Financial vs. Expectational dynamics: A horse race

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Abstract

This paper investigates whether financial frictions and boundedly rational expectations are substitutes. The answer to this question would help to clarify the nature of the transmission channels between the financial sector and the real economy. Overall, there is mixed evidence with regard to theoretical moments and correlations that are derived from the compared models, so that no clear winner emerges. My main result from the empirical analysis is that the presence of expectations reduces the quantitative importance of the financial acclerator mechanism, thus in part, expectations and financial frictions are substitutes. Overall, the estimation reveals large shares of boundedly rational expectations for some variables, but not for others.

Keywords: expectations, heterogeneity, financial accelerator

JEL Classification: E10, E32, E44, D83, D84

1 Introduction

Economists have been critized for ignoring the financial sector in DSGE models as well as for using unrealistic assumptions such as rational expectations (see Wieland/Schmidt 2012, p. 1499). Since the Great Recession, there is a growing effort to improve DSGE models in various respects. While the older literature has already introduced a financial sector into the model, the more recent literature emphasizes

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the role of boundedly rational expectations. In principle, there are two possibilities to introduce expectations into DSGE models: Expectations can either be taken as empirical expectations from surveys (Fuhrer 2017, e.g.) or modeled within a theoretical model, usually with reference to results from experimental research. Moreover, boundedly rational expectations are often linked to heterogeneity, as agents typically differ with respect to their cognitive abilities.

Financial frictions and boundedly rational expectations are sometimes considered to be substitutes. As Hommes (2011, p.2) notes, agent-based models are able to reproduce stylized facts in financial data and macro data due to positive feedback between expectations and observed variables. An overview of the empirical validation of agent-based models is provided by Lux/Zwinkels (2018). These models often rely on at least one expectation rule that involves bounded rationality. If various expectation rules are considered, we can speak of heterogeneous expectations. One big advantage of heterogeneous expectations lies in the fact that they capture volatility that is unrelated to economic fundamentals (so-called "excess volatility" (see Lux/Zwinkels 2018, p. 453f; Hommes 2011, p. 7)). However, heterogeneity in expectations might generate volatility that goes beyond the observed volatility of actual macroeconomic time series. Nevertheless, heterogeneous expectations lead to fat-tailed distributions, which would not be obtained under rational expectations and the assumption of iid shocks.

In principle, the behavior of macroeconomic variables in the context of financial markets could be obtained through financial frictions as well as through boundedly rational expectations. Although from a logical point of view true conclusions can also be derived from false premises, the right way forward seems to be a systematic comparison of economic models with different assumptions, which helps us to decide whether DSGE models should focus on financial frictions or on heterogeneous expectations or on a combination of both. This paper is a first step in this direction. So far, existing research has mainly compared rational and non-rational models. De Grauwe/Gerba (2018) have compared a DSGE model with rational and heterogeneous expectations with two types. However, their structural model always assumes financial frictions and ignores the possibility of expectational dynamics to serve as a substitute for a financial sector.

This paper compares a DSGE model with a financial sector and rational expectations to a DSGE model without a financial sector, but with heterogeneous, boundedly rational expectations. This comparison is based on the same underlying structural model. Financial fricitions are switched on and off by assuming different parameter values. One of the few DSGE models with financial dynamics was developed by

Bernanke/Gertler/Gilchrist (1999), which embeds a financial accelerator mechanism. This model amplifies the responses of macroeconomic variables to structural shocks. Nevertheless, it is based on rational expectations that have might involve unrealistic implications regarding cognitive abilities and information requirements. Therefore, alternative expectation mechanisms are introduced into the model with financial frictions being switched off. The comparison exercise between these two models might provide new insights into the transmission mechanism between the financial and the real economy.

The rest of the paper is structured as follows: Section 2 summarizes the structural model that is used for the comparison and discusses alternative expectation hypotheses. Section 3 looks at model simulations and compares various theoretical moments of both models with empirical data. Section 4 estimates the three models and compares parameter estimates. Finally, section 5 concludes.

2 Theoretical framework

Bernanke/Gertler/Gilchrist (1999) developed a New Keynesian DSGE model with monopolistic competition and Calvo price rigidities. Their model contains eleven endogenous variables and three shock processes (interest rate, government and technology shocks). The endogenous variables are cyclical output, consumption, investment, consumption of employers/net wealth, the rental rate of capital, the risk-free rate, Tobin's q, capital, working hours, the mark-up and inflation. Expectations are formed with respect to three variables: consumption, inflation and the rental rate of capital. The model contains a financial accelerator mechanism that can be switched off. The log-linearized equations are listed below. For a detailed derivation, see Bernanke/Gertler/Gilchrist (1999).

The empirical relevance of the financial accelerator has been investigated many times. A slightly modified version of the financial accelerator model is used by Christensen/Dib (2008). The financial accelerator improves the model fit, while the model without the financial accelerator mechanism is empirically rejected by likelihood-ratio tests. However, variance decompositions show that the overall contribution of the financial accelerator to output fluctuations is modest. They estimate the financial accelerator to be 0.042 (Christensen/Dib 2008, p. 164), a magnitude which is in line with the 0.05 used by Bernanke/Gertler/Gilchrist (1999). Gilchrist/Zakrajsek (2012) and Christiano/Motto/Rostagno (2014) extend standard DSGE models to incorporate the financial accelerator and find that these models have a better fit than models without financial frictions.

2.1 Structural model

Aggregate demand

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}i_t + \frac{G}{Y}g_t + \frac{C^e}{Y}c_t^e + ... + \phi_t^y \tag{2.1}$$

$$c_t = -r_{t+1} + E_t\{c_{t+1}\} \tag{2.2}$$

$$c_t^e = n_{t+1} + ... + \phi_t^{c^e} \tag{2.3}$$

$$E_t\{r_{t+1}^k\} - r_{t+1} = -\upsilon[n_{t+1} - (q_t + k_{t+1})] \tag{2.4}$$

$$r_{t+1}^k = (1-\epsilon)(y_{t+1} - k_{t+1} - x_{t+1}) + \epsilon q_{t+1} - q_t \tag{2.5}$$

$$q_t = \varphi(i_t - k_t) \tag{2.6}$$

Aggregate Supply

$$y_t = a_t + \alpha k_t + (1-\alpha)\Omega h_t \tag{2.7}$$

$$y_t - h_t - x_t - c_t = \eta^{-1}h_t \tag{2.8}$$

$$\pi_t = E_{t-1}\{\kappa(-x_t) + \beta\pi_{t+1}\} \tag{2.9}$$

Evolution of State Variables

$$k_{t+1} = \delta i_t + (1-\delta)k_t \tag{2.10}$$

$$n_{t+1} = \frac{\gamma RK}{N}(r_t^k - r_t) + r_t + n_t + ...\phi_t^n \tag{2.11}$$

