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TRUST AND MONETARY POLICY[1]

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Abstract
We analyze how trust affects the transmission of negative demand and supply shocks. We define trust to have two dimensions: there is trust in the central bank's inflation target and trust in the future of economic activity. We use a behavioural macroeconomic model that is characterized by the fact that individuals lack the cognitive ability to understand the underlying model and to know the distribution of the shocks that hit the economy. We find, first, that when large negative demand shocks occur the subsequent trajectories taken by output gap and inflation typically coalesce around a good and a bad trajectory. Second, these good and bad trajectories are correlated with movements in trust. In the bad trajectories trust collapses, in the good trajectories it is not affected. This feature is stronger when a negative supply shock occurs than in the case of a negative demand shock. Third, initial conditions (history) matters. Unfavorable initial conditions drive the economy into a bad trajectory, favorable initial conditions produce good trajectories.

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1. Introduction

The importance of trust in economic life is pervasive. Trust in the quality of institutions, trust in the executive and judiciary, trust in a stable environment governed by the rule of law, they all affect the behaviour of economic agents and makes them more willing to engage in contractual arrangements, to plan and to invest. There is now a large literature documenting how trust matters for economic development and growth[2].

Trust plays some role in standard macroeconomic models. These now typically incorporate a central bank that announces an inflation target. The credibility of this inflation target usually plays an importance role in the effectiveness of monetary policies and in the transmission of shocks. Thus, it can be said that trust in the central bank matters for the way monetary policies and exogenous shocks are transmitted into the economy.

In this paper we wish to pursue the analysis of trust in macroeconomic modeling more systematically. First, we will enlarge our definition of trust, and assume it has two dimensions. The first dimension is an institutional one. It is the trust in the central bank that has announced an inflation target. We will therefore use trust as a corollary of the credibility of the central bank. A central bank that has built a strong credibility of its inflation target is an institution that is trusted when it promises price stability. A second dimension is trust in the future. We will measure this by the degree of optimism about future economic activity. Trust here will mean a belief that future economic activity will be strong. Conversely, lack of trust will mean that there is pessimism about future economic activity.

Second, we will use a behavioural macroeconomic model (see De Grauwe(2012, and De Grauwe and Ji(2019)) to analyze trust. This is a model which assumes that agents have cognitive limitations. They do not know the underlying structure of the model nor do they know the distribution of the shocks that affect the economy. It will be seen that in such models with imperfect information trust becomes of great importance to understand how shocks are transmitted and how monetary policies affect the economy.

[2] The literature on how trust affects economic behaviour and ultimately economic growth and development is substantial. It is not the place here to present an exhaustive survey. Here are a few representative references: Arrow(1972), Putnam(1993) and (2000), Fukuyama(1995), Knack and Keefer(1997), La Porta, et al. (1997), Guiso, et al.(2000), Glaeser, et al. (2000), Acemoglu et al. (2003), Beugelsdijk, et al. (2004), Akçomak and ter Weel(2008), Dasgupta(2010), Tabellini(2010), Algan and Cahuc(2010) and (2013), Bjørnskov(2018)

Behavioural macroeconomic models generate an endogenous dynamics of booms and busts in economic activity. This dynamics is driven by self-fulfilling movements of optimism and pessimism (animal spirits). The fundamental reason of the emergence of such a dynamics is the fact that individuals have cognitive limitations preventing them from having rational expectations, i.e. preventing them from understanding the complexity of the underlying model. This lack of understanding provides the basis of a mechanism in which individuals find it rational to use simple rules of behaviour, check ex post how well these rules have worked and are willing to experiment with other rules when they observe that these work better. It also turns out that the shifting in the rules of behaviour at the individual level generates a collective process of herding based on the fact that successful rules will be copied by others. It is this collective process that is at the core of the waves of optimism and pessimism driving the business cycle movements and influencing the credibility of the central bank. It also follows that trust becomes an endogenous variable.

In this paper we will analyze how demand and supply shocks are propagated. We will focus on large shocks (to be defined appropriately). It will be shown that when the size of the shocks is large enough the transmission path after the shock will tend to coalesce around two possible trajectories, a good one and a bad one, as if there are two attractors around which the transmission dynamics is organized. It will be shown that the good trajectory coincides with a state of trust, while in the bad trajectory distrust prevails. This feature will also allow us to focus on the importance of initial conditions in guiding the economy towards the good or the bad trajectories.

The rest of the paper is structured as follows. Section 2 presents the behavioural macroeconomic model. We will develop the essence of that model and put some more technical material in appendix. Section 3 presents the impulse responses of large demand and supply shocks and show how the trajectories taken by these impulse responses are associated with trust. Section 4 analyzes the power of initial conditions in predicting the subsequent trajectories of output gap, inflation and interest rate. In section 5 we perform an econometric analysis on the predictive power of initial conditions. Section 6 performs a sensitivity analysis allowing us to trace the transition from small to large shocks. Section 7 concludes and provides policy implications.

2. The model

2.1 The basic behavioral macroeconomic model consists of an aggregate demand equation, an aggregate supply equation and a Taylor rule as described by De Grauwe (2011) and De Grauwe and Ji(2019).

The aggregate demand equation can be expressed in the following way:

$$y_t = a_1 \widetilde{\mathrm{E}}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2 \left(r_t - \widetilde{\mathrm{E}}_t \pi_{t+1} \right) + v_t \qquad (1)$$

where y_t is the output gap in period t, r_t is the nominal interest rate, π_t is the rate of inflation and two forward looking components , $\widetilde{\mathrm{E}}_t \pi_{t+1}$ and $\widetilde{\mathrm{E}}_t y_{t+1}$. The tilde above *E* refers to the fact that expectations are not formed rationally. How exactly these expectations are formed will be specified subsequently.

The aggregate supply equation is represented in (2). This New Keynesian Philips curve includes a forward looking component, $\widetilde{\mathrm{E}}_t \pi_{t+1}$, and a lagged inflation variable. Inflation π_t is sensitive to the output gap y_t. The parameter b_2 measures the extent to which inflation adjusts to changes in the output gap.

$$\pi_t = b_1 \widetilde{\mathrm{E}}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + \eta_t \qquad (2)$$

The aggregate demand and supply equations in (1) and (2) can be derived from expected utility maximization of consumers and expected profit maximization of firms (Hommes and Lustenhouwer(2019) and De Grauwe and Ji(2020)). See Appendix 1 where we provide for a microfoundation.

The Taylor rule describes the central bank's behaviour in setting the interest rate. This behavior can be described as follows:

$$r_t = (1 - c_3)[c_1(\pi_t - \pi^*) + c_2 y_t] + c_3 r_{t-1} + u_t \qquad (3)$$

where r_t is the interest rate in period t, π_t is the inflation rate, π^* is the target rate of inflation and y_t is the output gap.

This Taylor rule tells us that the central bank increases (reduces) the interest rate when currently observed inflation exceeds (falls short of) the target and when the currently observed output gap is positive (negative). We assume that the central bank wants to smoothen interest rate changes (see Levin et al. (1999) and Woodford (1999, 2003)). This is shown by including a lagged interest rate. When no smoothing occurs c_3 = 0 we obtain the original Taylor rule. Note also that we set the natural rate of interest equal to zero.

We have also added error terms in each of the equations (1) to (3a&b). These describe the nature of the different shocks that can hit the economy. There are demand shocks, v_t, supply shocks, η_t and interest rate shocks, u_t. It is assumed that these shocks are normally distributed with mean zero and a constant standard deviation.

2.2 Expectations formation

In this section we analyze how the forecast of output gap $\widetilde{E}_t y_{t+1}$ and inflation $\widetilde{E}_t \pi_{t+1}$ are formed in the model. The rational expectations hypothesis requires agents to understand the complexities of the underlying model and to know the frequency distributions of the shocks that will hit the economy. We take it that agents have cognitive limitations that prevent them from understanding and processing this kind of information. These cognitive limitations have been confirmed by laboratory experiments and survey data (see Carroll, 2003; Branch, 2004; Pfajfar, D. and B. Zakelj, (2011 &2014); Hommes, 2011).

Forecasting output gap

We assume two types of rules agents follow to forecast the output gap. A first rule is called a "fundamentalist" one. Agents estimate the steady state value of the output gap (which is normalized at 0) and use this to forecast the future output gap. A second forecasting rule is a "naïve" one. This is a rule that does not presuppose that agents know the steady state output gap. They are agnostic about it. Instead, they extrapolate the previous observed output gap into the future. There is ample evidence from laboratory experiments that support these assumptions that agents use simple heuristics to forecast output gap and inflation. See Pfajfar and Zakelj, (2011 &2014), Kryvtsov and Petersen (2013) and also Assenza et al.(2014a) for a literature survey. The fundamentalist and extrapolator rules for output gap are specified as follows:

$$\widetilde{E}_t^f y_{t+1} = 0 \qquad (4)$$

$$\widetilde{E}_t^e y_{t+1} = y_{t-1} \qquad (5)$$

This kind of simple heuristic has often been used in the behavioral macroeconomics and finance literature where agents are assumed to use fundamentalist and chartist rules (see Brock and Hommes(1997), Branch and Evans(2006), De Grauwe and Grimaldi(2006), Brazier et al. (2008)). It is probably the simplest possible assumption one can make about how agents who experience cognitive limitations, use rules that embody limited knowledge to guide their behavior. They only require agents to use information they understand, and do not require them to understand the whole picture. In De Grauwe (2012) more complex rules are used, e.g. it is assumed that agents do not know the steady state output gap with certainty and only have biased estimates of it. This is also the approach taken by Hommes and Lustenhouwer (2019).

The market forecast can be obtained as a weighted average of these two forecasts, i.e.

$$\widetilde{\mathrm{E}}_t y_{t+1} = \alpha_{f,t} \widetilde{\mathrm{E}}_t^f y_{t+1} + \alpha_{e,t} \widetilde{\mathrm{E}}_t^e y_{t+1} \qquad (6)$$

$$\alpha_{f,t} + \alpha_{e,t} = 1 \qquad (7)$$

where $\alpha_{f,t}$ and $\alpha_{e,t}$ are the probabilities that agents use the fundamentalist and the naïve rule respectively.

As indicated earlier, agents in our model are willing to learn, i.e. they continuously evaluate their forecast performance. We specify a switching mechanism of how agents adopt specific rule. As shown in Appendix 2, we follow the discrete choice theory (see Anderson, de Palma, and Thisse, (1992) and Brock & Hommes (1997)) to work out the probability of choosing a particular rule. We obtain:

$$\alpha_{f,t} = \frac{exp(\gamma U_{f,t})}{exp(\gamma U_{f,t}) + exp(\gamma U_{e,t})} \qquad (8)$$

$$\alpha_{e,t} = \frac{exp(\gamma U_{e,t})}{exp(\gamma U_{f,t}) + exp(\gamma U_{e,t})} \qquad (9)$$

where $U_{f,t}$ and $U_{e,t}$ the past forecast performance (utility) of using the fundamentalist and the naïve rules. The parameter γ measures the "intensity of choice". It can also be interpreted as expressing a willingness to learn from past performance. When $\gamma = 0$ this willingness is zero; it increases with the size of γ.

The forecast performance affects the probability of using a particular rule. For example, as shown in Equation (8), as the past forecast performance (utility) of the fundamentalist rule improves relative to that of the naïve rule, agents are more likely to select the fundamentalist rule for their forecasts of the output gap.

The forecasts made by extrapolators and fundamentalists play an important role. In order to highlight this role we define an index of market sentiments S_t, called "animal spirits" which will form the basis for our analysis of trust. This index can change between -1 and +1. It reflects how optimistic or pessimistic these forecasts are. It is obtained from the fraction of extrapolators ($\alpha_{e,t}$) and fundamentalists ($\alpha_{f,t}$) as follows:

$$S_t = \begin{cases} \alpha_{e,t} - \alpha_{f,t} & \text{if } y_{t-1} > 0 \\ -\alpha_{e,t} + \alpha_{f,t} & \text{if } y_{t-1} < 0 \end{cases} \tag{10}$$

where S_t is the index of animal spirits. This can change between -1 and +1. There are two possibilities:

- When $y_{t-1} > 0$, extrapolators forecast a positive output gap. The fraction of agents who make such a positive forecasts is $\alpha_{e,t}$. Fundamentalists, however, then make a pessimistic forecast since they expect the positive output gap to decline towards the equilibrium value of 0. The fraction of agents who make such a forecast is $\alpha_{f,t}$. We subtract this fraction of pessimistic forecasts from the fraction $\alpha_{e,t}$ who make a positive forecast. When these two fractions are equal to each other (both are then 0.5) market sentiments (animal spirits) are neutral, i.e. optimists and pessimists cancel out and $S_t = 0$. When the fraction of optimists $\alpha_{e,t}$ exceeds the fraction of pessimists $\alpha_{f,t}$, S_t becomes positive. As we will see, the model allows for the possibility that $\alpha_{e,t}$ moves to 1. In that case there are only optimists and $S_t = 1$.
- When $y_{t-1} < 0$, extrapolators forecast a negative output gap. The fraction of agents who make such a negative forecasts is $\alpha_{e,t}$. We give this fraction a negative sign. Fundamentalists, however, then make an optimistic forecast since they expect the negative output gap to increase towards the equilibrium value of 0. The fraction of agents who make such a forecast is $\alpha_{f,t}$. We give this fraction of optimistic forecasts a positive sign. When these two fractions are equal to each other (both are then 0.5) market sentiments (animal spirits) are neutral, i.e. optimists and pessimists cancel out and $S_t = 0$. When the fraction of pessimists $\alpha_{e,t}$ exceeds the fraction of optimists $\alpha_{f,t}$ S_t becomes negative. The fraction of pessimists, $\alpha_{e,t}$, can move to 1. In that case there are only

pessimists and $S_t = -1$ and we conclude that trust about the future is at its lowest point. When $S_t = 1$ trust about the future is at its highest.

Agents also have to forecast inflation. Similar heuristics rules as in the case of output forecasting are described in Appendix 3.

Forecasting inflation

Agents also forecast inflation. A similar simple heuristics is used as in the case of output gap forecasting, with one rule that could be called a fundamentalist rule and the other a extrapolative (naïve) rule. (See Brazier et al. (2008) for a similar setup). We assume an institutional set-up in which the central bank announces an explicit inflation target. The fundamentalist rule then is based on this announced inflation target, i.e. agents using this rule have confidence in the credibility of this rule and use it to forecast inflation. Agents who do not trust the announced inflation target use the naïve rule, which consists in extrapolating inflation from the past into the future. This allows us to define the first dimension as the fraction of agents that use the fundamentalist rule as their forecasting rule. They do this because they trust the central bank in keeping the inflation close to the announced target.

The fundamentalist rule will be called an "inflation targeting" rule. It consists in using the central bank's inflation target to forecast future inflation, i.e.

$$\widetilde{E}_t^f \pi_{t+1} = \pi^* \tag{10}$$

where the inflation target is π^*. The "naive" rule is defined by

$$\widetilde{E}_t^e \pi_{t+1} = \pi_{t-1} \tag{11}$$

The market forecast is a weighted average of these two forecasts, i.e.

$$\widetilde{E}_t \pi_{t+1} = \beta_{f,t} \widetilde{E}_t^f \pi_{t+1} + \beta_{e,t} \widetilde{E}_t^e \pi_{t+1} \tag{12}$$

$$\beta_{f,t} + \beta_{e,t} = 1 \tag{13}$$

Where $\beta_{f,t}$ and $\beta_{e,t}$ are the probabilities that agents use the fundamentalist and the extrapolative rule respectively. The same selection mechanism is used as in the case of output forecasting to determine the probabilities of agents trusting the inflation target and those who do not trust it and revert to extrapolation of past inflation. This inflation forecasting heuristics can be interpreted as a procedure of agents to find out how credible the central bank's inflation targeting is. If this is very credible, using the announced inflation target will produce good forecasts and as a result, the probability that agents will rely on the inflation target, $\beta_{f,t}$, will be high. If on the other hand the inflation target does not produce good forecasts (compared to a simple extrapolation rule) the probability that agents will use it will be small. Use the switching mechanism similar to the one specified equations (8) and (9), we can compute the probability of choosing a particular rule.

$$\beta_{f,t} = \frac{exp\left(\gamma U'_{f,t}\right)}{exp\left(\gamma U'_{f,t}\right)+exp\left(\gamma U'_{e,t}\right)} \qquad (14)^3$$

$$\beta_{e,t} = \frac{exp\left(\gamma U'_{e,t}\right)}{exp\left(\gamma U'_{f,t}\right)+exp\left(\gamma U'_{e,t}\right)} \qquad (15)$$

The previous analysis allows us to define trust in the central bank. The probability that agents will rely on the inflation target, $\beta_{f,t}$, to make inflation forecasts can also be interpreted as the fraction of agents who trust the central bank's inflation target. We will use this fraction, $\beta_{f,t}$, as our measure of institutional trust. Note that this fraction can also be interpreted as measuring the credibility of the central bank.

