^c) + \exp(-\gamma^c U_{\text{fun},t}^c)} = 1 - \alpha_{\text{opt},t}^c - \alpha_{\text{pes},t}^c. \tag{12}$$

[21] Two things must be recognized. First, the term "fundamental" should not be associated with rational expectations, as the latter would inter alia require that agents internalize the behavior of other agents, which is clearly not the case here. Second, the fact that the fundamental rule is unbiased does not imply that it has the edge over competing rules. For example, in times of economic slump it would be "rational" to switch from the fundamental to the pessimist rule.

[22] Of course, we could anchor the optimistic and pessimistic rules around a more sophisticated fundamental rule. Instead of employing the long run steady-state of zero, agents could e.g. use the expected path of real interest rates as the fundamental rule (see e.g. Massaro, 2013, for an analogue approach in the case of the New Keynesian Phillips curve). As a starting point, however, we apply the simplest rule.

γ^c is the "intensity of choice" parameter measuring how "rational" agents' decision making is. Higher values of γ^c imply that agents prefer rules with lower forecasting errors. In the case of $\gamma^c = 0$, agents are uniformly distributed over forecasting rules and for $\gamma^c \to \infty$ agents converge to the best performing rule (with the lowest MSFE).[23]

Ultimately, the aggregate forecast of future consumption, $\mathbb{E}_t\hat{c}_{t+1}$, is a weighted average of the three forecasts:

$$\mathbb{E}_t\{\hat{c}_{t+1}\} = \alpha^c_{\text{opt},t}\mathbb{E}^{\text{opt}}_t\{\hat{c}_{t+1}\} + \alpha^c_{\text{pes},t}\mathbb{E}^{\text{pes}}_t\{\hat{c}_{t+1}\} + \alpha^c_{\text{fun},t}\mathbb{E}^{\text{fun}}_t\{\hat{c}_{t+1}\}. \tag{13}$$

Obviously, the time-varying shares of optimistic and pessimistic forecasts, i.e. swings in *consumer sentiment*, are crucial for aggregate consumption expectations and thus macroeconomic fluctuations. As we will show in Section 5, monetary policy shocks can trigger such swings.

The expectation formation for the remaining variables except for inflation, which we discuss in the Section 3.2, is analogue to the consumption case described above. Thus we leave the description to Appendix C. As our prime interest is on the parameters that shape consumer confidence, we restrict the behavioral parameters for those remaining variables, i.e. β^x_d, γ^x, and δ^x_d to be identical. This strategy ensures a parsimonious number of additional behavioral parameters and proved sufficient to resemble the time series evidence from Section 2 with our behavioral model as reported in Section 4.3.

3.2 Expectations on Inflation

In this section, we discuss how households and firms form expectations on future price inflation. Again, we assume that agents choose between heuristics and condition their choice on the relative forecasting performance of competing rules.

In our behavioral setting, we model expectations on future price inflation as it is common practice in related literature (see e.g. Brazier et al., 2008; De Grauwe, 2011). Concretely, we assume that the central bank announces an inflation target. Accordingly, a fraction of agents uses the announced target to forecast inflation. As a competing rule, agents may also choose a naive heuristic that extrapolates inflation based on its latest realization. Cornea, Hommes and Massaro (2013) provide evidence that the permanent

[23] γ^c also has an interpretation as noise in agents' evaluation of rules (see Anderson, De Palma and Thisse, 1992; Brock and Hommes, 1997). An increase in γ^c implies less noise in the performance evaluation and therefore better decisions by agents.

evolutionary competition between extrapolating and fundamental forecasts can well explain US inflation data. Hence, heterogeneity of inflation expectations in our model is twofold and reads[24]

$$\mathbb{E}_t^{\text{tar}}\{\hat{\pi}_{t+1}\} = \pi^* \quad \text{and} \quad \mathbb{E}_t^{\text{ext}}\{\hat{\pi}_{t+1}\} = \hat{\pi}_{t-1}. \tag{14}$$

π^* represents the announced inflation target of the central bank, which is for convenience normalized to be zero. In general, if a high fraction of agents follows the inflation targeting rule, it indicates that the central bank's inflation target is credible.

Again, agents permanently evaluate the forecasting performance of rules according to

$$U_{\text{tar},t}^{\pi} = \sum_{k=1}^{\infty} \omega_k \left[\hat{\pi}_{t-k} - \mathbb{E}_{t-k-1}^{\text{tar}}\{\hat{\pi}_{t-k}\}\right]^2 \text{ and} \tag{15}$$

$$U_{\text{ext},t}^{\pi} = \sum_{k=1}^{\infty} \omega_k \left[\hat{\pi}_{t-k} - \mathbb{E}_{t-k-1}^{\text{ext}}\{\hat{\pi}_{t-k}\}\right]^2. \tag{16}$$

The fractions of extrapolators, $\alpha_{\text{tar},t}^{\pi}$, and fundamentalists, $\alpha_{\text{ext},t}^{\pi}$, are determined by

$$\alpha_{\text{tar},t}^{\pi} = \frac{\exp(-\gamma^{\pi} U_{\text{tar},t}^{\pi})}{\exp(-\gamma^{\pi} U_{\text{tar},t}^{\pi}) + \exp(-\gamma^{\pi} U_{\text{ext},t}^{\pi})} \text{ and} \tag{17}$$

$$\alpha_{\text{ext},t}^{\pi} = \frac{\exp(-\gamma^{\pi} U_{\text{ext},t}^{\pi})}{\exp(-\gamma^{\pi} U_{\text{tar},t}^{\pi}) + \exp(-\gamma^{\pi} U_{\text{ext},t}^{\pi})} = 1 - \alpha_{\text{tar,t}}^{\pi}. \tag{18}$$