Monetary Policy Rule and Shock Processes

$$r_t^n = \rho r_{t-1}^n + \varsigma\pi_{t-1} + \varepsilon_t^{rn} \tag{2.12}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g \tag{2.13}$$

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a \tag{2.14}$$

Parameters

$$\begin{aligned}
\phi_t^y &\equiv \frac{DK}{Y}\left[log\left(\mu\int_0^{\bar{\omega}} \omega dF(\omega) R_t^k Q_{t-1} K_t / DK\right)\right] \\
D &\equiv \mu \int_0^{\bar{\omega}} \omega dF(\omega) R^k \\
\phi_t^{c^e} &= log\left(\frac{1 - C_{t+1}^e / N_{t+1}}{1 - C^e/N}\right) \\
\phi_t^n &\equiv \frac{(R^k/R - 1)K}{N}(r_t^k + q_{t-1} + k_t) + \frac{(1-\alpha)(1-\Omega)(Y/X)}{N} y_t - x_t \\
v &\equiv \frac{\psi(R^k/R)}{\psi'(R^k/R)}, \epsilon \equiv \frac{1-\delta}{(1-\delta) + \alpha Y/(XK)} \\
\varphi &\equiv \frac{(\Phi(I/K)^{-1})'}{(\Phi(I/K)^{-1})''}, \kappa \equiv \left(\frac{1-\theta}{\theta}\right)(1 - \theta\beta)
\end{aligned}$$

Output y_t is produced with capital k_t and labor h_t (see equation 2.7) and is divided between consumption, investment, government spending and entrepreneurial consumption (see equation 2.1). Consumption c_t depends positively on consumption expectations and negatively on the risk-free interest rate r_t (equation 2.2). Consumption of entrepreneurs c_t^e is proportional to net wealth n (equation 2.3). The rental rate of capital r_t^k is linked to Tobin's q (equation 2.5), which represents the price of one unit of capital and depends on the difference between investment and capital (equation 2.6). The labor market clearing relates working hours h_t to the marginal product of labor corrected for the marginal utility of consumption $-c$ (equation 2.8). The Phillips curve 2.9 relates inflation π_t to the mark-up x_t and inflation expectations. The standard assumption is that mark-up is negatively related to demand, thus the term $-x$ in the Phillips curve establishes a positive relationship between demand and inflation. The capital stock k_{t+1} is equal to the capital stock of the previous period plus current investment (see equation 2.10).

The basic idea of the financial accelerator is as follows: Firms have two sources of financing, profits and credit (Bernanke/Gertler/Gilchrist 1999, p. 1347). Under asymmetric information, financial markets monitor firms' net wealth as a proxy for their creditworthiness (Bernanke/Gertler/Gilchrist 1999, p. 1345). With a lower net wealth, they will charge a higher external risk premium to compensate for monitoring costs. As profits and net wealth are procyclical, the risk premium will be countercyclical. Net wealth depends on net returns, i.e. the rental rate of capital minus the risk-free rate as well as on the risk-free rate and net wealth from the previous period. The term $\frac{\gamma RK}{N}$ represents the ratio of gross capital to net worth and could be larger than one, if firms are leveraged (equation 2.11). This implies a multiplier effect of net returns on net wealth. Thus, the financial accelerator mechanism countercyclically amplifies economic shocks and establishes a link between financial markets and the real economy.

Equation 2.4 embeds the financial accelerator. "In the absence of capital market frictions, this relation collapses to $E_t\{r^k_{t+1}\} - r_{t+1} = 0$. Investment is pushed to the point where the expected return on capital, $E_t\{r^k_{t+1}\}$, equals the opportunity cost of funds r_{t+1}. With capital market frictions present, however, the cost of external funds depends on entrepreneurs' percentage equity holding, i.e. net worth relative to the gross value of capital, $n_{t+1} - (q_t + k_{t+1})$. A rise in this ratio reduces the cost of external funds, implying that investment will rise." (Bernanke/Gertler/Gilchrist 1999, p. 1363) On the other hand, an unexpected fall in capital returns reduces net worth more than one for one, the external finance premium rises and investment demand drops. As the capital price falls, the net worth is further reduced. Hence, the countercyclical risk premium amplifies economic shocks. Thus, with $\upsilon > 0$, the financial accelerator is activated and the model exhibits *financial dynamics*. Without the financial accelerator, i.e. under $\upsilon = 0$, boundedly rational expectations drive a wedge between the expected rental rate of capital and the opportunity costs r_t. Hence, the model exhibits *expectational dynamics*.

2.2 Expectations

Rational expectations can be replaced by a convex combination of heterogeneous expectations. In the first model version, two types are considered: rational and naive expectations. These expectations are also called fundamentalist and extrapolative forecasts, respectively (see De Grauwe 2010, p. 468). Rational expectations correspond to the true mathematic expectation of an observed variable (see Hommes 2013, p. 98):

$$x^e_t = E_t[x_t] = x^* \tag{2.15}$$

An observed value depends on the fundamental value and random shocks. As the expected value of the shock term is zero, the expected value of the variable corresponds to the true value of the variable. The true value can only be calculated with the help of an economic model, therefore rational expectations are also referred to as "model-consistent expectations" (Wieland/Schmidt 2012, p. 1443).

Boundedly rational expectations only use some information to form expectations about the future. In most cases they are based on simple heuristics or treat agents as econometricians who learn from looking at past observations. They thus take into account the cognitive limitations of agents. In this paper, boundedly rational expectations can occur in two forms: naive and adaptive expectations. Naive expectations are equal to the last observed value of a variable (see Hommes 2013, p. 11):

$$x_t^e = x_{t-1} \tag{2.16}$$

Naive expectations are a simple autoregressive forecasting rule. However, naive expectations involve systematic forecasting mistakes and agents are unable to learn.

The second model version combines fundamental and adaptive expectations. Adaptive expectations are formed in the following way (see Hommes 2013, p. 101):

$$x_t^e = (1-w) \cdot x_{t-1}^e + w \cdot x_{t-1} = x_{t-1}^e + w \cdot (x_{t-1} - x_{t-1}^e) \tag{2.17}$$

Expectations are a weighted average of the last forecast and the last observation. Algebraic manipulation shows that expectations are equal to the last expectation, which is adjusted in the direction of the last forecasting error, i.e. the difference between the last realization and the last expectation. Consequently, agents with adaptive expectations are able to learn from their past mistakes.