To conclude: we have defined two measures of trust:

- Trust in the future, which we measure by the index of animal spirits, S_t
- Institutional trust, which we measure by the fraction of agents $\beta_{f,t}$ using the inflation target as their forecasting rule.

2.3. Calibration

The procedure to solve the model is shown in Appendix 3. As our model has strong non-linear features we use numerical methods to analyze the dynamics created by the model. In order to do so, we have to calibrate the model, i.e. to select numerical values for the parameters of the model. In Table 2 we show these numerical values with the references from the literature. The model was calibrated in such a way that the time units can be considered to be quarters. The three shocks (demand shocks, supply shocks and interest rate shocks) are independently

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[3] Note $U'_{f,t} = -\sum_{k=0}^{\infty} \omega_k \left[\pi_{t-k-1} - \widetilde{E}_{f,t-k-2}\pi_{t-k-1}\right]^2$ and $U'_{e,t} = -\sum_{k=0}^{\infty} \omega_k \left[\pi_{t-k-1} - \widetilde{E}_{e,t-k-2}\pi_{t-k-1}\right]^2$

and identically distributed (i.i.d.) with standard deviations of 0.5%. These shocks produce standard deviations of the output gap and inflation that mimic the standard deviations found in the empirical data using quarterly observations for the US and the Eurozone. The way we did this is be described in more detail in De Grauwe and Ji(2020). It should also be mentioned that the parameter values in Table 1 ensure local stability of the steady state. Finally, to simplify our analysis, we remove the structural inertia components in the demand and the supply equations. Hence, we set a1=1 and b1=1. It turns out that our results are not fundamentally affected by this assumption.

Table 2: Parameter values of the calibrated model

a1 = 0.5	coefficient of expected output in output equation (Smets and Wouters(2003))
a2 = -0.2	interest elasticity of output demand (McCallum and Nelson (1999)).
b1 = 0.5	coefficient of expected inflation in inflation equation (Smets and Wouters (2003))
b2 = 0.05	coefficient of output in inflation equation,
π^*=0	inflation target level
c1 = 1.5	coefficient of inflation in Taylor equation (Blattner and Margaritov(2010))
c2 = 0.5	coefficient of output in Taylor equation assuming a dual Mandate Central Bank (Blattner and Margaritov(2010))
c3 = 0.5	interest smoothing parameter in Taylor equation (Blattner and Margaritov(2010))
γ = 2	intensity of choice parameter, see Kukacka, Jang and Sacht (2018)
σ_v = 0.5	standard deviation shocks output
σ_η = 0.5	standard deviation shocks inflation
σ_u = 0.5	standard deviation shocks Taylor
ρ = 0.5	memory parameter (see footnote 3)

3. The results of the model

In this section we present impulse responses of demand and supply shocks. One important feature of impulse responses in a (non-linear) behavioural model is that these responses are sensitive to initial conditions. Thus, the transmission of, say, a demand shock will be influenced by the values of output, inflation, interest rate and the expectations of these variables at the moment the shock occurs. This also means that the timing of the shock matters. The same shock at one point in time may be transmitted very differently from one that occurs at a different time, as will be made clear in this section.

The way we computed the impulse responses to a particular shock was the following. We first run a base simulation using a particular realization of all the stochastic variables (the error terms in the demand, supply and Taylor rule equations). We then rerun the model with exactly the same realizations of these stochastic variables except for the fact that at period t = 100 a shock is introduced in the demand or in the supply equation. We then computed the differences between the output gap in the series with the shock and the series obtained in the base simulation. We also expressed these differences as 'multipliers', i.e. we divided them by the size of the shock. This yielded one particular impulse response for a given set of realizations of the stochastic variables. We repeated this 1000 times, each time with another realization of the stochastic variables in the model. This then yielded 1000 different impulse responses to the same shock, but with different initial conditions of the endogenous variables of the model.

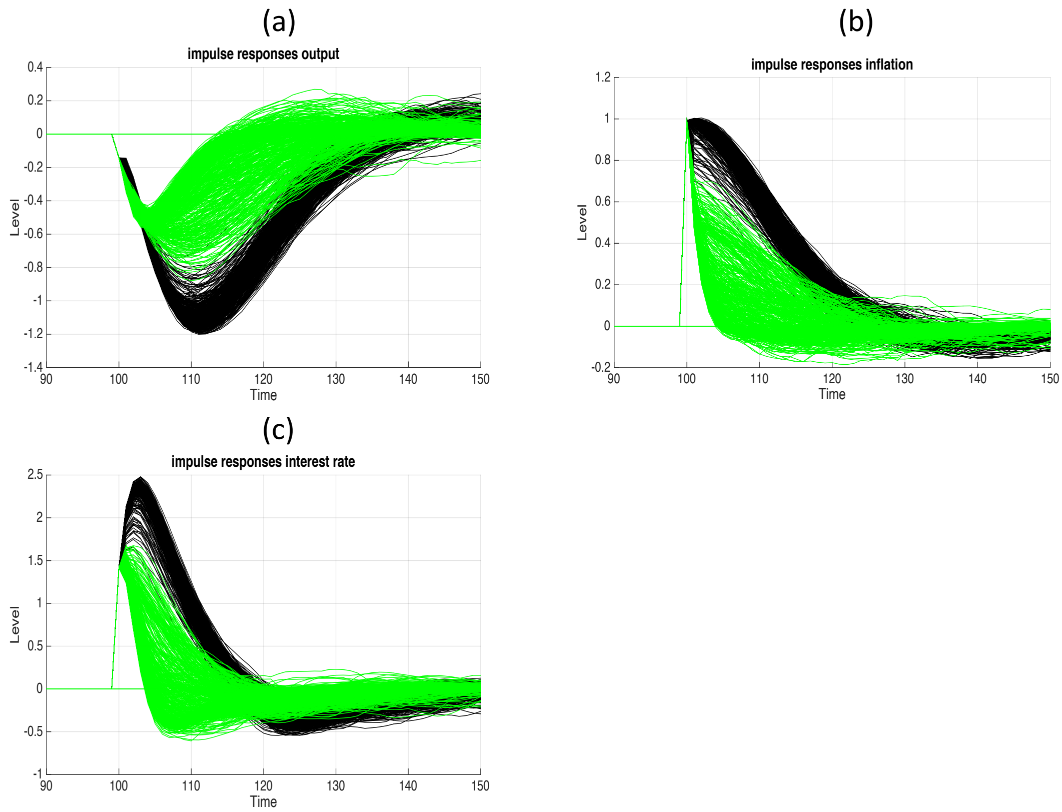
This procedure also implies that at the moment the shock occurs the system is out of equilibrium. Thus, each of the 1000 impulse responses will have as a starting point a different disequilibrium. Put differently, the initial conditions each reflect different initial disequilibria. We will show that this has important implications for the subsequent trajectories the impulse responses take.

3.1 Impulse response to supply shocks

We first discuss the impulse responses to a supply shock. We will consider a large shock which we define as a 10 standard deviation shock. This is a truly large shock but it corresponds to the size of the shock observed in early 2020 when GDP dropped by 10% to 20% in many countries as a result of the worldwide shutdown of production. The shock produced by the financial crisis of 2007-08 was of a similar order of magnitude. We will come back to this issue when we produce a sensitivity analysis with respect to the size of the shocks. There we will vary the size from 1 to 10 standard deviations and check how large the shocks have to be to reproduce the results shown in this section.

We present the 1000 impulse responses to a supply shock in Figure 1. A first thing to note is the large differences in the trajectories of the endogenous variables after the supply shock. Over time these impulse responses tend to converge, but it takes a long time for convergence to be reached. We observe the existence of two trajectories. The first one, a "good" trajectory (colored green), implies a relatively small decline of the output gap and a relatively quick return to the steady state value; the second trajectory, a "bad" one (colored black), follows a very deep decline in output and a slower recovery. A similar good and bad trajectory is detected in the impulse responses of inflation with a good trajectory of rapid declines in inflation and a bad trajectory characterized by a slower decline in inflation. These two trajectories seem to be related to the interest rate trajectory where we observe a bifurcation immediately after the shock into a (good) trajectory of quickly declining interest rate and a (bad) trajectory where the interest rate continues on an increasing path to start a decline only after 4 periods. We also not a wider variation of the individual impulse responses in the good trajectories as compared to the bad trajectories.

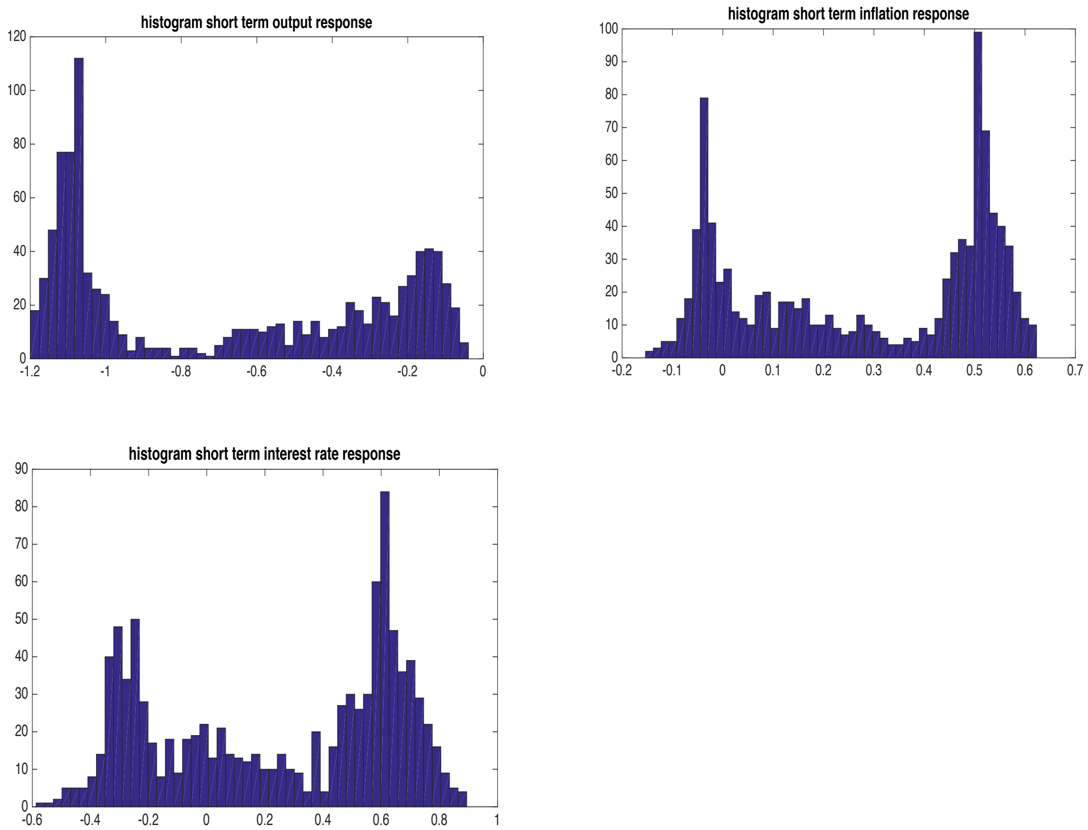
Figure 1: Impulse responses to a large supply shock (10 std)



The existence of two distinct trajectories can also be illustrated by presenting the distribution of the responses of the output gap in period 12 after the shock. This is obtained by taking a cross-section of the impulse responses of the output gap from Figure 1 at a particular period. Here we select period 112 (which corresponds to 12 quarters after the shock). We then plot the frequency distribution of the 1000 these impulse responses. We show the results in Figure 2.

We observe a clearly bi-modal distribution with peaks around -1.1 and -0.1 in the case of the output gap. For inflation, the peaks are around 0 and 0.5. This bimodal structure is associated with a bimodal structure of the interest rate with one peak at -0.3 and another at 0.6. We will come back to give an interpretation for the existence of bi-modal structure of the distribution of the impulse responses. We will then also discuss the importance of initial conditions. It will be shown that the initial conditions determine which trajectory is taken.

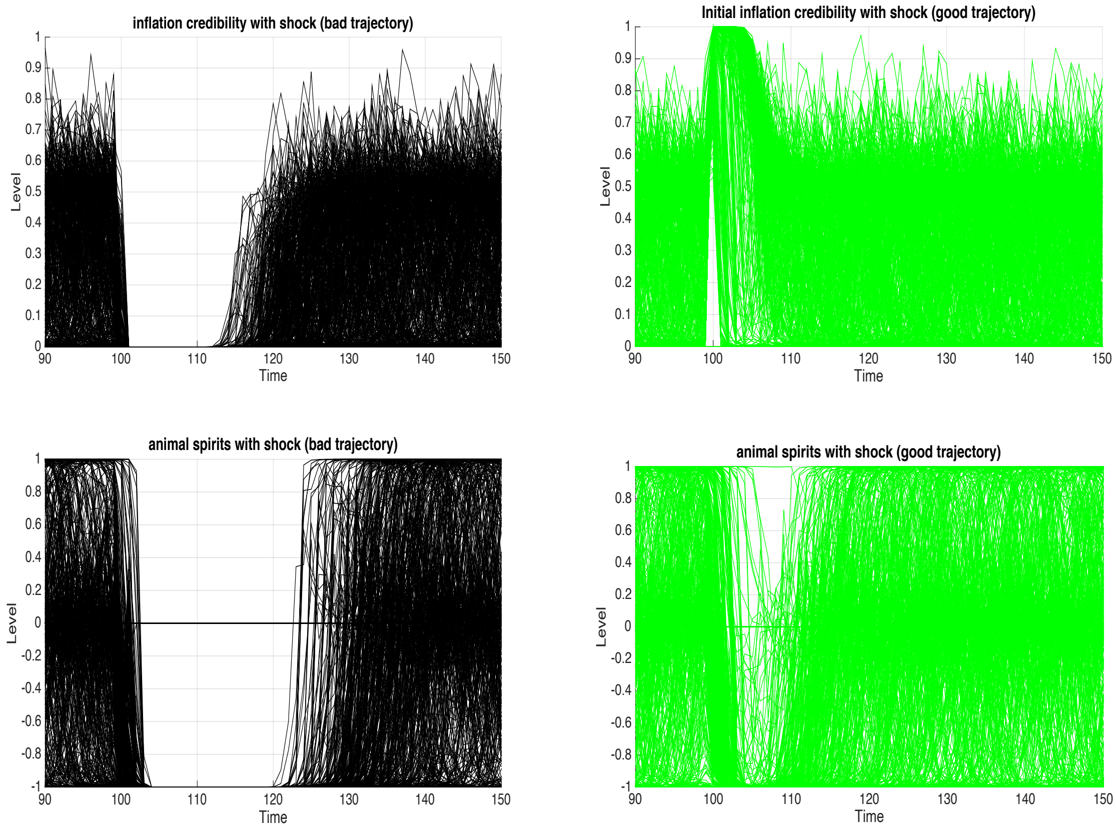
Figure 2: Frequency distribution of impulse responses (12 periods after shock)



How are these trajectories connected to our measures of trust? We show the answer in Figure 3. This presents the evolution of the animal spirits and credibility before and after the supply shock in period 100. Since we run the model 1000 times we obtain 1000 trajectories for these two variables. We have split these trajectories into two: one corresponding to the bad trajectories obtained in Figure 1, and one from the good trajectories. They are presented side by side for both the inflation credibility and animal spirits. Let us concentrate first on the inflation credibility. We observe something remarkable. Very soon after the supply shock inflation credibility drops to zero in all the bad trajectories. Thus, when the economy is in a bad trajectory this coincides with a collapse of credibility. No single agent trusts the central bank anymore: the fraction of agents that use the inflation target as their forecasting rule drops to zero and they all use the extrapolative rule to make inflation forecasts. This feature is absent in the good trajectories. Note that these positive trajectories are obtained when prior to the shock the inflation credibility of the central banks was very high.