Finally, the economy wide inflation forecast is given as

$$\mathbb{E}_t\{\hat{\pi}_{t+1}\} = \alpha_{\text{tar},t}^{\pi}\mathbb{E}_t^{\text{tar}}\{\hat{\pi}_{t+1}\} + \alpha_{\text{ext},t}^{\pi}\mathbb{E}_t^{\text{ext}}\{\hat{\pi}_{t+1}\}. \tag{19}$$

4 Estimation of the Behavioral Model

To enhance the empirical veracity of our argument that swings in consumer *sentiment* are an autonomous channel in monetary transmission, we estimate the behavioral Smets and Wouters (2007) style DSGE model by minimum distance. We employ a limited-information approach along the lines of Rotemberg and Woodford (1997) and Christiano, Eichenbaum and Evans (2005), which consists of two steps. First, we estimate structural impulse responses obtained from actual data as characterized in Section 2.1. Second, we generate impulse responses from our theoretical model as discussed in Section 4.1. We then derive

[24] A growing body of literature reports experimental and survey data evidence for heterogeneity in inflation expectations (see e.g. Hommes, 2013, among others).

the model's structural parameters by minimizing the weighted distance between both types of impulse responses. Our focus is to highlight the propagation of monetary policy, hence, we confine our estimation to the share of fluctuations caused by this type of shock (see e.g. Boivin and Giannoni, 2006). By doing so, we succeed to empirically pin down the behavioral parameters of our model.[25]

4.1 Solution and Construction of Impulse Responses

To simulate from our model, we transform it into the following matrix representation:

$$\mathbf{Z_t} = \mathbf{\Lambda^{-1}} \left(\mathbf{\Gamma} \mathbb{E}_\mathbf{t} \{ \mathbf{Z_{t+1}} \} + \mathbf{\Psi} \mathbf{Z_{t-1}} + \mathbf{V_t} \right), \tag{20}$$

where $\mathbf{\Lambda}$, $\mathbf{\Gamma}$, and $\mathbf{\Psi}$ are properly defined matrices comprising structural parameters. $\mathbf{Z_t}$ is the state vector, which includes the relevant variables and $\mathbf{V_t}$ contains the shock process.

Compared to a standard DSGE model, the construction of impulse response functions in the behavioral model is tedious and requires some discussion. The non-linearity of the behavioral model implies that the same shock to the Federal Funds rate has a diversified impact on the economy when occurring at a different state. Therefore, we follow the footsteps of De Grauwe (2011) for the computation of impulse responses. We proceed by simulating our model for a sample of T periods and fix the monetary policy shock in period $T-k$ at 100 basis points. We then re-run our model using the stochastic sequence of realized shocks from this simulation. In this case, though, we shut down the monetary policy shock in period $T-k$, i.e. we fix it at 0. This enables us to isolate the effect of the monetary policy shock in period $T-k$ on the future path of the economy by comparing the simulated variables from both experiments.[26] Ultimately, we repeat the aforementioned steps 20,000 times with different sequences of shocks for each draw. We then compute summary statistics for the impulse responses from all draws.

[25] Most related studies, in contrast, rely on calibration exercises. Note that there is a number of excellent papers that estimate single New Keynesian equations with behavioral heterogeneity like e.g. Cornea, Hommes and Massaro (2013). However, these papers do not focus on monetary transmission as in our case.

[26] A notable feature of a monetary policy shock in our *consumer sentiment* model is that its transmission depends on shock realizations before and after period $T-k$. To account for this, we allow for stochastic shock realizations in the aftermath of period $T-k$ (see De Grauwe, 2011).

4.2 Estimation Strategy

As our theoretical analysis builds on the Smets and Wouters (2007) model - a framework capable to capture diversified time series properties - we augment our VAR from Section 2.1 with two data series (see Barsky and Sims, 2012, for a similar strategy). To consider labor market dynamics, we add the log of real compensation per hour, $\texttt{WAGE}_t$, which is an important driver of price inflation and thus crucial in monetary policy transmission. Furthermore, we take investment dynamics into account by adding the log level of per capita real private investment, $\texttt{INV}_t$.[27] The vector of time series for this richer VAR is

$$\boldsymbol{Y_t} = [\ \texttt{CONS}_t\ \texttt{INV}_t\ \texttt{INFL}_t\ \texttt{WAGE}_t\ \texttt{FFR}_t\ \texttt{CONF}_t\ ]'. \tag{21}$$

As in Section 2.1, we maintain the identification assumption that $\texttt{FFR}_t$ and $\texttt{CONF}_t$ are the only variables, which react to monetary policy shocks contemporaneously. The impulse response functions from this estimation are depicted in Figure 4.