Rational and boundedly rational expectations have different advantages and disadvantages. Obviously, rational expectations are foreward-looking, while naive and adaptive expectations have a backward-looking character. While rational expectations do not involve systematic forecasting errors, boundedly rational account for cognitive limitations of market participants and adaptive expectations even allow for learning. Finally, expectations might be related to institutional characteristics of markets (see Hommes 2011, p.15f). While the real economy is characterized by negative feedback between expectations and observed prices as production decisions are strategic substitutes, financial markets are characterized by positive feedback between expectations and prices due to fixed quantities and speculative demand, i.e. higher expectations increase demand and prices, which again trigger higher expectations.

Recent contributions of DSGE models are based on heterogeneous expectations, i.e. on a combination of rational and boundedly rational expectations, or a combination of various boundedly rational expectation rules. These models assume time-varying group fractions (see e.g. De Grauwe 2010; De Grauwe 2011; Hommes 2011, p. 19f). As two endogenous variables are multiplied, i.e. variables and group shares, these models exhibit nonlinear dynamics and might not have an equilibrium path. By contrast, this paper assumes fixed group shares so that the models can also be

C/Y	0.64
C^e/Y	0.01
I/Y	0.15
G/Y	0.2
K/N	2
Y/N	0.282494996
X	1.1
β	0.99
R	$1/\beta$
α	0.35
η	3
ω	0.99
δ	0.025
ρ_a	0.999
ρ_g	0.95
φ	0.25
R^k	R + 0.02
γ	1-0.0272
μ	0.12
θ	0.75
ρ	0.9
σ	0.11
κ	$((1-\theta)/\theta) \cdot (1-\theta * \beta)$
ϵ	$(1-\delta)/((1-\delta)+((\alpha/X)\cdot(Y/N/K/N)))$
υ	0.052092347

Table 1: Calibration

estimated easily. However, this implies that the model is only semi-endogenous, because the endogenous dynamics still depend on an initial shock similar to De Grauwe (2010, p.479).

3 Model comparison

This section compares the rational model with financial frictions and the boundedly rational model without financial frictions.

3.1 Calibration

The parameter values are listed in Table 1. The calibration is entirely standard and all values can be found in Bernanke/Gertler/Gilchrist (1999).

The most interesting parameter is υ which captures financial frictions and drives a wedge into the difference between the rental rate and expectations that depends on the difference between net wealth and the gross value of capital. To switch off the financial accelerator mechanism, the parameter is set to $\upsilon = 0.001$.

3.2 Impulse response analysis

To begin with, the responses of endogenous variables to a stochastic shock are analyzed.

Figure 1 replicates the effect of a monetary shock with and without the financial accelerator. A lower interest rate stimulates investment demand and output. The financial accelerator reduces the risk premium and amplifies the responses of shocked variables. Moreover, the persistence of output und investment increase, as both variables take a longer time to return to their steady state values.

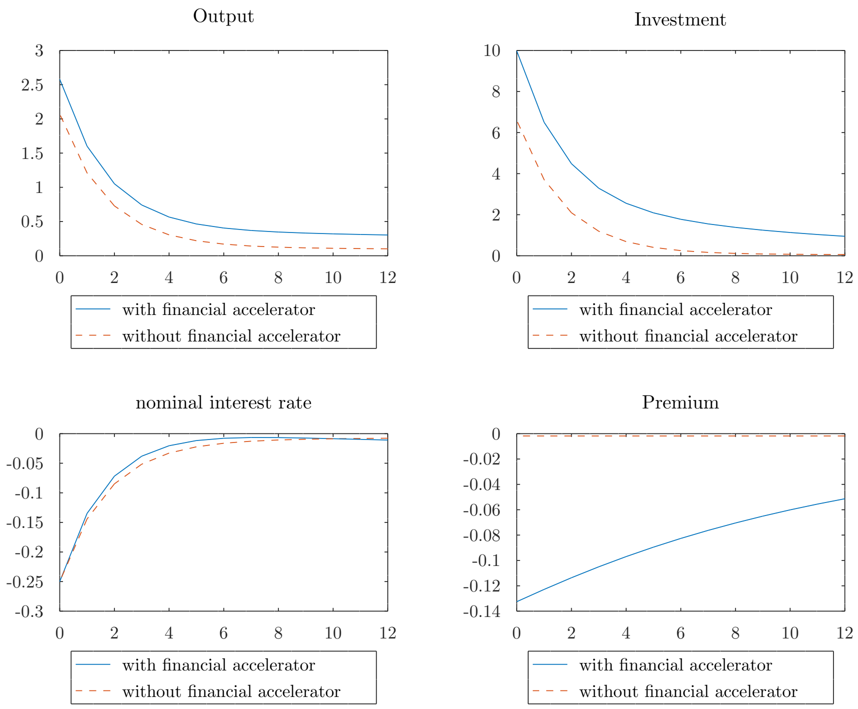

Figure 1: Monetary shock in Bernanke/Gertler/Gilchrist (1999, p.1371)

Figure 2 shows the responses of endogenous variables under naive expectations. The share of naive expectations is set to 0.5. A positive share of fundamental expectations ensures a stable equilibrium. We can see highly nonlinear responses of the shocked variables. Moreover, the initial reactions are stronger in the model version with the financial accelerator. With adaptive expectations the impulse responses are considerably more volatile (see Figure 3). Furthermore, the volatility is especially pronounced if adaptive expectations interact with the financial acclerator mechanism.

The risk premium under boundedly rational expectations without financial accelerator is not exactly zero, as the scaling properties of the figures suggest. This will become clear in the next simulations.