We obtain a similar result with animal spirits. When the economy is pushed into a bad trajectory animal spirits drop to -1, i.e. all agents have a pessimistic outlook on the future of economic activity. In the good trajectory we also observe some deterioration of animal spirits but this is much less extreme and much shorter.

Figure 3: Trust: Inflation credibility and animal spirits with large supply shock



3.2 Why do bifurcations occur?

The question that arises now is why the bifurcations occur. This is the question we want to analyse in this section. We start with the *supply shocks*. From Figure 3 we observe the following. When the supply shock is large the bad trajectory is characterized by the fact that immediately after the shock we obtain a limit solution, i.e. the inflation credibility drops to zero and animal spirits drop to -1. This means that the mean reverting processes in the expectations formations are switched off and only the extrapolating dynamics is left over. This creates a destabilizing dynamics that keeps the output gap low and the inflation high. For example, when credibility is zero, there are no agents anymore who expect the inflation to return to the target set by the central bank. As a result, the inflation dynamics is driven by extrapolative behaviour. The same holds for the output gap.

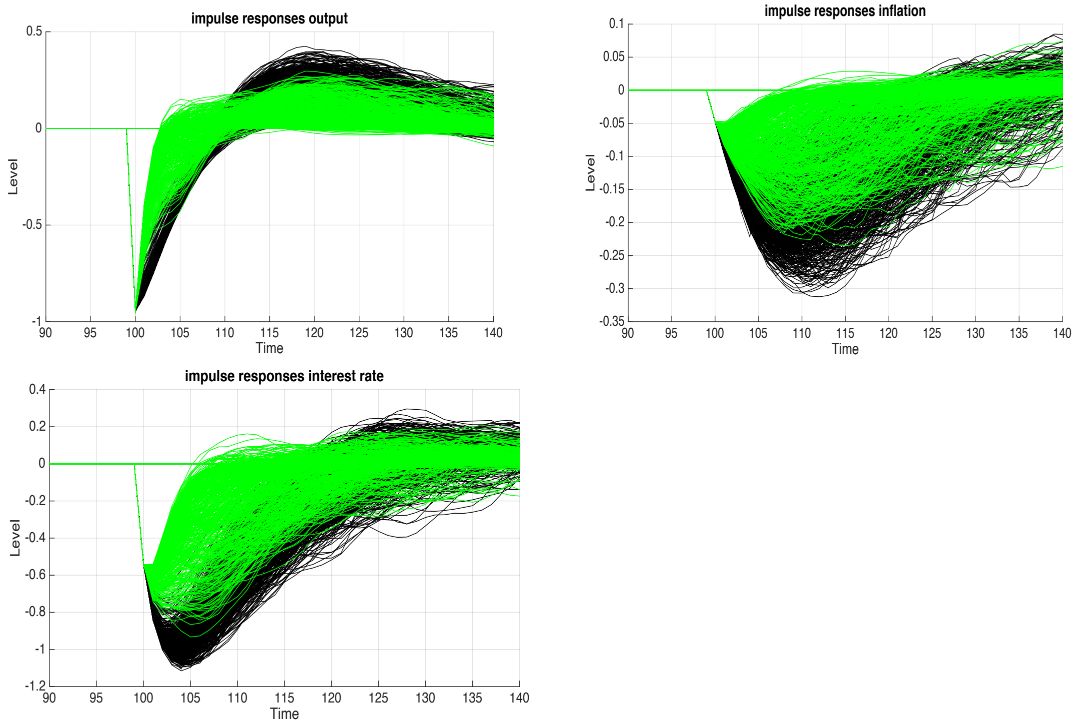
There is also the role played by initial conditions. In order to get stuck into this bad trajectory, the initial conditions must be bad, i.e. high inflation expectations and low output. These bad initial conditions make it possible for the large negative shock to push the system towards the limits of zero credibility and extreme pessimism. In contrast when the initial conditions are favorable (low inflation expectations and optimism about the economy) the same negative supply shock does not push credibility and animal spirits against its limits. Mean reverting processes continue to do their work of softening the impact of the supply shock and one ends up in a good trajectory. Thus, favourable initial conditions work as a buffer preventing large shocks from hitting the boundaries and preventing a collapse of trust.

Another way to interpret these results is as follows. Large shocks that arise under unfavorable initial conditions lead to a loss of trust; both a loss of trust in institutions (the central bank) and a loss of trust about the future (pessimism). In fact, as figure 3 shows one can conclude that a large shock can lead to a complete breakdown of trust. This intense loss of trust amplifies the negative effects of the supply shock. Thus, trust is key in smoothly returning the economy to equilibrium. Trust allows mean reverting dynamics to do its work to bring the economy back to equilibrium. Conversely, absence of trust makes the economy less resilient to absorb large exogenous shocks. When trust is absent, the economy is adrift lacking an anchor that is needed to stabilize the economy after a shock.

3.3 Impulse responses to demand shocks

We now turn to the impulse responses to a large negative demand shock. We show the results in Figures 4. Comparing this with Figure 1 we find the following results. The large demand shock leads to a similar but less pronounced bifurcation of the output trajectories into a good (green) and a bad one (black). In the good trajectory output returns relatively quickly to the steady state; in the bad trajectory the recovery after the shock is slower. This seems to be related to a similar bifurcation of the interest rate trajectories.

Figure 4: Impulse responses to a large demand shock (10 std)

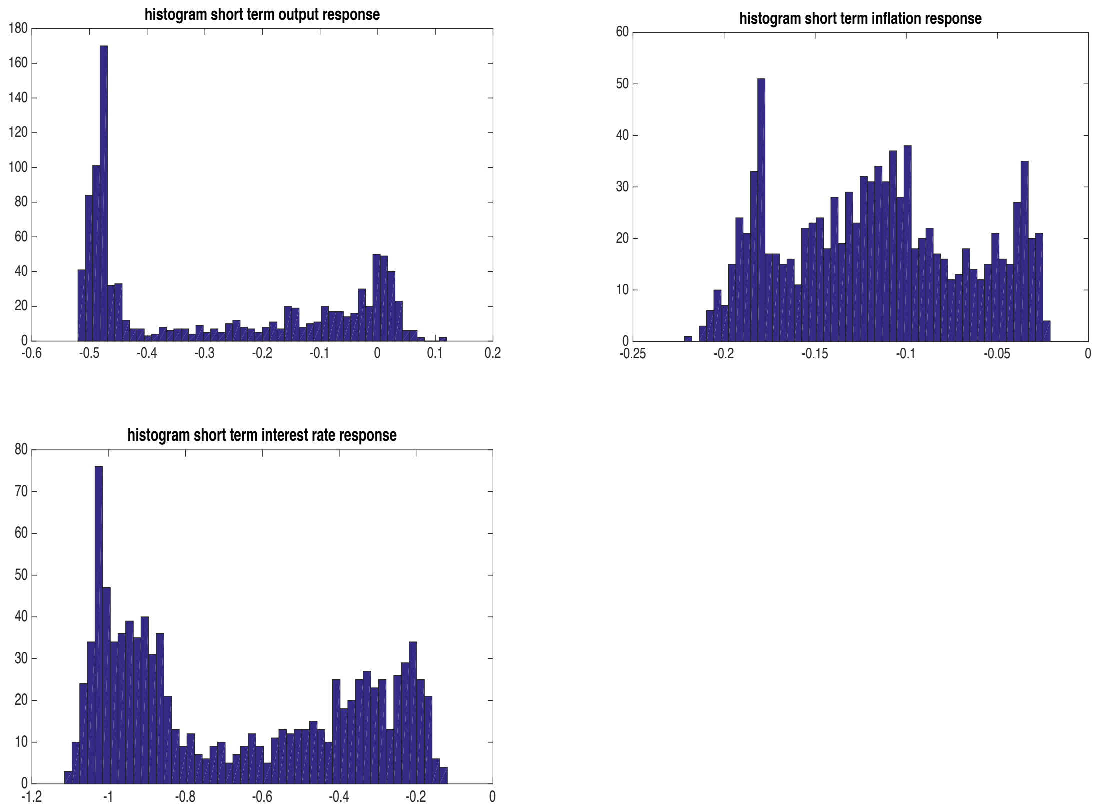


One difference with the supply shock is that the output gap tends to return to the steady state much quicker after the demand shock than after the supply shock. This is related to the fact that in contrast to a supply shock, a demand shock does not put the central bank in a dilemma situation. Both output and inflation decline and therefore give an unequivocal signal to the central bank that the interest rate should decline. This contrasts with a supply shock that produces and increase in inflation and a decline in output (stagflation). This creates a mixed signal for the central bank: the increase in inflation signals a required interest increase and the decline in output a required interest rate decline.

We also show the distribution of the responses of the output gap in period 4 after the shock (Figure 5). We chose 4 quarters because after the demand shock the output gap is much quicker to return to its long-term equilibrium than after the supply shock. One way to put this difference is that the sort-term is much shorter after a demand shock than after a supply shock.

Like in the case of the supply shock, we observe a bi-modal distribution of the impulse responses 4 quarters after the shock. This bi-modal structure is less pronounced than after the supply shocks though. Again, the interpretation is that the demand shock does not push the central bank in a dilemma situation allowing it to pursue an unequivocal policy of interest rate reduction.

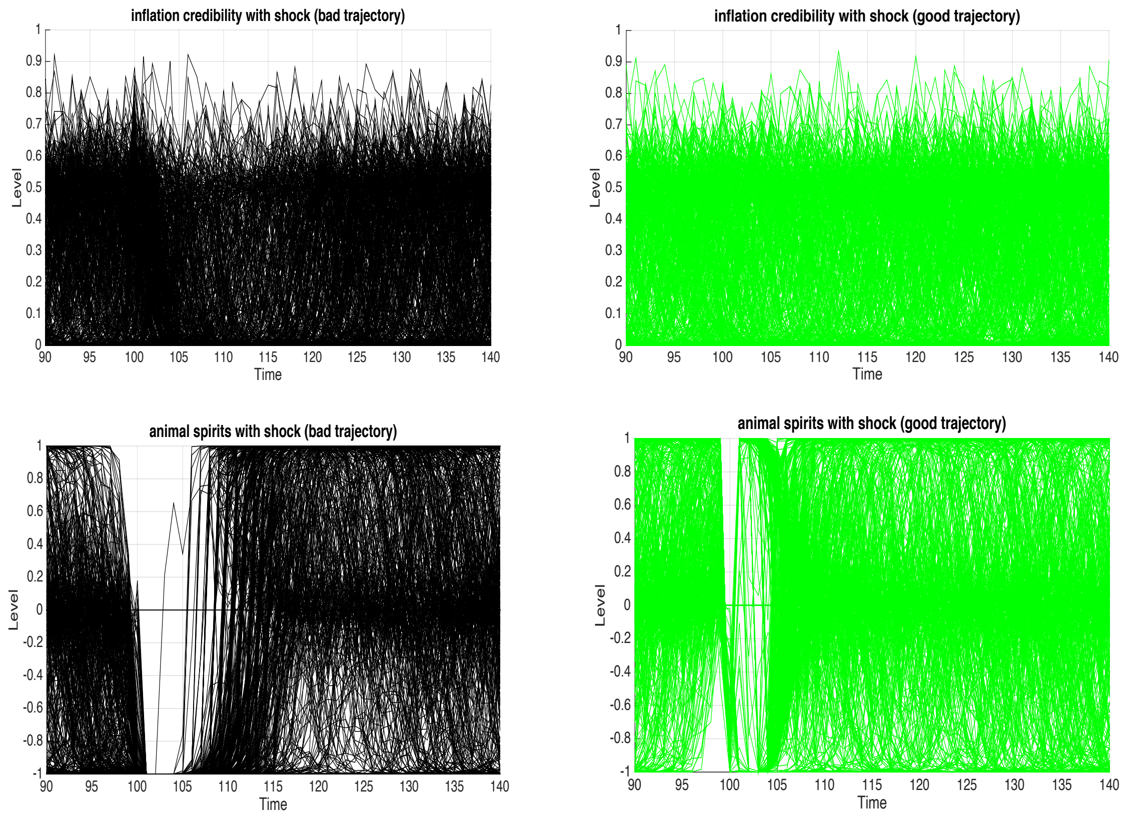
Figure 5: Frequency distribution of impulse responses (4 periods after shock)



What happens with our measures of trust after the demand shock? We show the answer in Figure 6. Following the negative shock in demand we observe that trust in the central bank is very little affected in the bad trajectory and not at all in the good trajectory. Bad and good trajectories in this demand shock scenario are associated mainly with negative developments in trust towards the future of economic activity. We observe that following the negative demand shock there is a strong decline in animal spirits reaching the limit of -1 and therefore creating a dynamics of deflation because agents extrapolate extreme pessimism in this bad trajectory. In the good trajectory these deflationary forces are much less pronounced and shorter-lived.

We conclude that after a negative demand shock the central bank does not suffer much from a loss of trust. This is related to the fact that after the demand shock the central bank is not pushed into a dilemma situation that prevents it to from pursuing a clear interest rate policy aimed at boosting the economy and bringing the inflation rate closer to its target. The loss of trust is concentrated in the goods market. When initial conditions are unfavorable, i.e. when there is initially a lot of pessimism, the demand shock will push this pessimism to its extremes, thereby intensifying the pessimism further because everybody extrapolates this pessimism into the future. When initial conditions are favorable, this deflationary mechanism is dampened.

Figure 6: Trust: Inflation credibility and animal spirits with large negative demand shock



4 The power of initial conditions

How do the initial conditions affect the output and inflation trajectories following the demand and the supply shocks? This is the question we analyze in this section. We have already hinted at the importance of initial conditions in an informal way. Here we do this more formally. We will first present simple charts, and in the next section we turn to the use of econometric methods.

4.2 Supply shocks

We start with the supply shocks. In Figure 7 we present one of the initial conditions, (i.e. inflation expectations prevailing just before the shock), on the horizontal axes, and the output gap and inflation 12 periods after the supply shock on the vertical axes. It is striking to find that after a large supply shock the initial expectations of inflation appear to be a very good predictor of the subsequent trajectory of the output gap and inflation. More specifically, when initially inflationary expectations exceeded the central bank's inflation target (normalized at 0) the output gap multiplier after 12 periods settles around -1.1. In other words, the subsequent output trajectory is always the bad one, i.e. the output gap is pushed down further as shown in Figure 1. In contrast when initially the inflation expectations are below the central bank's inflation target, the output gap multiplier after 12 periods settles close to -0.2 (but with a relatively large variance). Thus, in this case the subsequent trajectory is always a good one. In Figure 1 this corresponds to the (green) trajectory that quickly leads the output gap to return to equilibrium.

The initial expectations of inflation have an equally strong predictive power for subsequent inflation. Favorable initial inflation expectations (negative numbers) lead to the trajectory of low inflation 12 periods later. With unfavorable inflation expectations the economy is forced onto the high inflation trajectory.

The predictive power of the initial output forecasts is less strong, as can be seen from Figure 8. Optimistic forecasts of the output gap appear to lead to both a good and bad subsequent trajectory. Similarly optimistic output forecasts lead to both low and high inflation outcomes. In the econometric analysis reported in the next section we will show that initial output gap forecasts have some, but limited, predictive power.

In the next section we return to this issue using econometric techniques to estimate the predictive power of initial conditions (both the large and small supply shocks).