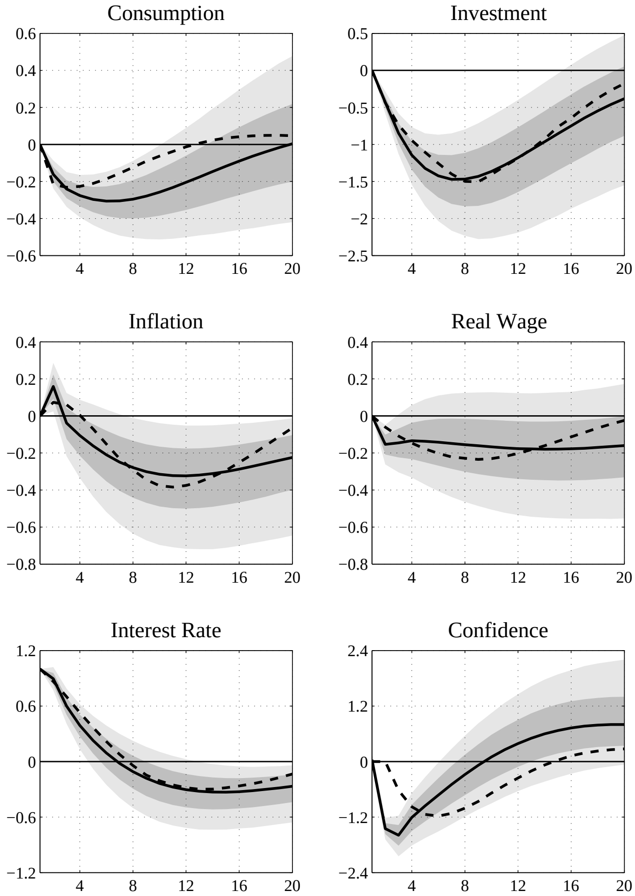
We find very similar results for the dynamics of our core data series in this specification, although, the price puzzle is muted and inflation turns negative more quickly. Most likely, this is due to the newly included wage series, which decreases significantly for two quarters and then becomes insignificant. The reaction of investment takes place in a hump-shaped manner and remains significantly negative for four years. Moreover, consumer confidence exhibits a transitory and significant drop by more than 1.5 index points after the monetary tightening. The consumption response again is short lived and unfolds slowly after peaking in quarter 7.[28]

Now, we investigate if our *sentiment* interpretation proves capable to resemble the empirical impulse responses. As usual, we calibrate a subset of structural parameters and set them along conventional wisdom (see e.g. Smets and Wouters, 2007; Altig et al., 2011; Galí, Smets and Wouters, 2012). Concretely, the quarterly discount factor, β, is calibrated to 0.99. The depreciation rate of capital, δ, is set to 0.025 and the capital share, α, is 0.19. The Kimball aggregators ϵ_p and ϵ_w are set equal to 10. The elasticity of the capital utilization cost function, ψ, is calibrated to 0.54. Furthermore, we assume log utility in consumption and abstract from habit formation.

[27] We allow for cointegration in the system (see e.g. Sims, Stock and Watson, 1990). Therefore, we do not detrend any time series in this estimation.

[28] Again, the transitory character of the comoving responses of investment and consumption associated with the short lived drop in confidence do not point to a triggered productivity mechanism with permanent effects on output and its components (see Bachmann and Sims, 2012).

Figure 4: Monetary Policy Shock in Empirical and Theoretical Analysis



Notes: The solid line depicts the median response. Shaded areas display the 68% (dark gray) and 95% (light gray) quantiles obtained from the posterior distribution of the VAR. The broken line denotes the median response obtained from the behavioral model.

With respect to the behavioral parameters, we calibrate those parameters that are related to the inflation process, while we estimate the remaining parameters.[29] Specifically, we assume the fraction of agents using the inflation target rule to be 0.5. Consequently, at each point in time 50 percent of agents use the extrapolating heuristic. Clearly, as the central bank sets interest rates in accordance to the Taylor principle, it a priori dampens the scope within which inflation fluctuations can arise. However, once deviations from the inflation target occur, the central bank's inflation target is not fully credible. This induces agents to be doubtful about future price inflation, such that their decision, which forecasting rule to use, is almost random. We implement this calibration strategy by setting the intensity

[29]We also included the behavioral parameters of the inflation process into our estimation strategy. It turned out that unfavorable parameter combinations prevent the estimation algorithm from converging. Thus we decided to calibrate this subset of behavioral parameters using values that are usually applied in related literature.

of choice parameter, γ^{π}, to 0. We set ρ, which governs the memory of agents to 0.5, and the number of past observations used to evaluate the forecast performance, z, to 8.[30] The remaining model parameters are stacked into vector $\boldsymbol{\varrho}$, where our prime interest lies on the subset of behavioral parameters, $\boldsymbol{\varrho_1}$:

$$\begin{aligned} \boldsymbol{\varrho} &= [\ \boldsymbol{\varrho_1}\ \boldsymbol{\varrho_2}\ ]',\ \text{where} \\ \boldsymbol{\varrho_1} &= [\ \delta_d^c\ \delta_d^x\ \beta_d^c\ \beta_d^x\ \gamma^c\ \gamma^x\ ]\ \text{and}\ \boldsymbol{\varrho_2} = [\ \theta_p\ \theta_w\ \iota_p\ \iota_w\ \eta\ \varphi\ \phi_r\ \phi_\pi\ \phi_y\ \phi_{\Delta y}\ \rho_r\ ]\,. \end{aligned} \tag{22}$$

The vector of impulse responses from the VAR is denoted by $\hat{\boldsymbol{\Xi}}$ and the impulse responses drawn from the model are stacked into vector $\boldsymbol{\Xi}(\boldsymbol{\varrho})$. Along the lines of Christiano, Eichenbaum and Evans (2005), the estimator $\hat{\boldsymbol{\varrho}}$ is found by minimizing the distance measure $\boldsymbol{J}(\boldsymbol{\varrho})$ with respect to $\boldsymbol{\varrho}$:

$$\hat{\boldsymbol{\varrho}} = \arg\min\ \boldsymbol{J}(\boldsymbol{\varrho}) = \left(\hat{\boldsymbol{\Xi}} - \boldsymbol{\Xi}(\boldsymbol{\varrho})\right)' \hat{\boldsymbol{\Omega}}^{-1} \left(\hat{\boldsymbol{\Xi}} - \boldsymbol{\Xi}(\boldsymbol{\varrho})\right). \tag{23}$$

$\hat{\boldsymbol{\Omega}}$ contains variances of the empirical impulse responses on the diagonal. So, the estimator attaches more precisely estimated elements of $\hat{\boldsymbol{\Xi}}$ higher loadings.[31]

4.3 Estimation Results

Figure 4 displays the mapping of the median response from the behavioral model (broken line) with the empirical counterpart (solid line) for the estimator $\hat{\boldsymbol{\varrho}}$. Obviously, our behavioral model captures the adjustment patterns after a monetary contraction remarkably well. The model responses match the VAR dynamics closely and for the majority of horizons they remain within the 68 percent posterior intervals of the VAR. Only in few cases, the responses lie inside the 95 percent intervals. Confidence is the only variable that breaks out of these intervals for the first two quarters. Apparently, this is due to the fact that the portion of confidence that reacts to monetary disturbances in the model is backward looking in nature.