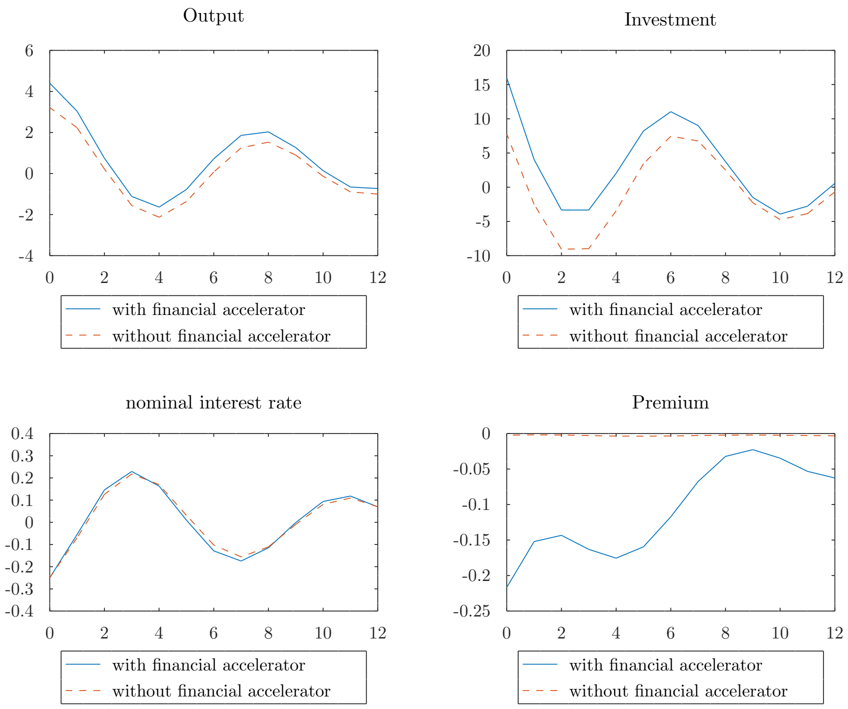

Figure 2: Monetary shock under naive expectations

In sum, heterogeneous, boundedly rational expectations add much more volatility to the economic system compared to purely rational expectations, while there is also an interaction effect with the financial accelerator.

Next, the share of boundedly rational expectations n is varied. Figure 4 and 5 compare the impulse responses under naive and adaptive expectations ($n = 0.5$) to those under rational expectations ($n = 0$) with the financial accelerator always switched off. As can be seen, heterogeneous expecations introduce substantial dynamics. Furthermore, the risk premium under both naive and adaptive expectations is fairly volatile. The risk premium represents the difference between the actual and the expected rental rate of capital and thus captures the extent of expectational dynamics. We can conclude from this analysis that the model is able to amplify business cycle shocks and to increase their persistence once boundedly rational expectations are considered, even if the financial accelerator is switched off. Overall, the expectational model generates more volatile reactions of shocked variables.