Figure 7: Initial inflation expectations, and output gap and inflation 12 periods after shock

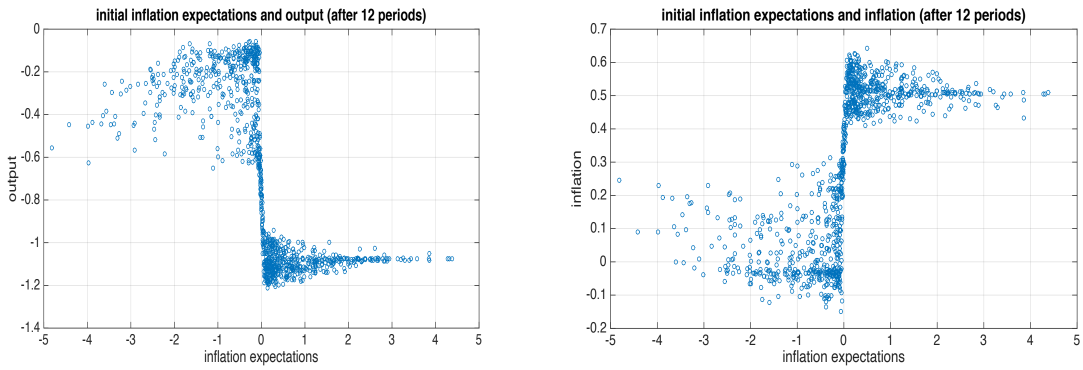
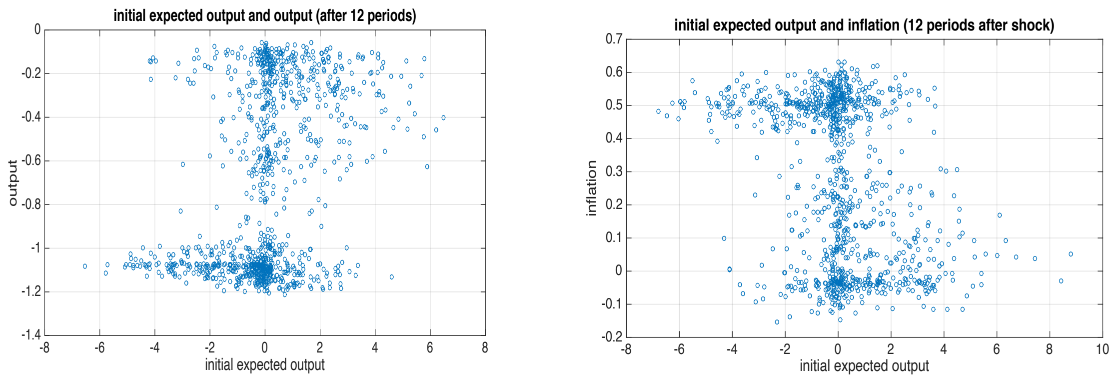


Figure 8: Initial output expectations, and output gap and inflation 12 periods after shock



What is the underlying mechanism that explains the strong power of the initial inflationary expectations to predict the subsequent trajectory of the output gap and inflation when the supply shock is large? To answer this question, we have to analyse the reactions of the central bank to the supply shock. To do so it is useful to turn to Figure 1 again.

We note the following. There is a quick bifurcation in the interest rate path after the shock. One path goes up; the other goes down. The upward interest rate path corresponds to the high inflation initial condition. This unfavourable initial condition has the effect of keeping the inflation rate at a high level after the supply shock. As a result, the central bank that attaches a relatively high weight on inflation in the Taylor rule feels obliged to raise the interest rate. This in turn pushes the output gap further down. The economy is pushed into a bad trajectory because the unfavourable inflation expectations that existed prior to the shock force the central bank to tighten up after the shock, thereby enhancing the downturn in output.

In contrast, when the inflationary expectations are initially favourable (below the inflation target), the upward movement of the inflation immediately after the shock remains subdued. As a result, the central bank observing a relatively favourable inflation outcome reacts by reducing the interest rate to deal with the negative effect of the supply shock on output. This mitigates the negative output effect of the supply shock and pushes the economy onto the good trajectory with a quick return of the output gap to its equilibrium level. Here again the initial favourable inflation expectations tend to reduce the inflation effect of the supply shock "freeing the hands" of the central bank to fight the decline in output by a reduction of the interest rate.

The previous analysis can be complemented by introducing the inflation credibility of the central bank that as will be remembered is measured by the fraction of agents that use the announced inflation target as their forecasting rule. With 100% credibility this fraction is 1, i.e. all agents rely on the inflation target to forecast next period's inflation. With 0% credibility no agents use the inflation target as their forecasting rule; instead all of them use extrapolation of the past inflation rate as their forecasting rule.

We now find the following results, represented in Figure 9. Figure 9(a) shows the relation between the inflation expectations before the shock (horizontal axis) and the central bank's credibility at the time of the shock. We observe that when in the past inflation expectations were very high, i.e. above the target, the effect of the supply shock is to reduce the central bank's credibility dramatically to zero. This then also explains the strong increase in inflation that is driven mainly by extrapolative behaviour. The dramatic loss of credibility then also becomes a very good predictor of the subsequent decline in the output gap as is shown in Figure 9(b). We observe that when the central bank's credibility is very low the output gap is very likely to follow the bad trajectory with a steep decline in period 12 after the supply shock.

The reverse happens when the initial inflation expectations are below the inflation target. The supply shock then actually improves the central bank's credibility and this guides the output gap into the good trajectory with a low decline in output.

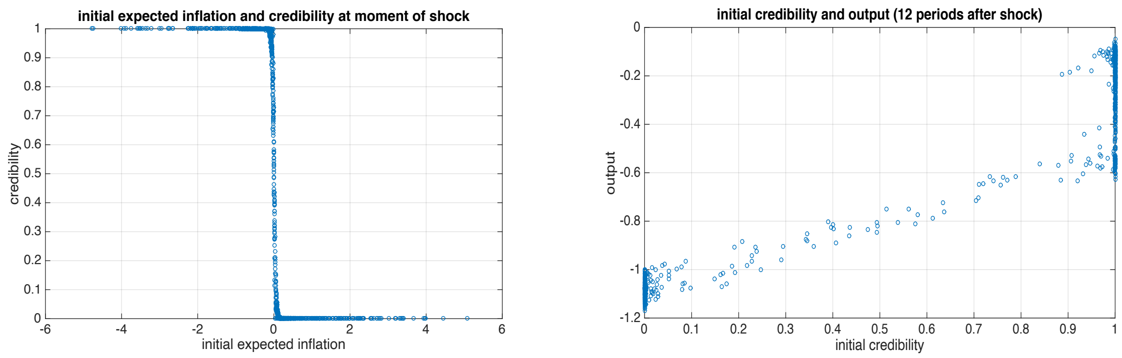
Our results have some relevance to understand the experience of the 1970s with the supply shocks and the recent covid supply shock. Preceding the supply shocks of the 1970s there had been a buildup of inflation and inflationary expectations. Our model predicts that with these initial conditions, the recovery would take a long time. This is also what happened for many countries with a prior history of significant inflation, especially after the second oil shock of 1979. According to the World Bank(2021) the world GDP growth rate took five years to return to its pre-1979 level of 4.2%. This growth rate was only reached in 1984 again. The trajectory of this protracted recovery also followed the prediction of our model: given the inflationary environment the supply shock of 1979 "forced" many central banks, in particular the US Federal Reserve under Paul Volcker, to raise the interest rates thereby intensifying the economic downturn.

The Covid supply shock of 2020 was preceded by a period of low inflation and low inflationary expectations. Our model predicts that this should make a quick recovery possible, mainly because the central banks did not worry about the inflationary consequences and therefore could actually follow expansionary monetary policies. It appears today that a relatively quick recovery is likely to happen. The European Commission(2021), for example, predicts that in 2022 most EU-countries will have returned to their pre-pandemic GDP growth path.

The previous discussion implies that history matters. A history of high inflation and expectations of inflation conditions the impact of a supply shock and is likely to produce bad outcomes of this shock. In contrast a history of price stability makes it possible for the economy to follow a more benign trajectory after the same supply shock.

Figure 9: Initial inflation expectations, credibility and the output gap

(a) (b)

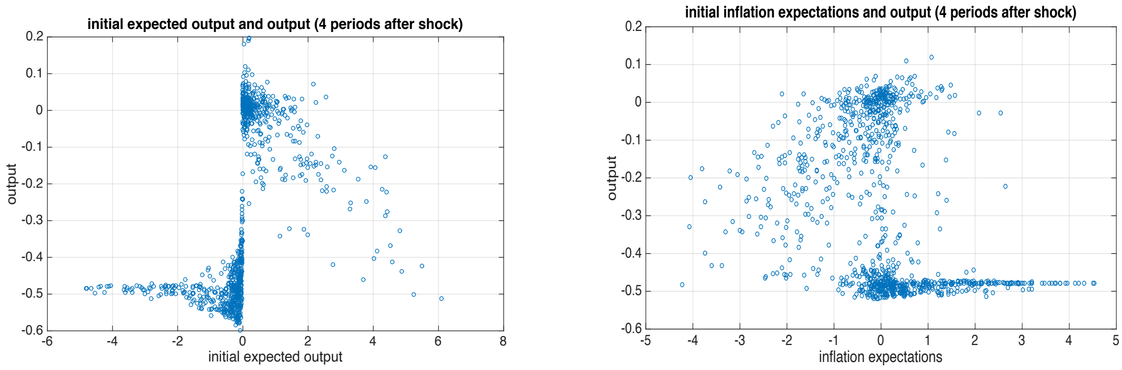


4.3 Demand shocks

We proceed as in the previous section and show two initial conditions, i.e. inflation expectations and output gap forecasts prevailing just before the shock on the horizontal axes, and the output gap 4 periods after the demand shock on the vertical axes. We show the results in Figure 9.

In contrast with the supply shock we now find that it is the initial output expectation that has the strongest predictive power. More precisely, when initially agents are optimistic about future output, the output gap 4 periods later clusters around 0%. In other words, initial optimism about the future business cycle forces the economy along the good trajectory after the demand shock. In contrast, when output forecasts are negative, the output gap 4 periods later settles around -0.5. Thus, pessimism about the future business cycle pushes the economy along the bad trajectory after the demand shock. Note that inflation forecasts have only limited power to predict which trajectory will be chosen.

Figure 9: Initial inflation and output expectations, and output gap 4 periods after demand shock



Comparing these results with the impulse responses after a large demand shock as shown in Figure 4 leads to the following paradox. The good trajectory is one where output recovers very quckly after the demand shock while at the same time the central bank quickly increases the interest rate. The bad trajectory is the one where output continues to decline after the shock while the central bank reduced the interest rate further. How can one explain this?

The answer has to do with the initial conditions, in particular with output expectations and initial output (not shown here, but to be included in the econometric analysis). When the economy is in a boom to start with (optimistic output expectations and positive output gap), the negative demand shock has a subdued effect on output. Also inflation does not decline much. As a result, the central bank quickly restores its pre-shock policy stance. When the economy is in a recession to start with (negative output gap and pessimistic outlook)) the negative shock has a much stronger negative effect on output and inflation forcing the central bank to drastically reduce the interest rate. This sharp decline then makes it possible to return to equilibrium but with a delay. Thus, it is the intial business cycle situation that determines the trajectory subsequent to the shock. The central bank is purely reactive.

5 Sensitivity analysis

In this section we establish the size of the shocks that will trigger a bifurcation in the trajectories. We do this with a sensitivity analysis in which we allow the size of the shocks to vary. We start with a one standard deviation shock and we gradually increase the size of the shock. We present the results for the supply shock in Figure 10.

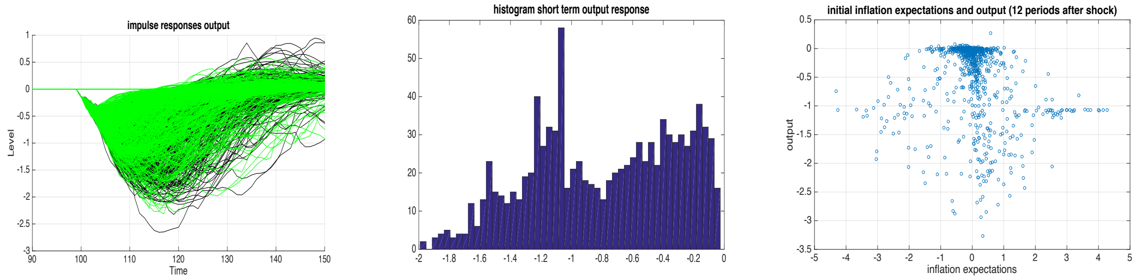
Concentrating first on the impulse responses (a) we find that as the size of the shock is increased, the bifurcation in the trajectories start to become visible with a shock of 3 standard deviations. This is also made clear from the (b) column in Figure 10. This shows the frequency distribution of the output response after 12 periods. We observe that from a supply shock equal to 3 on, the distribution starts showing a bi-modal distribution indicating that the impulse responses tend to bifurcate. Finally, the evidence in column (c) confirms this. With a supply shock of 3 we achieve some measure of predictability of the subsequent output responses by the initial inflationary expectations.

How can one interpret the low predictive power of initial conditions when the supply shock is small? Here is the answer. A supply shock equal to 1 standard deviation of the stochastic shocks hitting the economy is of the same order of magnitude as these stochastic shocks. As a result, the initial conditions create departures from the equilibrium that have the same order of magnitude as the supply shock. This does two things. First, it leads to a very low signal to noise ratio, the signal being the supply shock and the noise being the initial condition. As a result, the signal will tend to be overwhelmed by the noise. Second, as the initial conditions are departures from equilibrium, the supply shock has a similar magnitude as the departures from equilibrium. These initial departures from equilibrium can steer the economy in a different direction than the supply shock does. It can also be that the initial conditions and the supply shock reinforce each other. Since the forces of the initial conditions and of the supply shock are of a similar magnitude, it becomes near impossible to separate them out by computing impulse responses. All this produces a low predictability of the initial conditions on the output trajectory after the shock. This problem of unpredictability does not occur when the supply shock is large relative to the size of the stochastic shocks, or put differently, when the signal to noise ratio is large. We obtain similar results for demand shocks (not shown here).

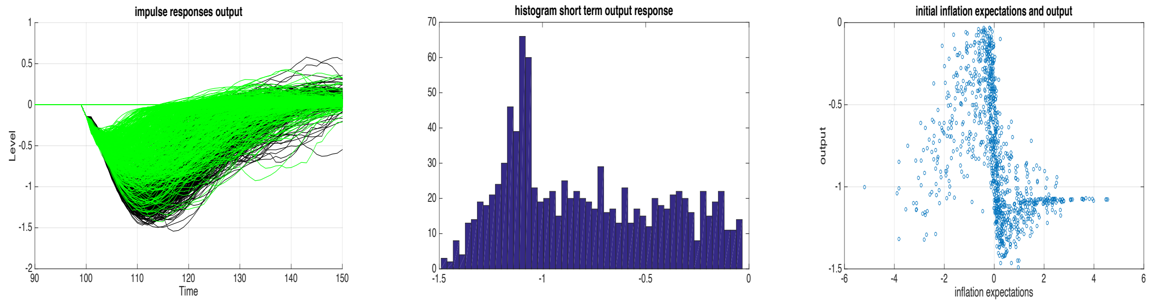
Figure 10: Increasing the size of the supply shock

(a) (b) (c)

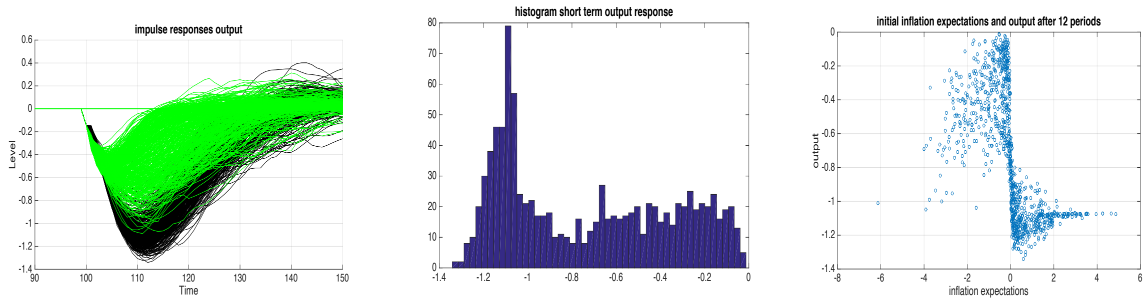
Supply shock = 1



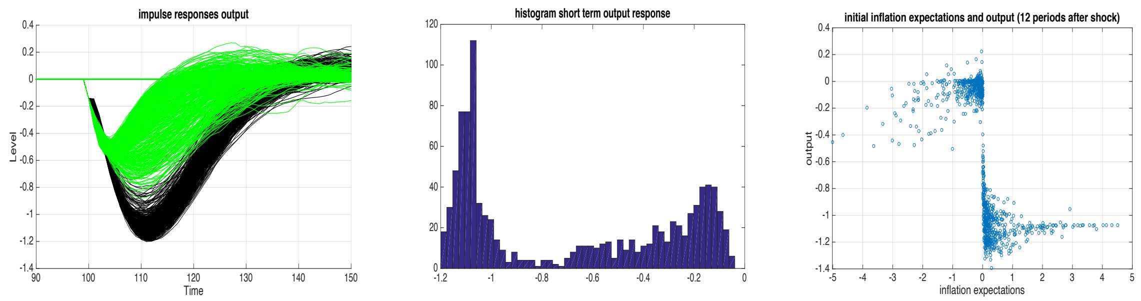
Supply shock = 3



Supply shock = 5



Supply shock = 10



There is another difference between the trajectories following large (3 standard deviation or more) and small (less than 3 standard deviations). Large shocks produce good and bad trajectories. In contrast small shocks do not produce such bifurcations in the trajectories. This has to do with the fact that small shocks do not push the trust indicators (credibility and animal spirits) against their limits. As a result, the mean reversion dynamics in forecasting is not switched off as it is following large shocks when the initial conditions are unfavourable.