Now, we evaluate our parameter estimates, which are reported in Table 2 together with delta method corrected standard errors (Christiano, Eichenbaum and Evans, 2005).

[30] In Appendix D, we provide robustness analysis for ρ and z and illustrate that the correlation between consumption and consumption optimism is quite robust.

[31] We exclude the impact quarters of variables in $\hat{\boldsymbol{\Xi}}$ that are zero because of the Cholesky identification. Additionally, for confidence, we do not include the second period as the model response is always zero due to the learning mechanism, which builds in a lag of one quarter in monetary policy transmission.

We first discuss β_d^c, δ_d^c, and γ^c, which shape the response of confidence to a monetary policy shock. Obviously Figure 1 illustrates that the *Consumer Confidence Index* is no binary variable. Instead, it has a tendency to revert before hitting its upper (only optimistic households) or lower bound (only pessimistic households). This empirical feature is reflected by a small value of $\gamma^c = 0.01$, which engineers that only an appropriate fraction of agents changes beliefs that is sufficient to replicate the confidence dynamics following a monetary policy shock. High estimates for $\beta_d^c = 14.95$ and $\delta_d^c = 0.63$ imply that although agents may not change their mind that fast, the divergence in beliefs between the camps is pronounced. Our estimation results for the parameters governing the formation of expectations for the remaining macroeconomic variables are $\beta_d^x = 2.52$, $\gamma^x = 0.85$, and $\delta_d^x = 1.95$. Interestingly, these estimates lie in ranges that are commonly found in related literature that calibrates those parameters (De Grauwe, 2010*a*, 2011).

Table 2: Estimated Parameters

Parameter	Estimate	Std. Err.	Description
Behavioral parameters			
β_d^c	14.95	(1.24)	Fixed divergence in beliefs: Consumption
β_d^x	2.52	(0.66)	Fixed divergence in beliefs: Rest
δ_d^c	0.63	(0.73)	Sensitivity of belief divergence: Consumption
δ_d^x	1.95	(1.03)	Sensitivity of belief divergence: Rest
γ^c	0.01	(0.00)	Intensity of choice: Consumption
γ^x	0.85	(0.22)	Intensity of choice: Rest
DSGE parameters			
θ_p	0.31	(0.10)	Calvo parameter: Prices
θ_w	0.52	(0.05)	Calvo parameter: Wages
ι_p	0.21	(0.47)	Price-indexation
ι_w	0.03	(0.39)	Wage-indexation
η	8.03	(1.77)	Inverse Frisch elasticity
φ	0.25	(0.03)	Elasticity of investment adjustment cost
ϕ_r	0.87	(0.06)	Taylor rule: Interest rate smoothing
ϕ_π	1.20	(0.41)	Taylor rule: Inflation stabilization
ϕ_y	0.41	(0.16)	Taylor rule: Output gap stabilization
$\phi_{\Delta y}$	0.22	(0.14)	Taylor rule: Changes in the output gap
ρ_r	0.24	(0.27)	Autocorrelation of monetary policy shock

Notes: The table displays parameter estimates (second column) together with corrected standard errors in parentheses (third column).

The estimates for the Taylor rule display familiar values. Monetary policy is guided by interest rate smoothing, $\phi_r = 0.87$, and responds to the cyclical component of inflation, $\phi_\pi = 1.20$. The reaction to output fluctuations, $\phi_y = 0.41$, is estimated to be strong. For the auto-correlation of a monetary policy shock, we obtain $\rho_r = 0.24$. The estimate of the investment adjustment cost parameter is $\varphi = 0.25$, which implies that investment increases by 0.25 percent following a 1 percent increase in the current price of installed capital. We estimate the Frisch elasticity of labor supply equal to $\eta = 8.03$, which is at the upper end, but still in line with e.g. Trigari (2006). Our results indicate that the supply side of the economy exhibits some degree of price and wage stickiness, with $\theta_p = 0.31$ and $\theta_w = 0.52$. The degree of indexation with $\iota_p = 0.21$ and $\iota_w = 0.03$ is somewhat lower than in many estimated rational expectations DSGE models. This reflects that the behavioral model builds in endogenous persistence when agents only gradually adjust expectations (see also Milani, 2007). Note however, that our estimates are in line with Bils and Klenow (2004), who report price durations below 2 quarters based on micro evidence.

5 A "Consumer Sentiment Channel" for Monetary Policy

In this section, we provide a structural interpretation how consumer confidence might influence monetary policy transmission. To highlight the mechanisms at work and to flesh out the marginal effect of the *sentiment channel*, we perform a counter-factual simulation exercise. Figure 5 portrays summary statistics for a monetary policy contraction in two structurally different economies.[32] For the benchmark economy, we simulate our model 20,000 times and compute median responses (solid line) together with 95 and 5 percent quantiles (shaded areas) reflecting the state dependence of the behavioral model. For a hypothetical economy, where we fix consumer confidence at its pre-shock period's value, we do the same procedure and plot median responses (broken line).