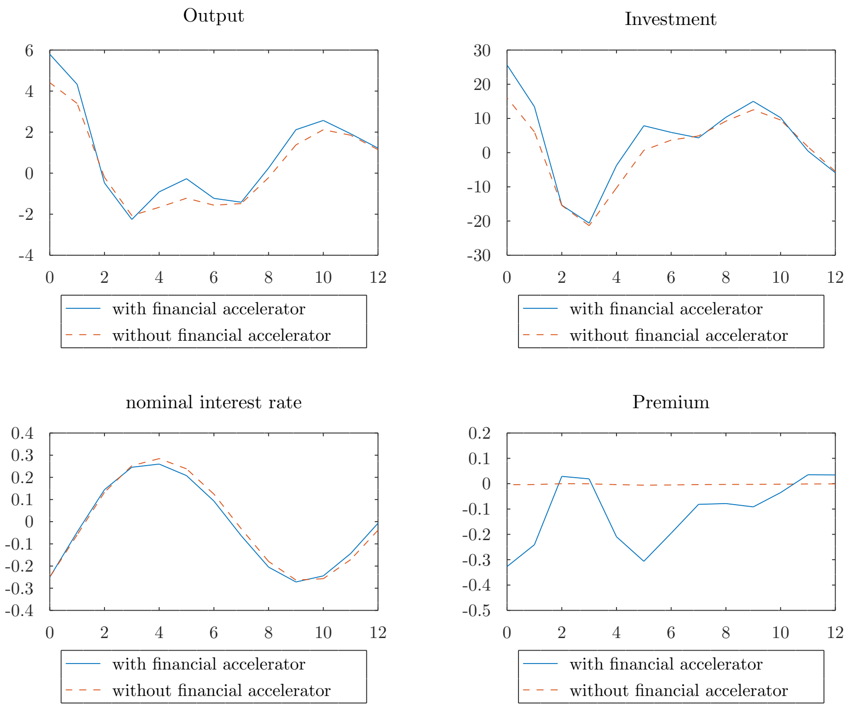

Figure 3: Monetary shock under adaptive expectations

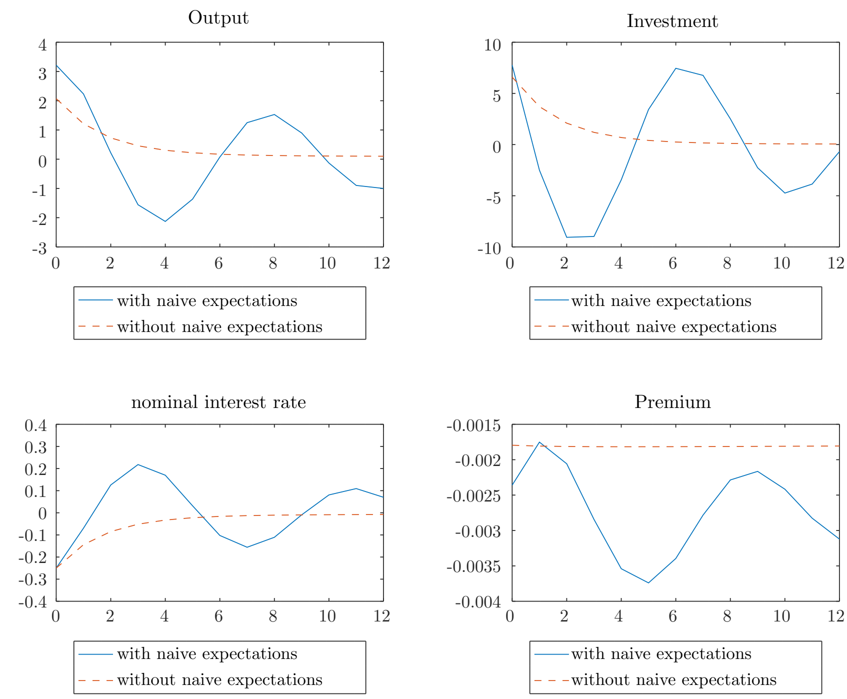

Figure 4: Monetary shock with and without naive expectations

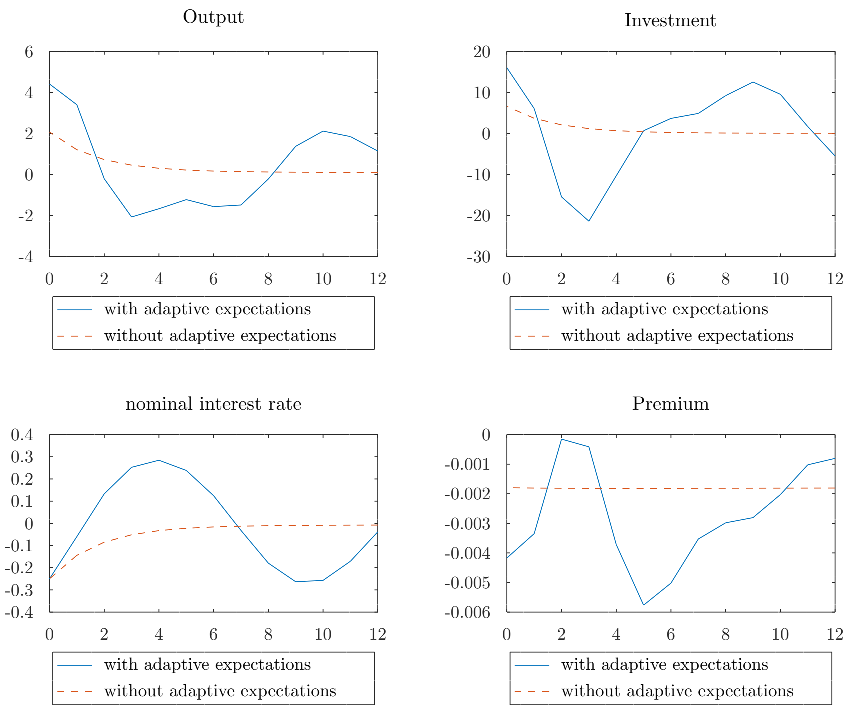

Figure 5: Monetary shock with and without adaptive expectations

3.3 Variance decomposition

This section compares the variance decomposition of the financial accelerator model and the expectational models (see Tables 2 to 4). In line with Bernanke/Gertler/Gilchrist (1999), the shock variance of the monetary shock is assumed to be 0.25, while the shock variances of government and productivity shocks are set to 0.1.

Under naive and adaptive expectations, higher shares of interest rate shocks are obtained for output, consumption and investment. The interest shock is the most important one in all models, which might result from the high shock variance. Overall, there is little difference with respect to the other variables considered.

3.4 Stylized facts

Next, the simulated data from our models are compared to empirical data for Austria as well as to stylized facts from the empirical business cycle literature (see Backus/Kehoe 1992). Most importantly, the data cover the financial crisis from 2007 to 2009. The most important stylized facts from empirical studies are:

1. investment is more volatile than output

2. consumption is as volatile as output

	e_{rn}	e_g	e_a
output	64.55	0.02	35.43
consumption	34.53	0.00	65.46
investment	96.03	0.00	3.97
government	0.00	100.00	0.00
consumption of employers	95.17	0.00	4.82
net wealth	95.17	0.00	4.82
rental rate of capital	99.92	0.00	0.08
risk-free interest rate	99.98	0.00	0.01
Tobin's q	99.71	0.00	0.28
capital	75.84	0.00	24.16
mark-up	99.98	0.00	0.02
productivity	0.00	0.00	100.00
hours	98.32	0.02	1.65
inflation	99.88	0.00	0.12
interest rate	98.83	0.01	1.16
risk premium	99.92	0.00	0.07

Table 2: Variance decomposition: FA model

	e_{rn}	e_g	e_a
output	81.67	0.01	18.33
consumption	83.70	0.00	16.30
investment	98.29	0.00	1.71
government spending	0.00	100.00	0.00
consumption of employers	99.22	0.00	0.78
net wealth	99.22	0.00	0.78
rental rate of capital	99.98	0.00	0.02
risk-free interest rate	99.99	0.00	0.01
Tobin's q	99.87	0.00	0.13
capital	42.15	0.01	57.85
mark-up	99.98	0.00	0.02
productivity	0.00	0.00	100.00
hours	99.43	0.01	0.56
inflation	99.98	0.00	0.02
interest rate	99.98	0.00	0.02
risk premium	99.97	0.00	0.03

Table 3: Variance decomposition: naive model

	e_{rn}	e_g	e_a
output	92.57	0.00	7.43
consumption	94.01	0.00	5.99
investment	99.65	0.00	0.35
government spending	0.00	100.00	0.00
consumption of employers	99.58	0.00	0.42
net wealth	99.58	0.00	0.42
rental rate of capital	99.96	0.00	0.04
risk-free interest rate	99.91	0.00	0.09
Tobin's q	99.90	0.00	0.10
capital	52.88	0.01	47.11
mark-up	99.91	0.00	0.09
productivity	0.00	0.00	100.00
hours	99.73	0.00	0.27
inflation	99.91	0.00	0.09
interest rate	99.89	0.00	0.11
risk premium	99.92	0.00	0.08

Table 4: Variance decomposition: adaptive model

3. consumption and investment are procyclical
4. inflation rates are volatile, persistent and countercyclical

(see Backus/Kehoe 1992, p. 874ff).

The time series data starts in the first quarter of 1996 and ends in the last quarter of 2017. Output, consumption and investment are measured as quarterly, seasonally adjusted and chain-linked volumes (Source: Eurostat). Short-term interest rate are provided by the OECD. As they are expressed on a yearly basis, they are divided by four. Total working hours, seasonally and calendrically adjusted, are taken from the ECB and the seasonally-adjusted GDP-Deflator is taken from the St. Louis Fed.

All variables with the exception of interest rates and inflation are deflated, logarithmized and hp-filtered. Interest rates are taken as nominal variables and inflation is calculated as log-differences of the GDP deflator.

As can be seen from Table 5 investment in Austria is more volatile than output, but consumption is less volatile. Both variables are procyclical (see Table 7). Inflation rates have a lower volatility (see Table 5), a negative autocorrelation (see Table 6) and are weakly procyclical (see Table 7). Thus, Austrian data deviate in some respects from the stylized facts found in the business cycle literature.