6 The predictive power of initial conditions: econometric analysis

In this section, using the impulse responses data from our theoretical model, we analyze econometrically what the power is of initial conditions to predict in which cluster the output gap will be pushed 12 periods after the supply shock and 4 periods after the demand shock. As before we distinguish between a large and a small shock.

We have observed that after a large shock the output gap appears to be following two separate distributions. Standard models will generally not be helpful when one has data from more than one distribution with no information to identify which observation goes with which distribution,. However, Finite Mixture Models (FMM) might come to the rescue (McLachlan and Peel, 2000)). They use a mixture of parametric distributions to model data, estimating both the parameters for the separate distributions and the probabilities of component membership for each observation.

To formally test these ideas, we collect the simulation data under different supply and demand shocks assuming either small (=1 std) or large (=10 std) shocks. In each specific shock, we fit these data with finite mixture models. As discussed earlier, the data generated from our theoretical model suggest that the output gap may be from more than one distribution. We fit the data using the finite model with two classes (assuming two distributions) and then a similar model with only one class (assuming one distribution).

Both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) from the two models favour the two-class model. This confirms that our theoretical model in fact generate output gaps with more than one distribution. We proceed with the two-class model in analyzing how expectations and other initial conditions are associated with the future output gap. The estimates results are shown in Tables 1 and 2.

In Table 1, we find that in the case of a large demand shock the output gap expectation is a perfect predictor of the future output. The coefficient is -94.4068 indicating that as long as the output gap expectation is positive, the probability of falling in a bad cluster (meaning at -0.4685) is almost at zero. Similarly, in the case of a large supply shock inflation expectation perfectly predicts the future output gap. The coefficient of 164.1634 informs us that when the inflation expectation is positive, the probability of being in a bad cluster (meaning at -1.0358) is close to 1. By contract, when shocks are small, expectations are much less powerful in predicting the future clustering of the output gap. We observe from table 1 that output expectations in the case of a small demand shock is a significant factor associated with the probabilities of the clusters. In a small supply shock, we do not find any significant factors that can be associated with the probabilities of the clusters.

Table 1. Determinants of being in bad cluster in the FMM models

	Demand shock 10	Demand shock 1	Supply shock 10	Supply shock 1
Output gap expectation	**-94.4068*****	-3.3598***	0.7623	0.0689
	(14.2671)	(0.5197)	(1.0044)	(0.1527)
Inflation expectation	1.1099	-0.4987	**164.1634*** **	0.0859
	(0.9903)	(0.4920)	**(32.6687)**	(0.2203)
Initial output gap	-0.2375	-1.8531***	-1.9343	-0.0890
	(0.5799)	(0.3755)	(1.3259)	(0.1367)
Initial inflation	0.9540	1.4470***	-0.0785	-0.2044
	(0.8563)	(0.4436)	(1.3743)	(0.2091)
Initial interest rate	-0.2348	-0.0438	0.3840	0.1305
	(0.4023)	(0.2186)	(0.8432)	(0.1063)
Constant	-1.2669***	-3.3598***	-0.9060**	0.1180
	(0.3179)	(0.3201)	(0.4351)	(0.0719)
Good cluster (mean)	0.0175	-0.0860	-0.0276	-0.0073
	(0.0029)	(0.0075)	(0.0044)	(0.0008)
Bad cluster (mean)	-0.4685	-0.7537	-1.0358	-0.7150
	(0.0032)	(0.0166)	(0.0080)	(0.0324)
Observations	1000	1000	1000	1000

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2 presents the predictive power of the initial conditions conditional on being in the good, respectively the bad cluster. We find significance of the initial output and initial forecasts of output in the case of a large and a small demand shock. Similarly, we find significance of initial inflation and inflation forecasts in the case of both a large and small supply shock. Thus, initial conditions continue to matter once the economy is traveling along one of these two trajectories.

Table 2. Impacts of initial conditions and output gap in each class: Finite mixture models

	Demand shock 10	Demand shock 1	Supply shock 10	Supply shock 1
Good cluster				
Output gap expectation	-0.0336***	-0.0493***	0.0107	-0.0017
	(0.0055)	(0.0164)	(0.0078)	(0.0017)
Inflation expectation	0.0220***	0.0264	0.0398***	-0.0078***
	(0.0076)	(0.0224)	(0.0117)	(0.0028)
Initial output gap	-0.0193***	-0.0608***	0.0032	0.0014
	(0.0050)	(0.0143)	(0.0073)	(0.0014)
Initial inflation	0.0194***	0.0362*	0.0032***	0.0085***
	(0.0075)	(0.0213)	(0.0104)	(0.0022)
Initial interest rate	0.0030	-0.0012	0.0002	-0.0021**
	(0.0038)	(0.0109)	(0.0056)	(0.0011)
Constant	0.0159***	-0.0927***	-0.0295***	-0.0073***
	(0.0029)	(0.0074)	(0.0043)	(0.0008)
Bad cluster				
Output gap expectation	-0.0119**	-0.0525**	0.02349*	-0.0011
	(0.0060)	(0.0244)	(0.0142)	(0.0701)
Inflation expectation	0.0064	0.0064	0.0636***	0.0463
	(0.0091)	(0.0338)	(0.0222)	(0.0988)
Initial output gap	0.0258***	-0.0110	-0.0104	0.0081
	(0.0059)	(0.0253)	(0.0141)	(0.0648)
Initial inflation	0.0045	0.0243	-0.0456**	-0.0915
	(0.0084)	(0.0306)	(0.0201)	(0.0984)
Initial interest rate	-0.0060	-0.0153	-0.0228**	0.0028
	(0.0043)	(0.0158)	(0.0104)	(0.0499)
Constant	-0.4693***	-0.7583***	-1.0333***	-0.7162***
	(0.0032)	(0.0171)	(0.0083)	(0.0323)
Observations	1000	1000	1000	1000

7 The power of output stabilization: supply shock

In this section we study how the intensity with which the central band stabilizes the output gap affects the transmission of large shocks. As will be remembered the intensity of output stabilization is measured by the c2 parameter in the Taylor rule equations. We have set c2 routinely equal to 0.5 in the previously reported results. Here we ask the question of how a stronger stabilization effort affects the transmission of a large supply shock. We show the results in Figure 11. We distinguish two output stabilization intensities, a strong one (c2=2) and a normal one (c2=0.5). (Note that the results reported in the “normal stabilization” column are the same reported supra). The results lend themselves to the following interpretation.

First, by increasing the intensity of output stabilization the central bank ensures that the bad trajectory becomes significantly less bad. This can be seen from the impulse responses of output. Under normal stabilization there is a deep negative trajectory. This downward movement of the bad trajectory is significantly reduced under strong stabilization. The good trajectory is pretty much unchanged when stabilization is strong. Another way to see this is provided by the histograms of the output gap. Under strong stabilization we observe that the peaks of the bimodal distribution are closer to each other, and that this is achieved by a movement of the “bad peak” to the right and closer to the “good peak”. Thus stronger stabilization achieves a less severe downturn in the bad trajectory.

All this comes at a price, though. When output stabilization is strong, we observe that the bad and the good inflation trajectories produce an inflation trajectory that is more protracted. In other words, stronger output stabilization leads to inflation that lasts longer after a supply shock.

Finally in Figure 12 we show the degree with which the initial inflation expectations predict the subsequent output trajectories. We observe from that figure the degree of predictability is not affected by the intensity of output stabilization. When initial inflation expectations are high the economy will take the bad trajectory under both strong and normal stabilization. The opposite occurs when the initial inflation expectations are low.

Figure 11: Transmission of large supply shock under strong and normal stabilization

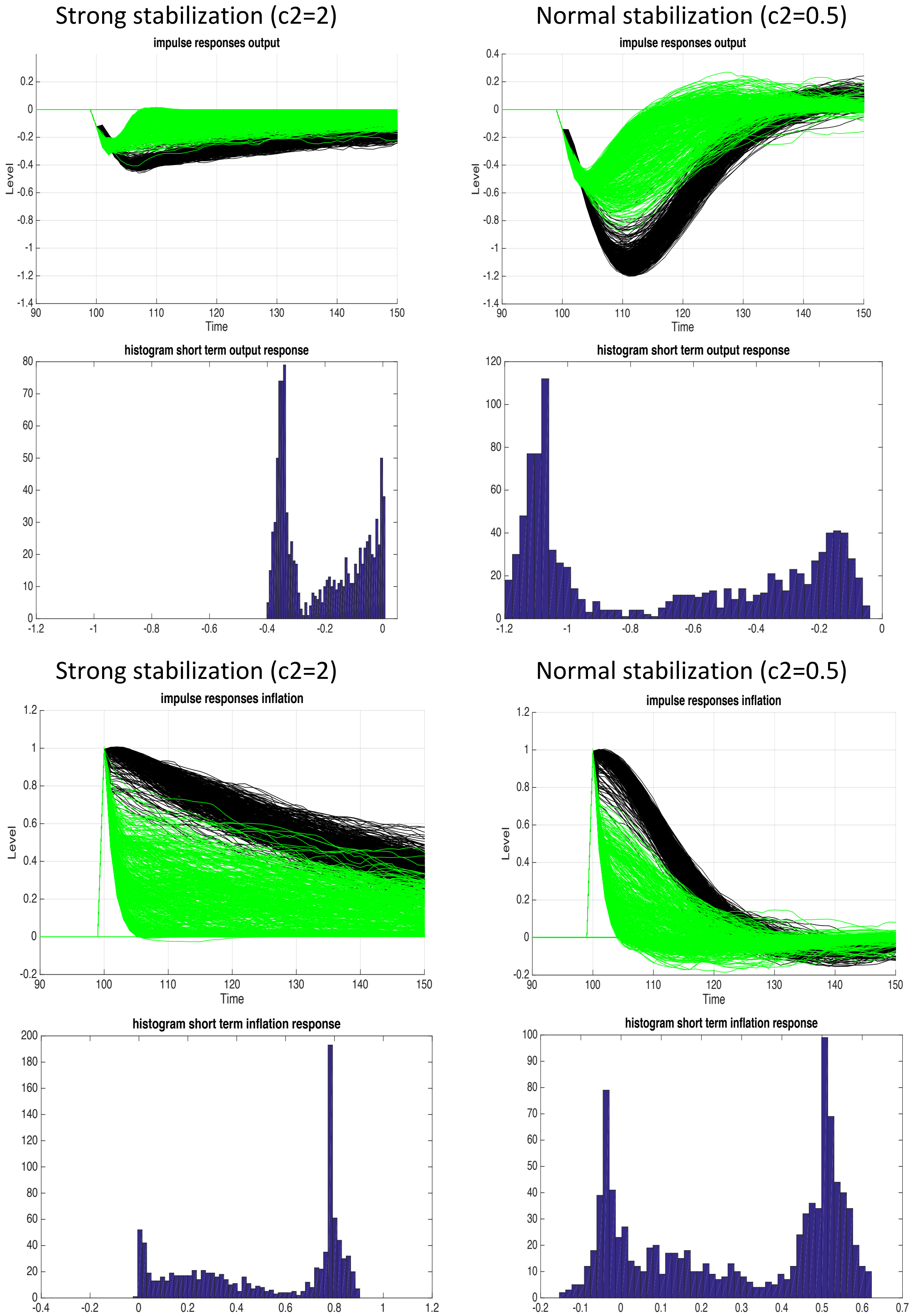
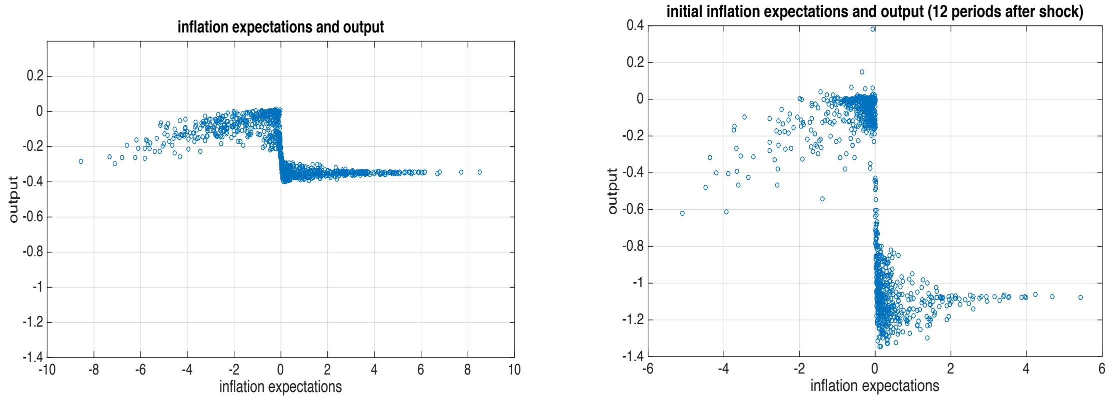


Figure 12: Predictability under strong and normal stabilization (large supply shock)

Strong stabilization (c2=2) Normal stabilization (c2=0.5)



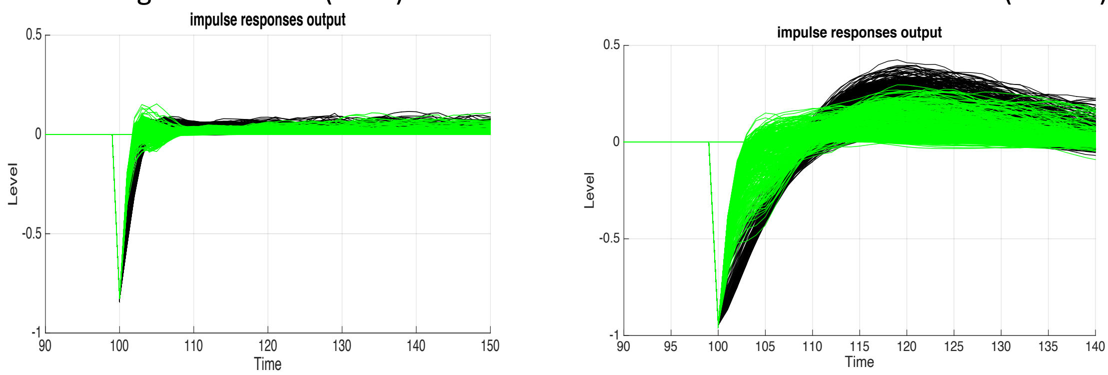
8 The power of output stabilization: demand shock

In this section we perform a similar exercise as in the previous section. We show the impulse responses after a large negative demand shock under strong and normal output stabilization. The results are shown in Figure 13. We find, not surprisingly, that after a large negative demand shock the power of output stabilization is stronger: both the output gap and inflation tend to return quicker the long run equilibrium and the bifurcation feature observed in the impulses responses of the output gap are considerably reduced in intensity.

We also find that the predictive power of the initially expected output gap is considerably reduced when output stabilization is strong (see Figure 14). This has to do with the fact that the bifurcation in the impulse responses between the good and bad trajectories have almost disappeared.