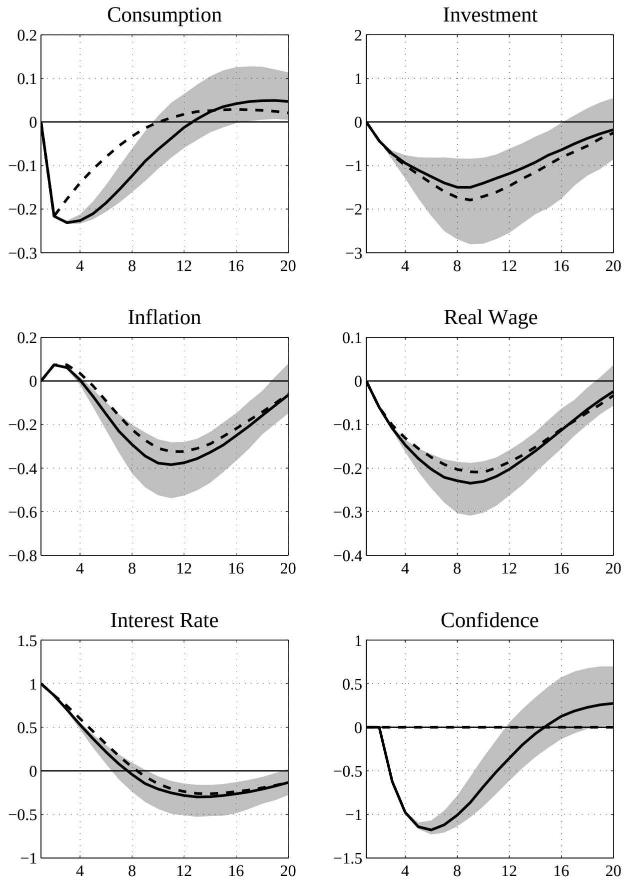
Three features stand out, when we contrast the two economies. First, it prevails that the *sentiment channel* is of major importance for monetary policy transmission into consumption. Second, this channel seems quantitatively negligible for the remaining variables as their counter-factual responses lie inside the 90 percent intervals of the benchmark economy. And third, the propagation of the monetary policy impulse via confidence into consumption is a short lived phenomenon as differences between the economies slowly decay after two years. All these counter-factual model features are in line with our empirical evidence. Of course, the question outstanding is how the *sentiment channel* works.

The standard channels of monetary policy transmission are operative in our behavioral model and are disconnected from the confidence response. A monetary tightening increases the real rate of interest in a sticky price environment. This induces consumers to postpone

[32]The parameterization is as reported in the previous section.

consumption and firms to delay investment into the future. Furthermore, firms react by cutting wages for labor markets to clear. The rise in the real interest rate combined with the weakened economic activity cause price inflation to fall below the inflation target at the medium horizon.[33] These mechanisms hold for both economies in Figure 5.

Figure 5: Monetary Policy Shock in the Behavioral DSGE Model



Notes: The figure portrays impulse responses to a 100 basis point monetary policy shock simulated in the behavioral DSGE model. The solid line shows the impulse responses for our baseline economy, the broken line represents the counter-factual economy, where confidence is fixed. Shaded areas are 5 and 95% percentiles obtained from all draws.

Apparently, the developments in consumer confidence account for the difference between the two economies. Given the definition from Equation 3, changes in confidence reflect changes in the overhang of optimism versus pessimism, i.e. *consumer sentiment*. These swings in *sentiment* arise, whenever the forecasting performance of a rule that agents use to form expectations improves relative to the competing alternatives. Thus the standard channels of contractionary monetary policy transmission are a pre-condition for the *sen-*

[33]Though, our model exhibits an initial rise in inflation after the shock. This is due to our modeling device of a "cost channel", which we implement to reconcile the empirical price puzzle (see Appendix B).

timent channel to become operative. The rationale is as follows: by deteriorating the fundamentals of the economy, e.g. consumption expenditures in the usual way, contractionary monetary policy makes it a rational choice for agents to become pessimistic with respect to future consumption. For instance, in an environment of restrictive monetary policy, it would not be "rational" to expect bubbling consumption cycles in the near future. Therefore, the pessimistic rule will most likely perform best after a monetary contraction and therefore become more attractive. Once monetary policy triggers such a contagion in pessimistic expectations, i.e. a drop in *consumer sentiment*, this has an inevitable feedback on the economy. Consumption dynamics imply that depressed consumption expectations have an immediate impact on actual consumption expenditures. So, the additional swing in consumer expectations strengthens the leverage of monetary policy on private consumption in a self-fulfilling fashion.

Furthermore, one can see from Figure 5 that this extra effect in consumption operates not only in terms of magnitude, but in terms of persistence. The consumption response in the benchmark economy exhibits a clear hump-shaped behavior, whereas this feature of the data is absent in the counter-factual economy. Inter alia, this is a result of the low estimate of agents' intensity of choice implying that agents adapt expectations only sluggishly. Put differently, once monetary policy triggers a downward swing in *consumer sentiment*, it takes some time to get the pessimism out of agents' minds. Thus the behavioral model introduces model inherent inertia in consumption after a monetary contraction that is not subject to exogenous factors like habit formation (Milani, 2007; Bofinger et al., 2013).

6 Conclusion

This paper has sought to answer the question if a *consumer sentiment channel* is operative in monetary policy transmission. We have answered this question with: Yes! There is a *consumer sentiment channel* of monetary policy. Based on standard VAR analysis, we have shown that consumer confidence drops significantly after a monetary contraction. By shutting down the confidence response in a counter-factual experiment, we illustrate that the impact of confidence, triggered by the change in the Federal Funds rate, amplifies the consumption response. Additionally, variance decompositions support our findings, as they show that monetary policy explains a meaningful part of the variation in consumer confidence. To provide a structural interpretation, we have built a behavioral DSGE model incorporating heterogeneous and biased beliefs. The transitory character of our empirical findings provides some rationale for the *pure sentiment* view. As beliefs are heterogeneous in our model, we succeed to classify consumers into optimists and pessimists that leaves us with an endogenous variable for consumer confidence. Our analysis suggests that the permanent competition and switches between forecasting heuristics are of macroeconomic importance when agents start to choose the same heuristic simultaneously. We show that a monetary contraction can trigger a contagion in pessimism. The associated drop in confidence causes a decline in consumption that is more pronounced and sluggish than usual monetary policy channels would predict.