In the model with the financial accelerator (FA model), investment is the most volatile variable, followed by output, while consumption is the least volatile of these three variables, but roughly as volatile as output. The introduction of boundedly

	FA model	naive	adaptive	data
output	4.6913	6.4830	10.1945	0.0120176
consumption	4.5112	8.9994	14.9414	0.006294
investment	14.4631	21.7846	54.2854	0.0235034
consumption of employers	12.8179	34.7126	49.0467	
net wealth	12.8179	34.7126	49.0467	
rental rate of capital	2.8976	4.5617	9.6830	
risk-free interest rate	0.8269	2.5884	4.2949	
Tobin's q	3.3672	5.4394	13.7075	
capital	5.6838	3.6077	3.9659	
mark-up	5.2778	13.3908	21.0933	
hours	5.0528	8.7923	14.4424	0.0079319
inflation	0.9834	3.4515	5.7441	0.0036945
risk premium	0.3488	0.0320	0.0444	
government shock	0.3203	0.3203	0.3203	
interest rate	0.3206	0.5047	1.1295	0.001819
productivity shock	2.2366	2.2366	2.2366	

Table 5: standard deviations

rational expectations amplifies the volatility of these three variables. Investment is always more volatile than output, but the same is true for consumption in the behavioral models. This also constrasts with Austrian data, where consumption is less volatile. Under the present calibration, the FA model seems to be closer to the data, while the other models fail to reproduce the relative ordering between consumption and output. Nevertheless, they are able to generate a higher investment volatility.

Inflation exhibit little volatility in the data. This fact is also obtained in the FA model. Naive and adaptive expectations increase the volatility of hours and inflation. Again, the FA model seems to be closer to the data, although a higher volatility of inflation rates has been observed empirically (see Backus/Kehoe 1992, p. 878). This fact can be reproduced by boundedly rational expectations. So far, there is mixed evidence for the considered models. An important takeaway is that adaptive expectations amplify the volatility of all variables considerably more than naive expectations.

With regard to autocorrelations (see Table 6), the FA model almost perfectly matches the high autocorrelation of output. By contrast, the autocorrelation of consumption is most closely matched by the model with naive expectations. The autocorrelation of investment is matched by both the FA model and the model with adaptive expectations. The high volatility of working hours is not obtained in the three models. In terms of the relative performance, the adaptive model is closer to the

	FA model	naive	adaptive	data
output	0.8165	0.6777	0.7283	0.8853
consumption	0.9191	0.7416	0.8414	0.6445
investment	0.7176	0.5809	0.7127	0.7252
consumption of employers	0.9093	0.9781	0.9402	
net wealth	0.9093	0.9781	0.9402	
rental rate of capital	-0.1803	0.1911	0.3624	
risk-free interest rate	0.5324	0.6686	0.8204	
Tobin's q	0.6663	0.5694	0.7115	
capital	0.9982	0.9886	0.9403	
mark-up	0.5590	0.6499	0.7824	
hours	0.6056	0.5886	0.6846	0.8576
inflation	0.5482	0.6797	0.8221	-0.1631
risk premium	0.9250	0.9958	0.9849	
government shock	0.9500	0.9500	0.9500	
interest rate	0.6044	0.5549	0.8045	0.8901
productivity shock	0.9990	0.9990	0.9990	

Table 6: autocorrelations

	y	c	i	h	π	r^n
y	1.0000	0.4551	0.7549	0.7885	0.0715	0.7945
c		1.0000	0.3765	0.3655	0.0290	0.2405
i			1.0000	0.7165	0.0539	0.7114
h				1.0000	0.0541	0.6734
π					1.0000	0.1526
r^n						1.0000

Table 7: crosscorrelations data

data than the other models. All models fail to reproduce the negative autocorrelation of inflation, which, however, seems to be in contrast with other empirical findings. Finally, the autocorrelation of interest rates is higher in the data than in the models, however, the adaptive model is relatively close.

In sum, there is mixed evidence for the three models. Some variables are matched by one or two of the models, while some are not even matched at all. The FA model matches output and investment, the naive model matches only consumption and the adaptive model matches investment and interest rates. Adaptive expectations also generate a high persistence of inflation. These results point to the necessity to consider different types of expectations for different variables in future investigations.

Next, the crosscorrelations between the variables are examined. In the data, we can observe the procyclicality of consumption and investment, while inflation is acyclical (see Table 7). Moreover, there is a positive correlation between consumption and investment. Hours are highly correlated with output and investment. Interest rates are only weakly correlated with the inflation rate, as monetary policy is conducted

	y	c	i	g	c^e	n	r^k	r	q	k	x	a	h	π	r^n	premium
y	1.0000	0.9276	0.8773	0.0121	0.8510	0.8510	0.3181	-0.7027	0.6656	0.6946	-0.7118	0.5949	0.6328	0.6456	-0.8280	-0.7048
c		1.0000	0.6351	-0.0065	0.6807	0.6807	0.2166	-0.4414	0.3619	0.7798	-0.4370	0.8079	0.3187	0.3668	-0.6258	-0.4590
i			1.0000	0.0050	0.8752	0.8752	0.3917	-0.8959	0.9196	0.4199	-0.9193	0.1982	0.9058	0.8751	-0.9116	-0.8564
g				1.0000	0.0064	0.0064	0.0008	0.0003	0.0036	0.0043	-0.0028	0.0000	0.0150	0.0037	0.0082	-0.0069
c^e					1.0000	1.0000	0.1319	-0.6126	0.6401	0.7479	-0.6458	0.2192	0.6427	0.5546	-0.7833	-0.9575
n						1.0000	0.1319	-0.6126	0.6401	0.7479	-0.6458	0.2192	0.6427	0.5546	-0.7833	-0.9575
r^k							1.0000	-0.5971	0.4636	-0.0743	-0.5675	0.0002	0.5211	0.5883	-0.5272	-0.0824
r								1.0000	-0.9361	-0.1170	0.9967	-0.0024	-0.9746	-0.9915	0.9297	0.6026
q									1.0000	0.0296	-0.9595	0.0082	0.9728	0.9605	-0.8079	-0.6973
k										1.0000	-0.1225	0.4855	0.0574	0.0075	-0.4533	-0.5680
x											1.0000	-0.0005	-0.9864	-0.9928	0.9220	0.6497
a												1.0000	-0.1263	-0.0291	-0.0971	-0.0033
h													1.0000	0.9817	-0.8798	-0.6924
π														1.0000	-0.8759	-0.5723
r^n															1.0000	0.7084
premium																1.0000