Figure 13: Transmission of large demand shock under strong and normal stabilization

Strong stabilization (c2=2) normal stabilization (c2=0.5)



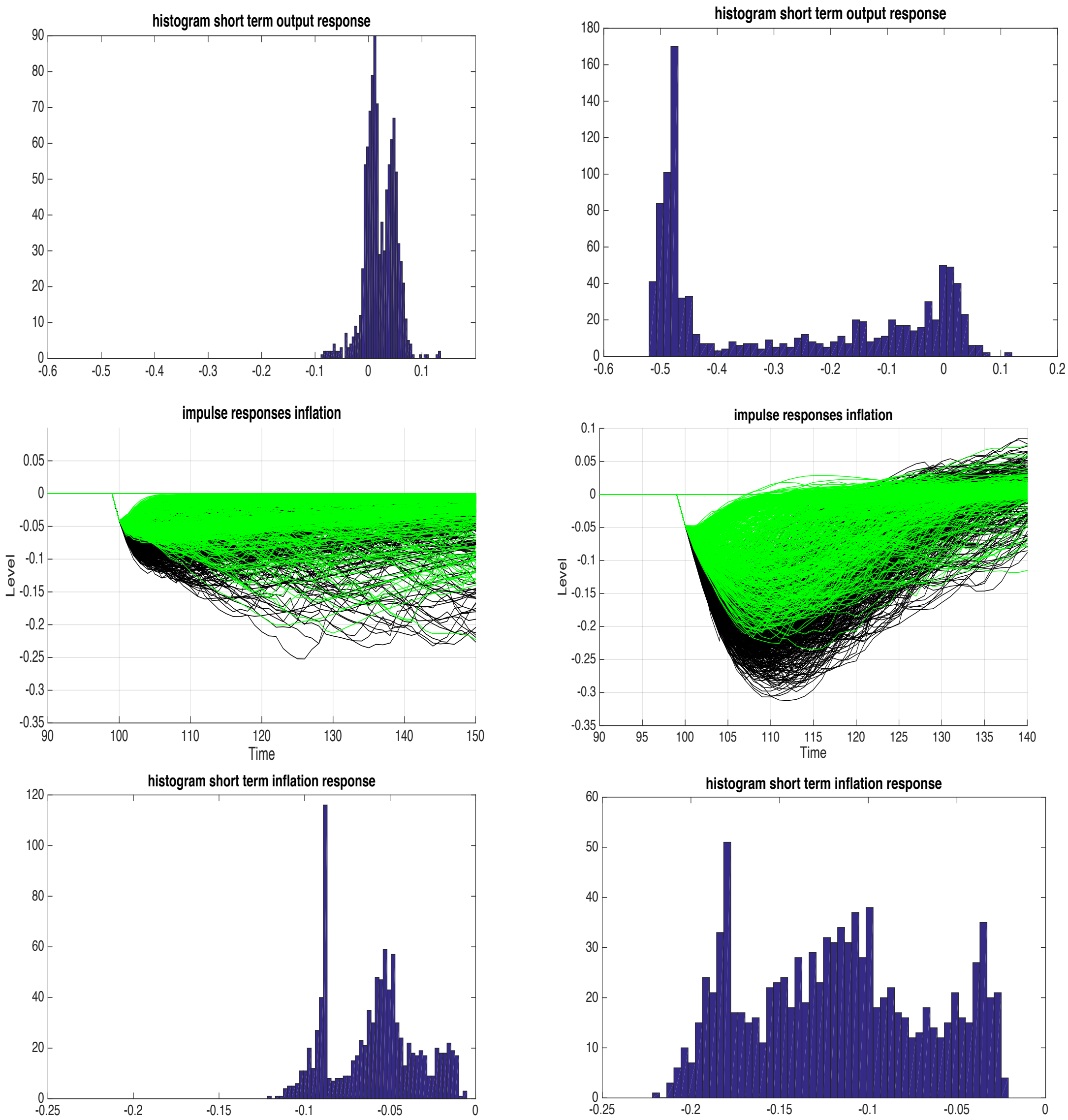
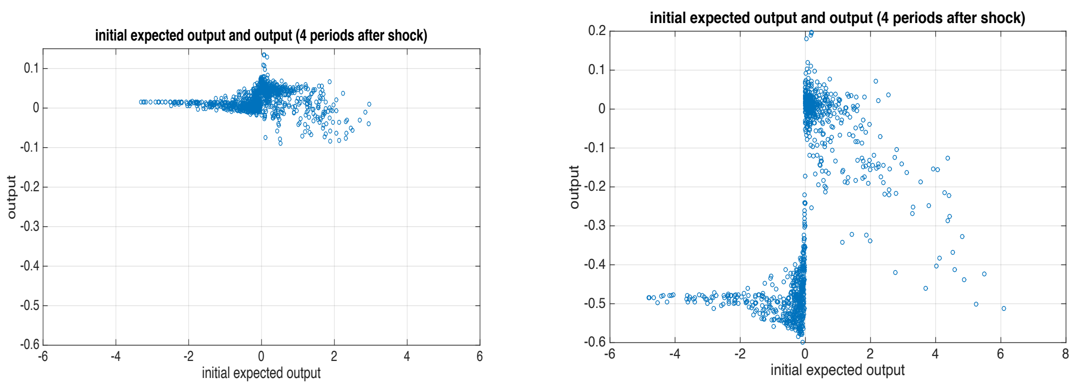


Figure 14: Predictability under strong and normal stabilization (large demand shock)

Strong stabilization (c2=2) normal stabilization (c2=0.5)



9 Output stabilization and trust

We have seen in previous sections that large shocks endanger the trust of economic agents in two dimensions, i.e. institutional (trust in the central bank) and in the economy. We also found that a breakdown of trust in these two dimensions is more likely when large supply shocks hit the economy, and less so when large demand shocks occur. How can the central bank affect trust after large shocks? This is the question we pursue in this section.

We answer this question by analyzing how the degree of output stabilization (measured by the Taylor parameter c2) affects trust. We first focus on a large negative supply shock and compare the case of "normal" output stabilization and "strong" output stabilization. As in the previous section, in the first case we set c2 = 0.5, in the second case we set c2=2. We show the results in Figure 15. We observe that when the central bank increases its ambition to stabilize output (c2 increases from 0.5 to 2) trust declines significantly after the supply shock. We see this from the fact that after the supply shock inflation credibility drops to 0 in both cases but it remains stuck at zero longer when output stabilization is strong. The same holds with animal spirits after the shock. Thus, when large negative supply shocks occur a central bank that aggressively pursues output stabilization will suffer a loss of trust longer than a central bank that pursues output stabilization more cautiously. In addition, trust in the economy (pessimism about future recovery) will then remain a feature for a longer time.

Remarkably, things are very different when large demand shocks hit the economy. We show this in Figure 16. We now find that output stabilization activism (a high c2) tends to dampen the effect of the shock on trust. We find that when c2 = 2 extreme pessimism (animal spirits equal to -1) is rare and recovers fast in comparison with the situation where the central bank uses normal stabilization. As far as inflation credibility is concerned the degree of output stabilization does not affect trust in the central bank.

From the preceding analysis we conclude that negative supply shocks create important threats to trust in the central bank and in the economy, all the more so when central banks pursue aggressive policies of output stabilization. Negative demand shocks are a much weaker threat to trust. Moreover, in this case more aggressive output stabilization reduces the threat of losses in trust. This is due to the fact that when a negative demand shock hits, the central bank can reduce both the negative effects on output and inflation, and therefore is perceived as being successful, while with a supply shock central banks are in a dilemma situation that prevents them from successfully stabilizing the economy. Trying harder only makes matters worse.

Figure 19: Trust under strong and normal stabilization (large supply shock)

Strong stabilization (c2=2) Normal stabilization (c2=0.5)

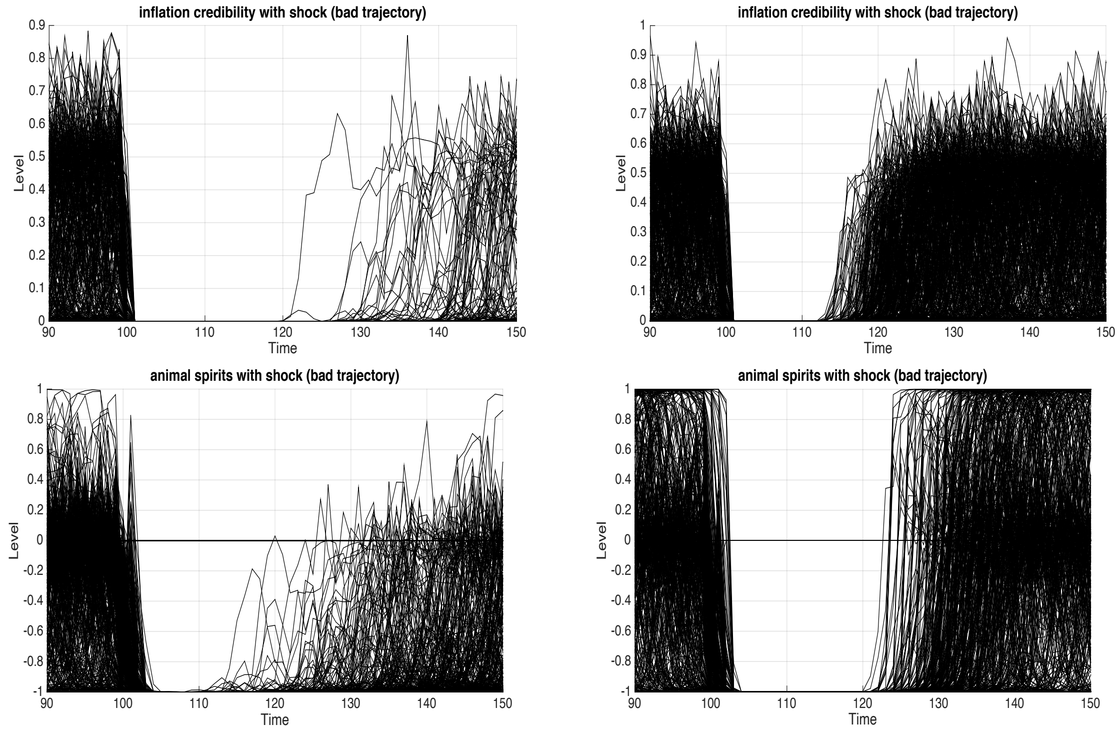
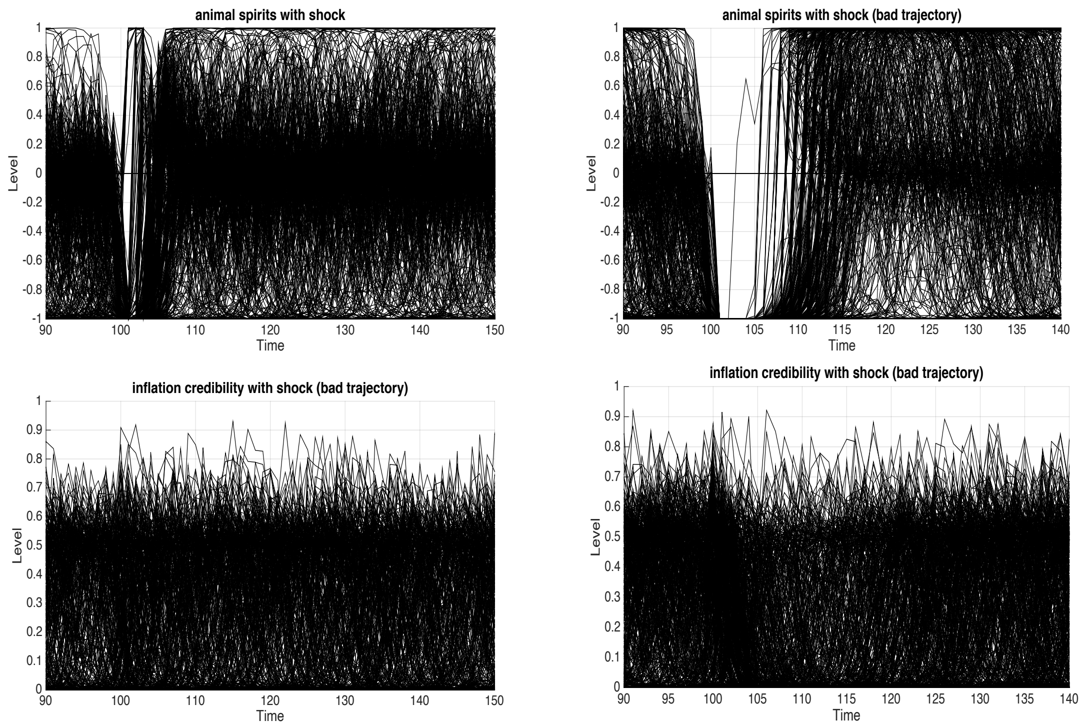


Figure 20: Trust under strong and normal stabilization (large demand shock)

Strong stabilization (c2=2) normal stabilization (c2=0.5)



10 Conclusion

In this paper we have analyzed the importance of trust in the transmission of demand and supply shocks in the economy. We have focused on two dimensions of trust. The first one is institutional. It is related to the credibility of the inflation target announced by the central bank, and we measured this by the fraction of agents using the inflation target as their prediction rule for inflation. The second one is trust in the future, measured by an index of optimism (pessimism) about future economic activity.

In order to analyze the importance of trust we used a behavioural macroeconomic model that is characterized by the fact that individuals lack the cognitive ability to understand the underlying model and to know the distribution of the shocks that hit the economy. In such a world it is rational for these individuals to use simple forecasting rules (heuristics) and to subject these rules to a regular fitness test. As a result, these agents frequently switch to the best performing rule. This creates a dynamics of booms and busts driven by waves of optimism and pessimism (animal spirits). It is also a model that allows us to give a quantitative content to our two measures of trust.

Our main results can be summarized as follows. Focusing on negative supply shocks we find, first, that when the negative supply shock is sufficiently large (3 standard deviations or more) there exist two trajectories of output. The first one, a "good" trajectory, implies a relatively small decline of the output gap and a relatively quick return to the steady state value; the second trajectory, a "bad" one, follows a deep decline in output and a slower recovery. A similar bifurcation between good and bad trajectories is detected in the impulse responses of inflation generating a good trajectory of rapid declines in inflation and a bad trajectory characterized by a slower decline in inflation.

Second, trust follows similar good and bad trajectories. We find that in all the bad trajectories of output and inflation, the credibility of the central bank drops to zero. Thus when the economy is in a bad trajectory this coincides with a collapse of credibility. No single agent trusts the central bank anymore: the fraction of agents that use the inflation target as their forecasting rule drops to zero and they all use the extrapolative rule to make inflation forecasts. At the same time trust in the future of economic activity (animal spirits) also drops to its minimum value (extreme pessimism). These features are absent in the good trajectories.

When the economy is in a good trajectory of output and inflation our two measure of trust do not decline. This makes the good trajectory possible.

Third, we find that initial conditions matter a great deal in determining which trajectory will be chosen. In order to get stuck into a bad trajectory, the initial conditions must be bad, i.e. there must be high inflation expectations and pessimism about future output. These bad initial conditions make it possible for the large negative supply shock to push the system towards the limits of zero credibility and extreme pessimism. As a result, the mean reverting processes in the forecasting behaviour of agents are switched off and forecasting is purely extrapolative. This means that along this bad trajectory the forces that push towards a return to equilibrium are weak.

In contrast when the initial conditions are favorable (low inflation expectations and optimism about the economy) the same negative supply shock does not push credibility and animal spirits against its limits. In that case mean reverting processes in the forecasting behaviour continue to do their work of softening the impact of the supply shock and one ends up in a good trajectory. Thus, favourable initial conditions work as a buffer preventing large shocks from hitting the boundaries and preventing a collapse of trust.

Summarizing these three results, one can conclude that large negative supply shocks that arise under unfavorable initial conditions lead to a loss of trust; both a loss of trust in institutions (the central bank) and a loss of trust about the future (pessimism). This intense loss of trust amplifies the negative effects of the supply shock. Thus, trust is key in smoothly returning the economy to equilibrium. Trust allows mean reverting dynamics to do its work to bring the economy back to equilibrium. Conversely, absence of trust makes the economy less resilient to absorb large exogenous shocks. When trust is absent, the economy is adrift lacking an anchor that is needed to stabilize the economy after a shock.

The results obtained for large negative demand shocks are similar to the ones obtained for large supply shocks, i.e. emergence of good and bad trajectories, correlation with trust and importance of initial conditions in determining the nature of the subsequent trajectories. There is a difference though. In general, the loss of trust in the central bank is much less pronounced when a negative demand shock occurs. This has to do with the fact that after a negative demand shock the central bank is not put into a dilemma situation (as it is after a negative supply shock). As a result, the central bank can keep inflation closer to its target more effectively and maintains much of its credibility.