A Data

Confidence Data: The confidence data are available on the Michigan Survey of Consumers website, `http://www.sca.isr.umich.edu/`. Concretely, we take the Index of Consumer Expectations ($\texttt{ICE}_t$):

$$\texttt{ICE}_t = \frac{X_2 + X_3 + X_4}{4.1134} + 2.0, \tag{24}$$

where to calculate the Index of Consumer Expectations ($\texttt{ICE}_t$), first compute the relative scores (the percent giving favorable replies minus the percent giving unfavorable replies, plus 100) for each of the index questions (see below), using the formula shown:

- x_2 = “Now looking ahead–do you think that a year from now you (and your family living there) will be better off financially, or worse off, or just about the same as now?”
- x_3 = “Now turning to business conditions in the country as a whole–do you think that during the next twelve months we’ll have good times financially, or bad times, or what?”
- x_4 = “Looking ahead, which would you say is more likely–that in the country as a whole we’ll have continuous good times during the next five years or so, or that we will have periods of widespread unemployment or depression, or what?”

B The Linearized Model

Following De Grauwe (2010*a*,*b*, 2011), we impose heuristics at the macroeconomic level. That is, we use a standard DSGE model similar to the one proposed in Smets and Wouters (2007) and assume that structural equations remain unchanged, when we substitute rational expectations against the alternative that agents choose among simple rules to form expectations. In this Appendix, we describe the log-linearized set of equations.

The aggregate resource constraint is given by

$$\hat{y}_t = c_y \hat{c}_t + i_y \hat{i}_t + z_y \hat{z}_t, \tag{25}$$

where output, $\hat{y}_t$, is used for consumption, $\hat{c}_t$, investment, $\hat{i}_t$, and resource costs attached to changes in capital utilization, $\hat{z}_t$. c_y and i_y denote steady-state shares in consumption and investment, respectively, with $c_y = 1 - i_y$. The steady-state investment share is given by: $i_y = (\gamma - 1 + \delta)\, k_y$, where γ is the growth rate in steady-state and δ denotes the capital depreciation rate. k_y defines the steady-state ratio of capital versus output. The parameter z_y is defined as: $z_y = r^k k_y$, where r^k is the steady-state rental rate of capital.

The consumption Euler equation is given by

$$\hat{c}_t \quad = \quad \mathbb{E}_t\{\hat{c}_{t+1}\} - \frac{1}{\sigma_c}(\hat{r}_t - \mathbb{E}_t\{\hat{\pi}_{t+1}\}). \tag{26}$$

Consumption, $\hat{c}_t$, is driven by the real rate of interest, $\hat{r}_t - \mathbb{E}_t\{\hat{\pi}_{t+1}\}$. σ_c scales the elasticity of intertemporal substitution, where we assume log utility in consumption, i.e. $\sigma_c = 1$.

The investment Euler equation is

$$\hat{i}_t = \frac{\beta}{1+\beta}\mathbb{E}_t\{\hat{i}_{t+1}\} + \frac{1}{1+\beta}\hat{i}_{t-1} + \frac{1}{\varphi\gamma^2(1+\beta)}\hat{q}_t, \tag{27}$$

where β is the discount factor. As in Christiano, Eichenbaum and Evans (2005), φ captures convex costs of capital adjustment. $\hat{q}_t$ measures the real value of the existing capital stock. The arbitrage condition for the value of capital reads

$$\hat{q}_t = \beta(1-\delta)\gamma^{-1}\mathbb{E}_t\{\hat{q}_{t+1}\} - \hat{r}_t + \mathbb{E}_t\{\hat{\pi}_{t+1}\} + (1 - \beta(1-\delta)\gamma^{-1}\mathbb{E}_t\{\hat{r}^k_{t+1}\}. \tag{28}$$

The production technology is described as

$$\hat{y}_t = \phi_p \left((1-\alpha)\, \hat{h}_t + \alpha \hat{\bar{k}}_t \right), \tag{29}$$

where output is produced with capital available in period t, $\hat{\bar{k}}_t$, and $\hat{h}_t$ denotes hours worked. α denotes the share of capital in production. Available capital is given by

$$\hat{\bar{k}}_t = \hat{k}_{t-1} + \hat{z}_t, \tag{30}$$

and comprises last periods capital stock, $\hat{k}_{t-1}$, which needs one period to become productive, adjusted by the current degree of capital utilization $\hat{z}_t$:

$$\hat{z}_t = \frac{1-\psi}{\psi} \hat{r}^k_t. \tag{31}$$

Capital utilization, $\hat{z}_t$, is a function of the rental rate of capital, $\hat{r}^k_t$, and depends on the elasticity of the capital utilization adjustment cost, ψ. The capital accumulation equation obeys the following dynamics:

$$\hat{k}_t = \frac{1-\delta}{\gamma} \hat{k}_{t-1} + (1 - (1-\delta)/\gamma)\,(1+\beta)\,\gamma^2 \varphi \hat{i}_t. \tag{32}$$

As standard, we assume monopolistic competition in the intermediate goods sector with staggered price setting and indexation as in Christiano, Eichenbaum and Evans (2005). Real marginal cost, $\hat{mc}_t$, are the inverse of the price mark-up, $\hat{\mu}^p_t$, and can be written as

$$\hat{mc}_t = -\hat{\mu}^p_t = \alpha \hat{r}^k_t + (1-\alpha)\hat{w}_t + (1-\alpha)\hat{r}_t, \tag{33}$$

In our model, the interest rate drives real marginal cost besides the usual (weighted) factor prices. The underlying idea is that firms have to pre-finance production to pay wage bills, the so called “cost channel” (see e.g. Barth and Ramey, 2002).