Table 8: crosscorrelations FA model

	y	c	i	g	c^e	n	r^k	r	q	k	x	a	h	π	r^n	premium
y	1.0000	0.8535	0.4531	0.0074	0.2487	0.2487	-0.2476	-0.8117	0.3680	0.5722	-0.8436	0.4276	0.8615	0.7761	-0.7427	-0.1426
c		1.0000	-0.0750	-0.0040	0.0539	0.0539	-0.5537	-0.8983	-0.1573	0.4723	-0.8787	0.4027	0.7081	0.9089	-0.3503	-0.0320
i			1.0000	0.0020	0.2922	0.2922	0.4723	-0.0266	0.9863	0.2390	-0.1223	0.1294	0.4478	-0.0614	-0.8421	-0.1223
g				1.0000	0.0018	0.0018	0.0004	0.0001	0.0014	0.0042	-0.0004	0.0000	0.0076	0.0000	0.0002	-0.0012
c^e					1.0000	1.0000	0.1180	-0.0041	0.1983	0.5983	-0.0244	0.0864	0.1240	-0.0081	-0.1328	-0.9828
n						1.0000	0.1180	-0.0041	0.1983	0.5983	-0.0244	0.0864	0.1240	-0.0081	-0.1328	-0.9828
r^k							1.0000	0.5467	0.4993	-0.0841	0.4696	0.0003	-0.2482	-0.5770	-0.1018	-0.0525
r								1.0000	-0.0007	-0.1566	0.9944	-0.0002	-0.8951	-0.9958	0.5372	-0.0134
q									1.0000	0.0754	-0.0982	0.0050	0.4365	-0.0881	-0.8381	-0.0366
k										1.0000	-0.1609	0.7522	0.1376	0.1471	-0.1567	-0.5230
x											1.0000	0.0004	-0.9342	-0.9823	0.6147	-0.0084
a												1.0000	-0.0731	-0.0001	-0.0007	-0.0081
h													1.0000	0.8535	-0.8440	-0.0448
π														1.0000	-0.4588	0.0104
r^n															1.0000	-0.0160
premium																1.0000

Table 9: crosscorrelations naive model

	y	c	i	g	c^e	n	r^k	r	q	k	x	a	h	π	r^n	premium
y	1.0000	0.6449	0.4821	0.0049	0.2079	0.2079	-0.2322	-0.7464	0.4355	0.7279	-0.8366	0.2713	0.9454	0.6743	-0.7288	-0.0301
c		1.0000	-0.3574	-0.0024	-0.1584	-0.1584	-0.5469	-0.9400	-0.4035	0.5464	-0.8958	0.2422	0.5467	0.9640	-0.0727	0.0991
i			1.0000	0.0011	0.3860	0.3860	0.3386	0.1615	0.9974	0.2432	0.0009	0.0517	0.5315	-0.2784	-0.8147	-0.0967
g				1.0000	0.0011	0.0011	0.0002	0.0002	0.0007	0.0050	-0.0002	0.0000	0.0047	-0.0002	-0.0006	-0.0005
c^e					1.0000	1.0000	0.2135	0.1317	0.3595	0.4377	0.0601	0.0585	0.1671	-0.1559	-0.2027	-0.9539
n						1.0000	0.2135	0.1317	0.3595	0.4377	0.0601	0.0585	0.1671	-0.1559	-0.2027	-0.9539
r^k							1.0000	0.5643	0.3658	-0.2954	0.4502	0.0001	-0.1918	-0.5373	0.1148	-0.1492
r								1.0000	0.1986	-0.4664	0.9796	-0.0001	-0.7388	-0.9869	0.3189	-0.1258
q									1.0000	0.1728	0.0370	0.0020	0.5031	-0.3136	-0.7959	-0.0729
k										1.0000	-0.4862	0.6814	0.4940	0.4161	-0.4234	-0.3406
x											1.0000	0.0004	-0.8432	-0.9604	0.4103	-0.0983
a												1.0000	-0.0447	0.0012	0.0067	-0.0032
h													1.0000	0.6610	-0.7789	0.0148
π														1.0000	-0.1707	0.1125
r^n															1.0000	-0.0596
premium																1.0000

Table 10: crosscorrelations adaptive model

by the ECB, which considers the conditions of the European economy rather than the economic conditions of Austria.

In the FA model, consumption, investment and inflation are procyclical, while the latter should be acyclical or even countercyclical (see Table 8). Compared to empirical data, there is an even higher correlation between consumption and investment, while the correlation between hours and output is somewhat reduced and the correlation between hours and investment is enhanced. Interest rates and inflation are strongly negatively correlated.

In the naive model, consumption, investment and inflation are also procyclical, however, consumption is more correlated with the cycle than investment (see Table 9). Surprisingly, there is a slightly negative correlation between consumption and investment. Hours are much more correlated with the cycle, the correlation is close to the one observed in the data. The correlation of hours and investment is lower. The correlation between interest rates and inflation is also negative, but lower than in the FA model.

Finally, consumption and investment in the adaptive model are procyclical (see Table 9). Compared to the naive model, the cyclicality is somewhat lower for consumption and higher for investment. However, the model does not match the higher cyclicality of investment relative to consumption. In this respect, the model does not differ from both the FA model and the naive model. The correlation between consumption and investment is still negative, which is contradicted by the empirical data. Inflation is still strongly procyclical, while it should be acyclical (data) or countercyclical (research). As in the data, hours are almost perfectly correlated with the business cycle, but hours are lower correlated with investment. Although the model generates a negative correlation between interest rates and inflation, it is almost acylical as in the data.

Compared to the stylized facts, the FA model performs better with the exception of inflation. Naive and adaptive expectations perform worse with respect to consumption, but better with respect to inflation. The comparison with Austrian data reveals that all models have roughly the same performance. The FA model is slightly better, as it captures the low volatility. With regard to crosscorrelations, the FA model succeeds in reproducing the positive correlation between consumption and investment and the correlation between hours and investment, while the behavioral models fail to replicate the first correlation and only capture the correlation between hours and output. The adaptive expectation model comes relatively close to matching the correlation between interest rates and inflation. Taken together, the first round of the horse race yields no clear winner, although the FA model seems to perform

parameter	distribution	priors	
ν	inverse gamma	0.05	0.15
ψ	normal	0.25	0.15
σ	inverse gamma	0.11	0.15
ρ	beta	0.9	0.07
ρ_g	beta	0.8	0.14
ρ_a	beta	0.8	0.14
stderr e_g	inverse gamma	0.25	2
stderr e_a	inverse gamma	0.1	2
stderr e_{rn}	inverse gamma	0.1	2
n_c	beta	0.5	0.2
n_{r^k}	beta	0.5	0.2
n_π	beta	0.5	0.2
w_c	beta	0.65	0.2
w_{r^k}	beta	0.65	0.2
w_π	beta	0.65	0.2
stderr e_c^e	inverse gamma	0.1	2
stderr e_π^e	inverse gamma	0.1	2
stderr $e_{r^k}^e$	inverse gamma	0.1	2

Table 11: Priors

slightly better. Therefore, the models are estimated in the next section.