We also performed a sensitivity analysis to find out how large supply and demand shocks have to be to generate good and bad trajectories that can be predicted by initial conditions and that are highly correlated with trust. We found that for shocks of 3 standard deviations of more the conditions exist to generate bifurcations in the impulse responses to these shocks. When shocks are small (less than 3 standard deviations) this bifurcation does not emerge. Initial conditions still matter a great deal to determine the trajectories after the shock, but these initial conditions do not have much predictive power.

Our results have some relevance to understand the experience of the 1970s with the large supply shocks and the recent covid supply shock. Preceding the supply shocks of the 1970s there had been a buildup of inflation and inflationary expectations. Our model predicts that with these initial conditions, the recovery would take a long time. This is also what happened for many countries with a prior history of significant inflation, especially after the second oil shock of 1979. According to the World Bank(2021) the world GDP growth rate took five years to return to its pre-1979 level of 4.2%. This growth rate was only reached in 1984 again. The trajectory of this protracted recovery also followed the prediction of our model: given the inflationary environment the supply shock of 1979 “forced” many central banks, in particular the US Federal Reserve under Paul Volcker, to raise the interest rates thereby intensifying the economic downturn.

The Covid supply shock of 2020 was preceded by a period of low inflation and low inflationary expectations. Our model predicts that this should make a quick recovery possible, mainly because the central banks did not worry about the inflationary consequences and therefore could actually follow expansionary monetary policies. It appears today that a relatively quick recovery is likely to happen. The European Commission(2021), for example, predicts that in 2022 most EU-countries will have returned to their pre-pandemic GDP growth path.

The previous discussion implies that history matters. A history of high inflation and expectations of inflation condition the impact of a supply shock and is likely to produce bad outcomes of this shock. In contrast a history of price stability makes it possible for the economy to follow a more benign trajectory after the same supply shock.

Appendix 1. Microfoundations of the basic behavioral model

We show that the aggregate demand and supply equations used in the main text can be micro-founded on individual utility maximization of households and profit maximization of firms.

1. Aggregate demand

Let us start by modeling the demand side of the model. This will be based on the maximization of individual's utility of consumption over an infinite horizon. The individual consumer, *i*, maximizes the following function over an infinite horizon:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t^i, N_t^i) \qquad \text{(A1)}$$

where β is discount factor, U is the utility function which is assumed to have the same form every period and every agent, C_t^i is consumption of agent i in period t and N_t^i is hours worked by agent i.

The budget constraint faced by consumer *i* is:

$$P_t C_t^i + Q_t B_t^i \leq B_{t-1}^i + W_t N_t^i - T_t \qquad \text{(A2)}$$

where B_t^i is the quantity of one period discount bond purchased by agent i in period t and maturing in *t+1*; Q_t is price of bond, P_t is the price of consumption goods, W_t is the wage rate and T_t is a lump-sum tax

First order condition for consumer's optimum (Euler equation):

$$-\frac{U_{n,t}}{U_{c,t}} = \frac{W_t}{P_t} \qquad \text{(A3)}$$

$$Q_t = \beta \tilde{E}_t^i \left[\frac{U_{c,t+1}}{U_{c,t}} \frac{P_t}{P_{t+1}} \right] \qquad \text{(A4)}$$

where $\tilde{E}_t^i$ is the forecast made by agent i in period t using the behavioral heuristic explained in the main text.

Assume a CES utility function

$$U(C_t^i, N_t^i) = \frac{C_t^{i,1-\sigma}}{1-\sigma} - \frac{N_t^{i,1+\varphi}}{1+\varphi} \qquad \text{(A5)}$$

First order optimality conditions can then be written as:

$$\frac{W_t}{P_t} = C_t^{i,\sigma} N_t^{i,\varphi} \qquad \text{(A6)}$$

$$Q_t = \beta \tilde{E}_t^i \left[\left(\frac{C_{t+1}^i}{C_t^i} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] \qquad \text{(A7)}$$

Log-linearization (A6) yields the labour supply equation

$$w_t - p_t = \sigma c_t^i + \varphi n_t^i \qquad \text{(A8)}$$

where lower case letters are natural logarithms. We will not use this labour supply equation as I currently assume full wage flexibility.

Similarly log-linearization (A7) yields the consumption equation (Euler equation) for individual i:

$$c_t^i = \tilde{E}_t^i c_{t+1}^i - \frac{1}{\sigma}\left(r_t - \tilde{E}_t^i \pi_{t+1} - \rho\right) \qquad \text{(A9)}$$

where the interest rate $r_t = -\log(Q_t)$, the inflation rate $\pi_t = \log P_{t+1} - \log P_t$ and $\rho = -\log \beta$.

We follow Hommes and Lustenhouwer (2016) in assuming that the probability to follow a particular forecasting rule (heuristic) in period t is the same across agents, and independent of the heuristic they followed in the past. This follows from the fact that agents are not inherently different, but that each of them is confronted with the same choice between being following a naïve or fundamentalist forecasting rule. In addition, as in Hommes and Lustenhouwer(2016), we assume "agents know that all agents have the same probability to follow a particular heuristic in the future, and that they know that consumption decisions only differ between households in so far as their expectations are different". In this case households' forecasts about their individual consumption must be the same as their forecast of the consumption of any other individual. It follows that the individual's forecast of his own consumption will coincide with the forecast of aggregate consumption:

$$\tilde{E}_t^i c_{t+1}^i = \tilde{E}_t^i c_{t+1} \qquad \text{(A10)}$$

where c_{t+1} is aggregate consumption.

This allows us to rewrite the Euler equation as

$$c_t^i = \tilde{E}_t^i c_{t+1} - \frac{1}{\sigma}\left(r_t - \tilde{E}_t^i \pi_{t+1} - \rho\right) \qquad \text{(A11)}$$

In equilibrium aggregate demand = aggregate supply of output, i.e. $c_t = y_t$

Assume that agents understand market clearing. As a result, their forecast of consumption coincides with their forecast of output. It can be written as

$$\tilde{E}_t^i c_{t+1} = \tilde{E}_t^i y_{t+1} \qquad \text{(A12)}$$

As a result, (A11) can be written as

$$c_t^i = \tilde{E}_t^i y_{t+1} - \frac{1}{\sigma}\left(r_t - \tilde{E}_t^i \pi_{t+1} - \rho\right) \qquad \text{(A13)}$$

Aggregating this expression over all agents i, and using the market clearing condition, yield

$$y_t = \tilde{E}_t y_{t+1} - \frac{1}{\sigma}\left(r_t - \tilde{E}_t \pi_{t+1} - \rho\right) \qquad \text{(A14)}$$

This is the aggregate demand equation used in the main text (without inertia). Thus the aggregate demand equation in our behavioral model can be micro-founded.

The aggregate demand equation used in the main text includes a lagged output gap. Such a lagged output gap can be introduced by assuming habit formation (see Fuhrer(200), Dennis(2008)). We then have a utility function of the form:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t^i, H_t^i, N_t^i) \qquad \text{(A15)}$$

where H_t^i is the habit stock of agent i.

Assuming the habit stock obeys the expression

$$H_t^i = \eta C_{t-1}^i$$

where it is assumed that external habit formation (see Dennis(2008). This allows us to derive an aggregate demand equation of the form (see Dennis(2008))

$$y_t = \frac{1}{1+\eta}\tilde{E}_t y_{t+1} + \frac{\eta}{1+\eta} y_{t-1} - \frac{1}{\sigma}\left(r_t - \tilde{E}_t \pi_{t+1} - \rho\right) \qquad \text{(A16)}$$

which is the aggregate demand equation (1) used in the main text where

$$a_1 = \frac{1}{1+\eta}$$

2. Aggregate supply

There is a continuum of firms each producing a differentiated good j in monopolistically competitive markets.

The production function of firm j is specified as follows

$$Y_t^j = A_t N_t^{j,1-\alpha} \quad \text{(A17)}$$

We introduce a "New-Keynesian" feature in the model which is that prices are sticky. It is customary to assume so-called Calvo pricing. It is possible to micro-found the behavioral model under the same assumptions about price rigidity as in the standard DSGE-models.

Calvo pricing assumes that each firm will reset prices in period t with probability $1-\theta$, where θ is the fraction of firms that keep their prices fixed. Thus, θ can be considered as a measure of prices stickiness.

Each period firms that have drawn the "Calvo lottery ticket", i.e. are allowed to change their price, will set that price, P_t^* , such that it maximizes the current value of profits generated while that price remains effective

Firms maximize expected profits with respect to P_t^*

$$\sum_{k=0}^{\infty}(\beta\theta)^k\, \tilde{E}_t^j\left[P_t^{j,*}Y_{t+k/t}^j - \Psi_{t+k}\left(Y_{t+k/t}^j\right)\right] \quad \text{(A18)}$$

subject to the demand constraints

$$Y_{t+k/t}^j = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\varepsilon} C_{t+k}^j \quad \text{(A19)}$$

Where $\Psi_{t+k}\left(Y_{t+k/t}^j\right)$ is the cost function, $Y_{t+k/t}^j$ is the output of the firm that last reset its price in period t.

The first order condition of an optimum is:

$$\sum_{k=0}^{\infty}(\beta\theta)^k\, \tilde{E}_t^j\left[Y_{t+k/t}^j\left(P_t^{j,*} - M\psi_{t+k/t}^j\right)\right] = 0 \quad \text{(A20)}$$

where $\psi_{t+k/t}$ is the marginal cost in *t+k* for firm that last reset its price in *t* and *M* is mark-up, i.e.

$$M = \frac{\varepsilon}{\varepsilon-1} \quad \text{(A21)}$$

Log-linearizing and solving for the price, yields

$$p_t^{j,*} = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k\,\tilde{E}_t^j\left[mc_{t+k/t}^j + p_{t+k}^j\right] \qquad \text{(A22)}$$

where μ is the desired mark-up, $mc_{t+k/t}$ is the (real) marginal cost. Note that $mc_{t+k/t} + p_{t+k}$ is the nominal marginal cost.

Equation (A21) says that firms resetting their price will choose a price equal to desired (equilibrium) mark-up plus expected marginal costs that will prevail as long as the price is effective (is not changed).

Using

$$\pi_t = (1-\theta)(p_t^* - p_{t-1}) \qquad \text{(A23)}$$

We obtain

$$\pi_t^j = \lambda\sum_{k=0}^{\infty}\beta^k\,\tilde{E}_t^j\left[\widehat{mc}_{t+k}^j\right] \qquad \text{(A24)}$$

where $b_2 = \frac{(1-\theta)(1-\beta\theta)}{\theta}\frac{1-\alpha}{1-\alpha\varepsilon}$ and $\widehat{mc}_{t+k}^j$ is the marginal cost expressed as a deviation from the steady state.

Thus when the deviation of marginal cost from steady state is positive a fraction of prices is adjusted upwards, leading to more inflation.

Just as in the case of the demand equation the discrete choice model of the selection of forecasting rules implies that

$$\tilde{E}_t^j\left[\widehat{mc}_{t+k}^j\right] = \tilde{E}_t^j\left[\widehat{mc}_{t+k}\right] \qquad \text{(A25)}$$

Finally we can rewrite

$$\pi_t^j = \beta\hat{E}_t^j[\pi_{t+1}] + \lambda\widehat{mc}_t \qquad \text{(A26)}$$

Aggregating over all firms j (see Hommes and Lustenhouwer(2016), we obtain

$$\pi_t = \beta\widetilde{E_t}[\pi_{t+1} + \lambda mc_t] \qquad \text{(A27)}$$

The last step consists in relating marginal cost to the output gap

$$\pi_t = \beta\tilde{E}_t[\pi_{t+1}] - \lambda\hat{\mu}_t \qquad \text{(A28)}$$

where $\hat{\mu}_t = \mu_t - \mu = -\widehat{mc}_t$ and $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}\,\frac{1-\alpha}{1-\alpha+\alpha\varepsilon}$

In a way analogous to the assumptions on the price-setting constraints facing firms, assume that for each period only a fraction $1 - \theta_w$ of households drawn randomly from the population reoptimize their posted nominal wage. We now consider how households choose the wage for their labour when allowed to reoptimize that wage. The household will choose w_t at period t in order to maximize.

$$\tilde{E}_t^i\{\sum_{t=0}^{\infty}(\beta\theta_w)^k\, U(C_{t+k|t}^i, N_{t+k|t}^i)\} \qquad \text{(A29)}$$

Where $C_{t+k|t}^i$ and $N_{t+k|t}^i$ repectively denote the consumption and labour supply in period t+k of a household I that last rest its wage in period t. Note that the utility generated under any other wage set in the future is irrelevant from the point of view of the optimal setting of the current wage, and thus can be ignored in (A28).

Given the utility function specified in (A5), the first-order condition associated with the problem above is given by

$$\sum_{k=0}^{\infty}(\beta\theta_w)^k\, \tilde{E}_t^i\left\{N_{t+k|t}\, U_c(C_{t+k|t}^i, N_{t+k|t}^i)(\frac{w_t}{p_{t+k}} - M_w \mathrm{MRS}_{t+k|t})\right\} = 0 \qquad \text{(A30)}$$

$MRS_{t+k|t}^i = -\frac{U_n(C_{t+k|t}^i, N_{t+k|t}^i)}{U_c(C_{t+k|t}^i, N_{t+k|t}^i)}$ denote the marginal rate of substitution between consumption and labour in period t+k for the household resetting the wage in period t and $M_w = \frac{\mathcal{E}_w}{1-\mathcal{E}_w}$. Note that $\mathcal{E}_w$measures the elasticity of substitution among labour varieties.

Log-linearizing (A30) around the steady state (zero inflation) yields the following approximate wage setting rule

$$w_t^* = \mu^w + (1 - \beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k \tilde{E}_t^i\{mrs_{t+k|t} + p_{t+k}\} \qquad \text{(A31)}$$

Where μ^w is household markup. $mrs_{t+k|t}$ is the (log) marginal rate of substitution in period t+k for a household that reset its wage in period t.

Using $\pi_t^w = (1 - \theta_w)(w_t - w_{t-1})$

We obtain:

$$\pi_t^w = \beta\tilde{E}_t^i\{\pi_{t+1}^w\} - \lambda_w\hat{\mu}_t^w \qquad \text{(A32)}$$

Where $\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\mathcal{E}_w\varphi)}$ and $\hat{\mu}_t^w = \mu_t^w - \mu^w$

Just as in the demand equation and price setting equations, the discrete choice model of the selection of forecasting rules (concerning wages inflation) implies that it is feasible to aggregate over all households *i*, hence:

$$\pi_t^w = \beta \tilde{E}_t\{\pi_{t+1}^w\} - \lambda_w \hat{\mu}_t^w \qquad \text{(A33)}$$

To obtain the Philips curve used in our model, we follow Gali (2008):

Define real wage $\omega_t = w_t - p_t$, real natural wage $\omega_t^n = w_t^n - p_t^n$, and real wage gap $\widetilde{\omega}_t = \omega_t - \omega_t^n$,

$$\hat{\mu}_t^w = \widetilde{\omega}_t - (\sigma + \frac{\varphi}{1-\alpha})y_t$$

$$\hat{\mu}_t = -\widetilde{\omega}_t - \frac{\alpha}{1-\alpha} y_t$$

Referring to Equation (A26), the New Keynesian Philips curve is

$$\pi_t = \beta \tilde{E}_t[\pi_{t+1}] - \lambda \hat{\mu}_t$$

$$= \beta \tilde{E}_t[\pi_{t+1}] + \lambda(\widetilde{\omega}_t + \tfrac{\alpha}{1-\alpha} y_t)$$

$$= \beta \tilde{E}_t[\pi_{t+1}] + \lambda(\hat{\mu}_t^w + (\sigma + \tfrac{\varphi}{1-\alpha})y_t + \tfrac{\alpha}{1-\alpha} y_t)$$

$$= \beta \tilde{E}_t[\pi_{t+1}] + \lambda \left(\tfrac{\sigma(1-\alpha)+\varphi+\alpha}{1-\alpha}\right) y_t + \lambda \hat{\mu}_t^w$$

$$= \beta \tilde{E}_t[\pi_{t+1}] + b_2 y_t + \lambda \hat{\mu}_t^w$$

where $b_2 = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{\sigma(1-\alpha)+\varphi+\alpha}{1-\alpha+\alpha\mathcal{E}}$

To obtain an aggregate supply equation with a lagged inflation, as we have in the main text an indexation scheme has to be introduced. In such an indexation scheme the prices that in the context of the Calvo rule cannot be optimized in period t are indexed to inflation in period t-1. This is done in Smets and Wouters(2003). It is shown there that with indexation the aggregate supply curve is of the form:

$$\pi_t = \frac{\beta}{1+\beta\wedge} \tilde{E}_t[\pi_{t+1}] + \frac{\xi}{1+\beta\wedge} \pi_{t-1} + b_2 y_t + \lambda \hat{\mu}_t^w$$

where $\wedge$ expresses the degree of indexation. When $\wedge = 0$ there is no indexation and we obtain an aggregate supply curve without lagged inflation. When $\wedge = 1$ there is full indexation and we obtain the aggregate supply curve used in the main text. In that case the coefficients on the forward looking and lagged inflation add up to 1. This leads to equation (2) in the main text.