The New Keynesian Phillips curve is standard

$$\hat{\pi}_t = \frac{\beta}{1+\iota_p\beta} \mathbb{E}_t\{\hat{\pi}_{t+1}\} + \frac{\iota_p}{1+\iota_p\beta} \hat{\pi}_{t-1} - \frac{(1-\beta\theta_p)(1-\theta_p)}{(1+\iota_p\beta)(1+(\phi_p-1)\epsilon_p)\theta_p} \hat{\mu}^p_t, \tag{34}$$

where ι_p denotes the degree of indexation to past inflation and θ_p is the Calvo parameter. Additionally, the speed of price adjustment depends on the curvature of the Kimball goods market aggregator, ϵ_p, and the share of fixed cost in production, $(\phi_p - 1)$, implied by the zero profit condition. As standard, cost minimization implies that the capital-labor ratio is equal to the inverse of factor prices:

$$\hat{r}_t^k = \hat{h}_t + \hat{w}_t - \hat{\bar{k}}_t^s. \tag{35}$$

The wage mark-up is defined as the difference between the real wage and the marginal rate of substitution between working and consuming:

$$\hat{\mu}_t^w = \hat{w}_t - \eta \hat{h}_t - \hat{c}_t, \tag{36}$$

Staggered wage setting in conjunction with partial wage indexation gives rise to the following adjustment equation for real wages:

$$\begin{aligned} \hat{w}_t &= \frac{\beta}{1+\beta}(\mathbb{E}_t\{\hat{w}_{t+1}\} + \mathbb{E}_t\{\hat{\pi}_{t+1}\}) + \frac{1}{1+\beta}(\hat{w}_{t-1} + \iota_w \hat{\pi}_{t-1}) \\ &- \frac{1+\beta\iota_w}{1+\beta}\hat{\pi}_t - \frac{(1-\beta\theta_w)(1-\theta_w)}{(1+\beta)(1+(\phi_w - 1)\epsilon_w)\theta_w}\hat{\mu}_t^w, \end{aligned} \tag{37}$$

where θ_w specifies a Calvo wage parameter and ι_w is the degree of partial indexation to past real wages. Real wages only gradually adjust to the desired mark-up, where the velocity of adjustment depends on the steady-state wage mark-up $(\phi_w - 1)$ as well as the curvature of the Kimball aggregator, ϵ_w, in the labor market.

The model is closed by a Taylor rule:

$$\hat{r}_t = \phi_r \hat{r}_{t-1} + (1-\phi_r)(\phi_\pi \hat{\pi}_t + \phi_y(\hat{y}_t - \hat{y}_t^*)) + \phi_{\Delta y}(\Delta\hat{y}_t - \Delta\hat{y}_t^*) + \epsilon_t^r. \tag{38}$$

The central bank adjusts its monetary policy instrument in response to inflation and output gaps, where ϕ_π and ϕ_y denote the respective elasticities. Additionally, we assume that the interest rate is adjusted to the change in the output gap, where $\hat{y}^*$ reflects the flex price output gap. ϕ_r denotes the degree of interest rate smoothing. The monetary policy shock, ϵ_t^r, follows a stationary first-order auto-regressive process:

$$\epsilon_t^r = \rho_r \epsilon_{t-1}^r + \eta_t^r. \tag{39}$$

C Rest of Expectations Operators

As our main interest rests on consumer expectations, we model expectation operators for all other variables, $\hat{x}_t$, structurally identical. The expectation formation regards the following variables: investment, $\hat{i}_t$, Tobin's q, $\hat{q}_t$, rental rate of capital, $\hat{r}_t^k$, and real wages, $\hat{w}_t$. Again, we specify an optimistic and a pessimistic forecasting rule:

$$\mathbb{E}_t^{\text{opt}}\{\hat{x}_{t+1}\} = \frac{d_t^x}{2} \text{ and } \mathbb{E}_t^{\text{pes}}\{\hat{x}_{t+1}\} = -\frac{d_t^x}{2}. \tag{40}$$

The divergence in beliefs is

$$d_t^x = \beta_d^x + \delta_d^x \sigma(\hat{x}_t) \tag{41}$$

An additional "fundamental" rule is specified as

$$\mathbb{E}_t^{\text{fun}}\{\hat{x}_{t+1}\} = 0. \tag{42}$$

As beforehand, agents evaluate the forecast performance of rules according to

$$U_{\text{opt},t}^x = \sum_{k=1}^{\infty} \omega_k \Big(\hat{x}_{t-k} - \mathbb{E}_{t-k-1}^{\text{opt}}\{\hat{x}_{t-k}\}\Big)^2, \tag{43}$$

$$U_{\text{pes},t}^x = \sum_{k=1}^{\infty} \omega_k \Big(\hat{x}_{t-k} - \mathbb{E}_{t-k-1}^{\text{pes}}\{\hat{x}_{t-k}\}\Big)^2, \text{ and} \tag{44}$$

$$U_{\text{fun},t}^x = \sum_{k=1}^{\infty} \omega_k \Big(\hat{x}_{t-k} - \mathbb{E}_{t-k-1}^{fun}\{\hat{x}_{t-k}\}\Big)^2 \text{ with } \omega_k = (1-\rho)\rho^k. \tag{45}$$