4 Estimation

This section estimates the parameters of the models, especially the financial accelerator and the degree of heterogeneity in the economy that is consistent with aggregate volatility. The estimation is based on Bayesian methods and takes the empirical data as given. The three observed variables are cyclical output, consumption and inflation. Only three variables are considered, as the number of observed variables cannot be larger than the number of shocks, because this would lead to stochastic singularity. The parameter values are shown in Table 11. The estimation assumes an inverse gamma distribution if parameters are bound to be positive, a beta distribution if parameters are between 0 and 1 and a normal distribution for the rest.

At first, the basic financial accelerator model with rational expectations is estimated. Implicitly, the share of boundedly rational expectation is constrained to be zero. The results are shown in Table 12. In the FA model, the financial accelerator ν is only , which is half of its prior value. Financial frictions seem to matter less in Austria than initially thought, nevertheless this parameter is still positive, so that the financial accelerator mechanism improves the model fit.

	prior mean	posterior mean	90% HPD interval
ν	0.050	0.0264	0.0125 0.0411
φ	0.250	0.5294	0.3616 0.6913
sig	0.110	1.7908	1.1649 2.4169
ρ	0.900	0.4227	0.2308 0.5897
ρ_g	0.800	0.7342	0.6196 0.8517
ρ_a	0.800	0.1923	0.0831 0.2907
e_g	0.250	0.0383	0.0333 0.0432
e_a	0.100	0.0261	0.0227 0.0298
e_{rn}	0.100	0.0124	0.0118 0.0131

Table 12: Estimation results FA model

	prior mean	posterior mean	90% HPD interval
ν	0.050	0.0205	0.0111 0.0351
φ	0.250	0.6889	0.6713 0.7051
σ	0.110	0.7309	0.6925 0.7571
ρ	0.900	0.8583	0.8328 0.8800
ρ_g	0.800	0.8575	0.8393 0.8893
ρ_a	0.800	0.3402	0.3108 0.3642
n_c	0.500	0.9710	0.9455 0.9934
n_{r^k}	0.500	0.0399	0.0146 0.0657
n_π	0.500	0.0597	0.0086 0.1138
e_g	0.250	0.0370	0.0316 0.0416
e_a	0.100	0.0220	0.0165 0.0270
e_{rn}	0.100	0.0127	0.0118 0.0135
e_c^e	0.100	0.0132	0.0118 0.0146
e_π^e	0.100	0.0127	0.0118 0.0138
$e_{r^k}^e$	0.100	0.0186	0.0138 0.0230

Table 13: Estimation results naive model

Next, rational expectations are replaced by a combination of naive and fundamental expectations, which allows to estimate their relative weights.

$$x_t^e = n \cdot x_{t-1} + (1-n) \cdot x_t^* + e_{x,t}^e \tag{4.1}$$

The estimation also considers expectation shocks which represent sentiment shocks that are unrelated to economic fundamentals (see Cole/Milani 2016, p.12ff). If expectations do not improve the model fit, the share of naive expectations n would be close to zero. The prior for the group weight follows a Beta distribution with mean 0.5 and standard deviation 0.2. Table 13 presents the results.

The estimation of the naive model shows that the financial accelerator is 0.0205 and thus smaller than in the FA model, where it was 0.0264. In part, expectations

	prior mean	posterior mean	90% HPD interval
ν	0.050	0.0183	0.0110 0.0257
φ	0.250	0.2593	0.2313 0.2818
σ	0.110	0.4645	0.4309 0.5062
ρ	0.900	0.9724	0.9610 0.9836
ρ_g	0.800	0.4275	0.4003 0.4550
ρ_a	0.800	0.5516	0.5092 0.5836
n_c	0.500	0.0319	0.0068 0.0567
n_{r^k}	0.500	0.0812	0.0268 0.1454
n_π	0.500	0.0585	0.0148 0.1046
w_c	0.650	0.7659	0.7069 0.8300
w_{r^k}	0.650	0.9795	0.9580 0.9989
w_π	0.650	0.5095	0.4568 0.5548
e_g	0.250	0.0447	0.0387 0.0509
e_a	0.100	0.0200	0.0166 0.0234
e_{rn}	0.100	0.0120	0.0118 0.0123
e_c^e	0.100	0.0774	0.0633 0.0957
e_π^e	0.100	0.0318	0.0215 0.0399
$e_{r^k}^e$	0.100	0.0442	0.0289 0.0659

Table 14: Estimation results adaptive model

and financial dynamics seem to be substitutes, but the parameter is still positive. The share of naive expectations increases to almost 100% for consumption. By contrast, theses shares are close to zero for expectations regarding inflation and the rental rate of capital. Expectations for these variables are better described by fundamental forecasts. For all three forecasted variables, the expectation shocks are smaller than their prior value. Last, the adaptive model is estimated. This involves not only the estimation of the group weights and the expectation shocks, but also parameter w of the adaptive rule (2.17), i.e. the relative weight of the last observation and the last forecast, henceforth w_c, w_{r^k} and w_π for consumption, the rental rate and inflation, respectively.

The estimation of the adaptive model yields $\nu = 0.0183$, which represents the lowest value of the financial accelerator. However, this parameter is still not zero. The shares of adaptive expectations are below 10% for all variables. The standard deviation of the expectation shocks is again smaller than the prior value. This time, the parameters of the adaptive expectation rules were also estimated. The weight on the last observation increases for consumption and the rental rate of capital. By contrast, the weight on the last forecast increases for inflation expectations.

5 Conclusion

This paper is a first step towards investigating the relative importance of expectational and financial dynamics. It provides insights into the transmission channel between the financial economy and the real economy. Expectations and financial frictions capture the same underlying idea: namely that financial shocks have a large and long-lasting impact on the real economy. This can either be modeled by introducing a leverage measured by the ratio of net wealth to gross capital or through backward-looking expectations that store shocks and hence influence decisions in the next period. While there is evidence for the financial accelerator mechanism, according to which economic shocks are transmitted to the real economy due to borrowing constraints, economic shocks also influence investment expectations and hence economic variables that depend on these expectations. In the empirical analysis, both the financial and the expectational models have a comparable performance. The model estimation reveals that a combination of financial and expectational dynamics performs best. However, in part, financial and expectational dynamics are substitutes, as the presence of boundedly rational expectations reduces the financial accelerator.

Future research should continue this investigation by comparing new structural models that also allow for a larger number of shocks. Furthermore, it is necessary to identify the exact structure of expectation formation, which might also differ across variables, e.g. between consumption and investment. Finally, the empirical evidence in this paper points to the necessity of modeling a combination of boundedly rational expectations and financial frictions.

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