APPENDIX 2: Selecting the forecasting rules in output forecasting

We define the forecast performance (utility) of a using particular rule as follows[4].

$$U_{f,t} = -\sum_{k=0}^{\infty} \omega_k \left[y_{t-k-1} - \widetilde{E}_{f,t-k-2} y_{t-k-1}\right]^2 \qquad \text{(B1)}$$

$$U_{e,t} = -\sum_{k=0}^{\infty} \omega_k \left[y_{t-k-1} - \widetilde{E}_{e,t-k-2} y_{t-k-1}\right]^2 \qquad \text{(B2)}$$

where $U_{f,t}$ and $U_{e,t}$ are the utilities of the fundamentalist and naïve rules, respectively. These are defined as the negative of the mean squared forecasting errors (MSFEs) of the forecasting rules; ω_k are geometrically declining weights. We make these weights declining because we assume that agents tend to forget. Put differently, they give a lower weight to errors made far in the past as compared to errors made recently. The degree of forgetting turns out to play a major role in our model. This was analyzed in De Grauwe(2012).

Agents evaluate these utilities in each period. We apply discrete choice theory (see Anderson, de Palma, and Thisse, (1992) and Brock & Hommes(1997)) in specifying the procedure agents follow in this evaluation process. If agents were purely rational they would just compare $U_{f,t}$ and $U_{e,t}$ in (10) and (11) and choose the rule that produces the highest value. Thus under pure rationality, agents would choose the fundamentalist rule if $U_{f,t} > U_{e,t}$, and vice versa. However, psychologists have stressed that when we have to choose among alternatives we are also influenced by our state of mind (see Kahneman(2002)). The latter can be influenced by many unpredictable things. One way to formalize this is that the utilities of the two alternatives have a deterministic component (these are $U_{f,t}$ and $U_{e,t}$) and a random component $\xi_{f,t}$ and $\xi_{e,t}$ The probability of choosing the fundamentalist rule is then given by

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[4] (B1) and (B2) can be derived from the following equation:

$$U_t = \rho U_{t-1} + (1-\rho)[y_{t-1} - \tilde{E}_{t-2} y_{t-1}]^2 \quad \text{(B1')}$$

where ρ can be interpreted as a memory parameter. When $\rho = 0$ only the last period's forecast error is remembered; when $\rho = 1$ all past periods get the same weight and agents have infinite memory. We will generally assume that $0 < \rho < 1$. Using (9') we can write

$$U_{t-1} = \rho U_{t-2} + (1-\rho)[y_{t-2} - \tilde{E}_{t-3} y_{t-2}]^2 \text{(B1'')}$$

Substituting (B1") into (B1') and repeating such substitutions ad infinitum yields the expression (B1) where

$$\omega_k = (1-\rho)\rho^k$$

$$\alpha_{f,t} = P\left[(U_{f,t} + \xi_{f,t}) > (U_{e,t} + \xi_{e,t})\right] \qquad \text{(B3)}$$

In words, this means that the probability of selecting the fundamentalist rule is equal to the probability that the stochastic utility associated with using the fundamentalist rule exceeds the stochastic utility of using the naïve rule. In order to derive a more precise expression one has to specify the distribution of the random variables $\xi_{f,t}$ and $\xi_{e,t}$. It is customary in the discrete choice literature to assume that these random variables are logistically distributed. One then can obtain the probabilities specified in (8) and (9).

The parameter γ measures the "intensity of choice". It is related to the variance of the random components. Defining $\xi_t = \xi_{f,t} - \xi_{e,t}$ we can write (see Anderson, Palma and Thisse(1992)):

$$\gamma = \frac{1}{\sqrt{var(\xi_t)}}$$

When var(ξ_t) goes to infinity, γ approaches *0.* In that case agents' utility is completely overwhelmed by random events making it impossible for them to choose rationally between the two rules. As a result, they decide to be fundamentalist or extrapolator by tossing a coin and the probability to be fundamentalist (or extrapolator) is exactly 0.5. When $\gamma = \infty$ the variance of the random components is zero (utility is then fully deterministic) and the probability of using a fundamentalist rule is either 1 or 0.

Appendix 3 Solving the model

The solution of the model is found by first substituting equation (3) into (1) and rewriting in matrix notation. This yields:

$$\begin{bmatrix} 1 & -b_2 \\ -a_2c_1 & 1-a_2c_2 \end{bmatrix}\begin{bmatrix} \pi_t \\ y_t \end{bmatrix}$$

$$= \begin{bmatrix} b_1 & 0 \\ -a_2 & a_1 \end{bmatrix}\begin{bmatrix} \widetilde{\mathrm{E}}_{\mathrm{t}}\pi_{t+1} \\ \widetilde{\mathrm{E}}_{\mathrm{t}}y_{t+1} \end{bmatrix} + \begin{bmatrix} 1-b_1 & 0 \\ 0 & 1-a_1 \end{bmatrix}\begin{bmatrix} \pi_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ a_2c_3 \end{bmatrix} r_{t-1} + \begin{bmatrix} \eta_t \\ a_2u_t + \varepsilon_t \end{bmatrix}$$

i.e.

$$\boldsymbol{AZ_t} = \boldsymbol{B\widetilde{E_t}\,Z_{t+1}} + \boldsymbol{CZ_{t-1}} + \boldsymbol{b}r_{t-1} + \boldsymbol{v_t} \tag{C1}$$

where bold characters refer to matrices and vectors. The solution for $\boldsymbol{Z_t}$ is given by

$$\boldsymbol{Z_t} = \boldsymbol{A^{-1}}\left[\boldsymbol{B\widetilde{E_t}\,Z_{t+1}} + \boldsymbol{CZ_{t-1}} + \boldsymbol{b}r_{t-1} + \boldsymbol{v_t}\right] \tag{C2}$$

The solution exists if the matrix $\boldsymbol{A}$ is non-singular, i.e. $(1-a_2c_2)-a_2b_2c_1 \neq 0$. The system (C2) describes the solutions for y_t and π_t given the forecasts of y_t and π_t discussed in equations (6) and (15). The solution for r_t is found by substituting y_t and π_t obtained from (C2) into (3).

References:

Acemoglu, D., Johnson S., Robinson J., and Yunyong Thaicharoen (2003). "Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth", *Journal of Monetary Economics* , 50, 49–123

Akerlof, G., and Shiller, R., (2009), *Animal Spirits. How Human Psychology Drives the Economy and Why It Matters for Global Capitalism*, Princeton University Press, 230pp.

Akçomak, S., ter Weel, B., (2008), Social Capital, Innovation and Growth: Evidence from Europe , IZA Discussion Paper, 3341

Algan, Y, and Cahuc. P. (2010). "Inherited Trust and Growth." *American Economic Review*, 100 (5): 2060-92.

Algan, Y., and Cahuc, P., (2013), Trust and Growth, *Annual Review of Economics*, vol. 5:521-549

Anderson, S., de Palma, A., Thisse, J.-F., 1992, Discrete Choice Theory of Product Differentiation, MIT Press, Cambridge, Mass.

Arrow, K., 1972, Gifts and Exchanges, *Philosophy and Public Affairs*, (1), 343-362.

Ascari, G., Fagiolo, G., and Roventini, A. (2015). Fat-Tail Distributions And Business-Cycle Models. Macroeconomic Dynamics , 19(02):465-476.

Assenza, T., Heemeijer, P., Hommes, C.H. & Massaro, D. (2020). Managing self-organization of expectations through monetary policy: a macro experiment, Journal of Monetary Economics, in press.

Beugelsdijk, S. deGroot, H., and van Schaik, A., (2004), Trust and Economic Growth, A Robustness Analysis, *Oxford Economic Papers*, 56, 1.

Bjørnskov, C., (2018), Social Trust and Economic Growth, in Eric Uslaner, (ed), Oxford Handbook of Social and Political Trust, Oxford University Press.

Blanchard, O., (2018), On the Future of macroeconomic models, *Oxford Review of Economic Policy*, Volume 34, Issue 1-2, 5 January 2018, Pages 43–54, https://doi.org/10.1093/oxrep/grx045

Blattner, T.S. and Margaritov, E., 2010. Towards a robust monetary policy rule for the euro area.

Branch W.A. (2004), The theory of rationally heterogeneous expectations: evidence from survey data on inflation expectations, Economic Journal, 114 (497), 592–621.

Branch, W., and Evans, G., (2006), Intrinsic heterogeneity in expectation formation, *Journal of Economic theory*, 127, 264-95.

Brazier, A., Harrison, R., King, M., Yates, T., (2008), The danger of inflation expectations on macroeconomic stability: heuristic switching in an overlapping generations monetary model, in *International Journal of Central Banking*, 32:2428-2452.

Brock, W., and Hommes, C., (1997), A Rational Route to Randomness, *Econometrica*, 65, 1059-1095

Calvo, G., (1983), Staggered prices in a utility maximizing framework. Journal of Monetary Econonomics12, 383-398.

Dasgupta, P., (2010), A Matter of Trust: Social Capital and Economic Development, Manchester School, Working Paper, no. 1

De Grauwe, P., (2012), Lectures on Behavioral Macroeconomics, Princeton University Press.

De Grauwe, P. and Ji, Y. (2018), Inflation Targets and the Zero Lower Bound in a Behavioural Macroeconomic Model. *Economica*. doi:10.1111/ecca.12261

De Grauwe, P., and Ji, Y., (2019), Behavioural Macroeconomics. Theory and Policy, Oxford University Press.

De Grauwe, P. and Ji, Y., 2020. Structural reforms, animal spirits, and monetary policies. *European Economic Review*, 124, p.103395.

Delli Gatti, D., Di Guilmi, C;, Gaffeo, E., Giuloni, G., Gallegati, M., Palestrini, A., (2005), A new approach to business fluctuations: heterogeneous interacting agents, scaling laws and financial fragility, *Journal of Economic Behavior and Organization*, vol. 56, 489-512

Dennis, R., (2008), Consumption Habits in a New Keynesian Business Cycle Model, Federal Reserve Bank of San Francisco, Discussion Paper.

Evans, G., and Honkapohja, S., 2001, Learning and Expectations in Macroeconomics, Princeton University Press, 421pp.

European Commission, (2021), https://ec.europa.eu/info/business-economy-euro/economic-performance-and-forecasts/economic-forecasts/spring-2021-economic-forecast_en

Fagiolo, G., Napoletano, M., Roventini, A., (2008), Are Output Growth Rate Distributions Fat-Tailed: Evidence for OECD-countries, *Journal of Applied Econometrics*, 23: 639–669

Farmer, Roger, E.A., (2006), Animal Spirits, *Palgrave Dictionary of Economics.*

Farmer, J. Doyne, and Duncan Foley. 'The Economy Needs Agent- Based Modelling.' Nature 460 (**2009**): 685-686

Franke, R., & Westerhoff, F. (2017). Taking stock: A rigorous modelling of animal spirits in macroeconomics. *Journal of Economic Surveys*, *31*(5), 1152-1182.

Fuhrer, J. (2000) .Habit Formation in Consumption and its Implications for Monetary-Policy Models,.*American Economic Review*, 90:3, 367-90.

Fukuyama, F., 1995, *Trust: The Social Virtues and The Creation of Prosperity*, Free Press.

Gabaix, X., (2014), A Sparsity-Based Model of Bounded Rationality, *The Quarterly Journal of Economics* (2014), 1661–1710.

Galí, J., (2008), Monetary Policy, Inflation and the Business Cycle, Princeton University Press, 203pp.

Glaeser E., Laibson D., Scheinkman J., and Soutter C., (2000), Measuring Trust, *Quarterly Journal of Economics*, 95, 811–846

Guiso, L., Sapienza, P., and Zingales, L., (2000), "The role of social capital in financial development ," American Economic Review 94, no. 3.

Hommes, C. (2011), "The Heterogeneous Expectations Hypothesis: Some Evidence from the Lab", Journal of Economic Dynamics and Control, Elsevier, 35(1), pp. 1-24.

Hommes, C.H. and Lustenhouwer, (2019), Infation targeting and liquidity traps under endogenous credibility, Journal of Monetary Economics 107

Hommes, C.H. (2020), Behavioral & experimental macroeconomics and policy analysis: a complex systems approach, Journal of Economic Literature, forthcoming.

Kahneman, D., 2002, Maps of Bounded Rationality: A Perspective on Intuitive Judgment and Choice, Nobel Prize Lecture, December 8, Stockholm (also published in *American Economic Review*, 2003).

Kirman. A., (1992), Whom or What Does the. Representative Individual Represent?, *Journal of Economic Perspectives* · vol. 6, no. 2, Spring, pp . 117-136.

Kirman, A., (1993), Ants, Rationality and Recruitment, *Quarterly Journal of Economics,* 108: 137-156.

Knack, S. and Keefer, P., 1997, Does social capital have a economic payoff, A cross-country comparison, *Quarterly Economic Journal*, (112), 1251-1288.

Kukacka, J., Jang, T.S. and Sacht, S., 2018. On the estimation of behavioral macroeconomic models via simulated maximum likelihood. Available at SSRN 3299450.

Mankiw, G., and Reis, R., (2002), Sticky information versus sticky prices: A proposal to replace the new Keynesian Phillips curve. *Quarterly Journal of Economics* 117(4): 1295-1328

McLachlan, G.J. and Peel, D. (2000*). Finite Mixture Models. Wiley. ISBN 978-0-471-00626-8.*

Orphanides, A., 2001. Monetary policy rules based on real-time data. *American Economic Review*, *91*(4), pp.964-985.

Orphanides, A., Williams, J.C., 2007. Inflation targeting under imperfect knowledge. In: Mishkin, F.,Schmidt-Hebbel, K. (Eds.), Monetary policy under inflation targeting. Central Bank of Chile,Santiago, Chile.

Putnam, R., 1993, *Making Democracy Work*, Princeton University Press, Princeton, NJ.

Putnam, Robert 2000. *Bowling Alone: The Collapse and Revival of American Community*. Simon & Schuster.

Smets, F. and Wouters, R., (2003), An Estimated Dynamic Stochastic General Equilibrium Model, *Journal of the European Economic Association*, 1, 1123-1175.

Svensson, L.E., 1997. Inflation forecast targeting: Implementing and monitoring inflation targets. *European economic review*, *41*(6), pp.1111-1146.

Svensson, L. E. O. (2003), What is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules, *Journal of Economic Literature 41*, 427–477.

Tabellini, G., Culture and Institutions: Economic Development in the Regions of Europe, *Journal of the European Economic Association*, Volume 8, Issue 4, 1 June 2010, Pages 677–716, https://doi.org/10.1111/j.1542-4774.2010.tb00537.x

Taylor, J.B., 1993a. Discretion versus policy rules in practice. Carnegie Rochester Conference Series on Public Policy 39, 195–214.

Tesfatsion, L. (2001), Guest Editor, Special Issue on Agent-Based Computational Economics, Journal of Economic Dynamics and Control, 25(3–4).

Tesfatsion, L., and KL Judd, (2006), Handbook of Computational Economics Volume 2: Agent-Based Computational Economics, Elsevier.

Westerhoff, F., and Franke, R., (2012), Agent-based models for economic policy design: two illustrative examples. Working Paper No. 88, Iowa State University.

Woodford, M., 1999. Optimal monetary policy inertia. Manchester School 67, 1–35 Supplement.

Woodford, M., 2003. Interest and prices. Princeton University Press, Princeton, NJ.

World Bank, (2021), https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG

Wren-Lewis, S., (2018), Ending the microfoundations hegemony, *Oxford Review of Economic Policy*, Volume 34, Issue 1-2, 5 January 2018, Pages 55–69, https://doi.org/10.1093/oxrep/grx054