The fraction of agents choosing the respective rule is determined by

$$\alpha_{\text{opt},t}^x = \frac{\exp(-\gamma^x U_{\text{opt},t}^x)}{\exp(-\gamma^x U_{\text{opt},t}^x) + \exp(-\gamma^x U_{\text{pes},t}^x) + \exp(-\gamma^x U_{\text{fun},t}^x)}, \tag{46}$$

$$\alpha_{\text{pes},t}^x = \frac{\exp(-\gamma^x U_{\text{pes},t}^x)}{\exp(-\gamma^x U_{\text{opt},t}^x) + \exp(-\gamma^x U_{\text{pes},t}^x) + \exp(-\gamma^x U_{\text{fun},t}^x)}, \text{ and} \tag{47}$$

$$\alpha_{\text{fun},t}^x = \frac{\exp(-\gamma^x U_{un,t}^x)}{\exp(-\gamma^x U_{\text{opt},t}^x) + \exp(-\gamma^x U_{\text{pes},t}^x) + \exp(-\gamma^x U_{\text{fun},t}^x)}, \tag{48}$$

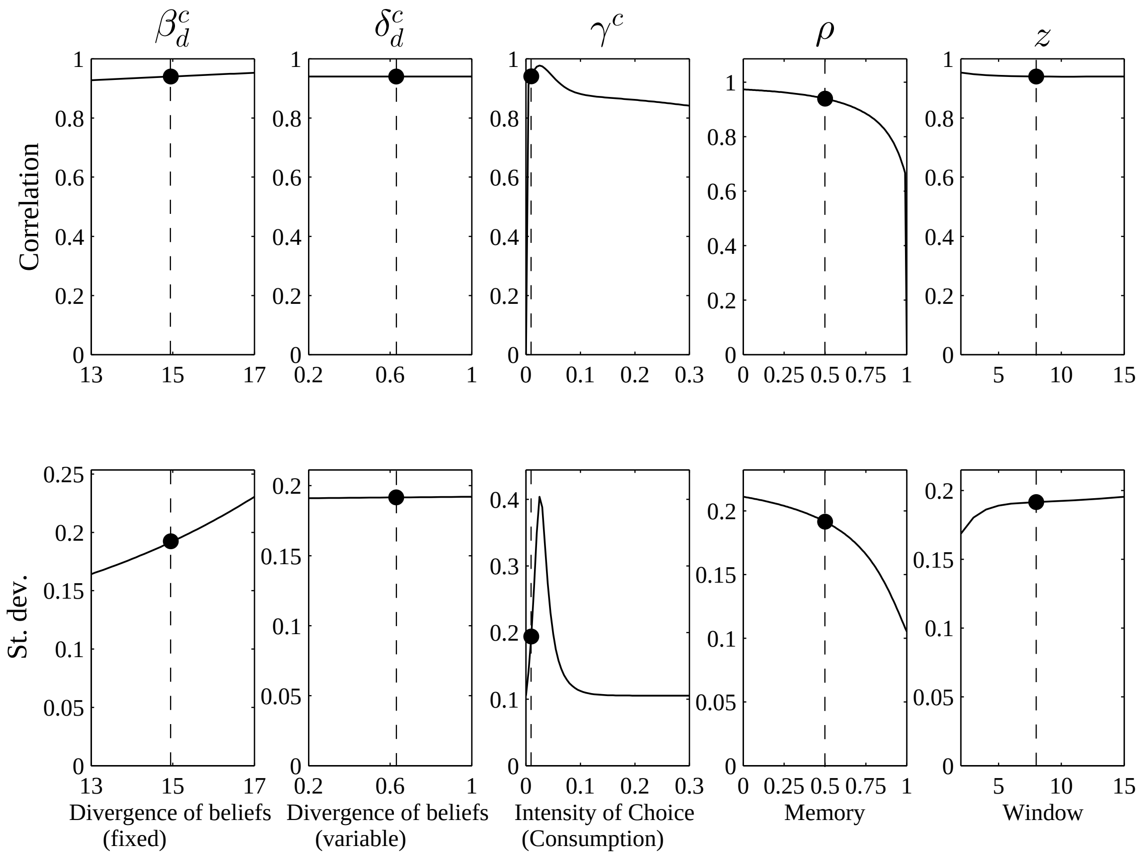
with $\alpha_{\text{opt},t}^x + \alpha_{\text{pes},t}^x + \alpha_{\text{fun},t}^x = 1$. The aggregate forecast is a weighted average of these rules:

$$\mathbb{E}_t\{\hat{x}_{t+1}\} = \alpha_{\text{opt},t}^x \mathbb{E}_t^{\text{opt}}\{\hat{x}_{t+1}\} + \alpha_{\text{pes},t}^x \mathbb{E}_t^{\text{pes}}\{\hat{x}_{t+1}\} + \alpha_{\text{fun},t}^x \mathbb{E}_t^{\text{fun}}\{\hat{x}_{t+1}\}. \tag{49}$$

D Sensitivity Analysis

In this section, we present some sensitivity analysis for the behavioral parameters shaping consumer confidence in the model, i.e. β_d^c, δ_d^c, and γ^c. Additionally, we provide robustness exercises for the memory parameter, ρ, and the evaluation window, z. As in De Grauwe (2011), we plot the correlation between the share of optimists, $\alpha_{\mathrm{opt},t}^c$, and consumption, $\hat{c}_t$ (upper panel of Figure 6) and the standard deviation of consumption (lower panel of Figure 6) for different values of the behavioral parameters. When varying a parameter, we hold the remaining coefficients fixed at their estimated values (see Table 2). Due to the non-linearity of the behavioral model, we simulate it 5,000 times over 1,200 periods, drop the first 400 periods to avoid starting point issues and calculate the moments of interest.

Figure 6: Influence of Behavioral Parameters on Consumption



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