Tales of Transition Paths:
Policy Uncertainty and Monetary-Fiscal Interaction

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Abstract

What happens when fiscal and/or monetary policy change systematically? We build a DSGE model in which agents have to estimate fiscal and monetary policy rules and assess how this uncertainty surrounding the conduct of policymakers influences transition paths after policy changes. We find substantial effects and uncover that policy changes of the magnitude often considered in the literature can lead private agents to hold substantially different views about the nature of equilibrium than what a full information analysis would predict.

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1 Introduction

What happens when fiscal or monetary policy rules change dramatically? Large changes in fiscal and monetary policy rules are routinely evaluated in micro-founded dynamic equilibrium models (see for example Curdia and Finocchiaro (2013)). Two strong assumptions underlie these kinds of exercises: agents are unaware of possible policy changes and agents become immediately aware of the new policy rule once it is implemented. Work on Markov-switching DSGE models such as Bianchi (2013) and Liu *et al.* (2011) dispenses of the first assumption, but keeps the second. We instead model agents as econometricians that have to estimate coefficients of policy rules to remove the second assumption. We borrow the assumption of 'anticipated utility' decisionmaking (Kreps (1998)) that is common in the learning literature (Sargent *et al.* (2006), Primiceri (2005), and Milani (2007) are three examples) and thus keep the first assumption of the standard approach in play[1].

We study two stylized examples of policy transitions: one is motivated by the Volcker disinflation and studies the change of a monetary policy rule from parameter values that would imply indeterminacy under full-information rational expectations to values that imply determinacy. We thus explicitly model the transition that is absent in studies that separately study indeterminate and determinate outcomes such as Lubik and Schorfheide (2004). Throughout this example we keep fiscal policy passive in the language of Leeper (1991).

The second example we study is a transition from an active monetary policy / passive fiscal policy regime to a situation where fiscal policy is active and monetary policy is passive. This example might be especially relevant now in the aftermath of the financial crisis and the large changes in fiscal policy thereafter.

Both examples show that the speed of learning is crucial. In a standard calibration of our dynamic equilibrium model learning about the response coefficient in the monetary policy rule can be slow, leading to substantial differences in outcomes between the standard approach and our environment. In particular, agents can easily find themselves in situations where they mis-perceive the nature of the equilibrium: In the first example they might believe that equilibrium indeterminacy persists for substantial periods and in the second example agents are lead to believe that the economy is temporarily explosive. Temporarily explosive dynamics can also be a feature of a Markov-switching rational expectations model, an outcome highlighted by Bianchi and Ilut (2013).

[1] Bianchi and Melosi (2013) introduce a very specific type of learning into a Markov-switching DSGE model: Their agents do observe the policy rule coefficients currently in play, but are uncertain how persistent the current regime is.

We highlight how policy shocks that make the signal extraction problem faced by agents harder influence equilibrium outcomes.
We endow our agents with substantial knowledge of the economy. They are only uncertain about the finite dimensional policy rule parameter vector. Furthermore, we endow them with knowledge of the timing of the structural change. We do so to minimize the differences between our approach and the standard approach outlined before. Notwithstanding, even with this substantial knowledge of the economy, equilibrium outcomes in our environment are substantially different from those determined via the standard approach.

2 Model

Our model is a typical version of a medium scale new-keyensian model along the lines of, for example, Smets and Wouters (2007) and Christiano *et al.* (2005). It incorporates nominal frictions, habits, capital utilization and in addition to that also a fiscal sector. The fiscal branch can accumulate debt if its income from the distortionary labor and capital tax is not matching outlays of government spending and transfers. First-order conditions and the complete log-linearized model may be found in the Appendix. The calibration for all parameters is standard in the literature and stems mostly from Traum and Yang (2011) who estimate a very similar model using US data. The values for all parameters can be found in table 6 in the Appendix.

2.1 Households

Households maximize their expected utility [2] where the instantaneous utility function of the representative household i takes the following form:

$$U_t(j) = U_t^b \left[\frac{(C_t(j) - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{L_t(j)^{1+\phi}}{1+\phi} \right] \tag{1}$$

Utility of household j is drawn from Consumption which is denoted by $C_t(j)$ and which should not vary too much from the external habit of last period's overall consumption

[2] Agents treat the coefficients in the fiscal as well as in the monetary policy rule as fixed when making their decisions. We use an *anticipated utility* assumption, which is common in the literature on adaptive learning. A more thorough description follows in the section where the learning algorithm is described more in detail.

C_{t-1}. Labor $L_t(j)$ represents the disutility from carrying labor services. U_t^b is a preference shock that can shift the whole utility function and follows in its log-linearized form an AR(1) process[3]:

$$log(u_t^b) = Const_u^b + \rho_{u^b} log(u_{t-1}^b) + \epsilon_t^{u^b} \tag{2}$$

Each period households can choose to either consume, invest (I_t) or save in the form of government bonds (B_t). Therefore the maximization runs over the infinite sum of discounted utility under the budget constraint:

$$\begin{aligned} C_t(j) + B_t(j) + I_t(j) &= \int_0^1 W_t(l)L_t(j,l)(1-\tau_t) + (1-\tau_t)R_t^K V_t \bar{K}_{t-1} + \psi(V_t)\bar{K}_{t-1} & (3)\\ &+ \frac{R_{t-1}B_{t-1}(j)}{\pi_t} + Z_t(j) + Pr_t & (4) \end{aligned}$$

and the law of motion for private capital:

$$\bar{K}_t(j) = (1-\delta)\bar{K}_{t-1}(j) + U_t^i \left[1 - s\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{5}$$

The household's income stems from working at the wage W_t and interest payments on their savings at the rate R_t. Z_t represents lump-sum transfers, Pr_t are the profits households obtain from the intermediate firm. τ_t denotes the distortionary tax rate that the government levies equally on labor and capital [4]. Effective capital $\bar{K}_t$ is rented by households to firms at the rate R_t^K and is related to physical capital by its utilization rate V_t along the lines of:

$$K_t = V_t \bar{K}_{t-1} \tag{6}$$

The cost of the utilization rate is denoted by $\psi(V_t)$ where the functional form follows standard assumptions in the literature: V is 1 in steady state and $\psi(1) = 0$. Additionally $\psi\epsilon[0,1]$ is defined, so that the following equation is satisfied: $\frac{\psi''()}{\psi'(1)} = \frac{\psi}{1-\psi}$. Capital is subject to a certain depreciation rate δ, but is accumulated over time via investment I_t. Investment is subject to adjustment costs $s(.)$ and to the shock U_t^i) which captures an exogenous disturbance as to how efficiently investment can be turned into effective

[3]Note that throughout lower case letters are used for the log-linear form

[4]In using only one tax rate for both input factors we follow Traum and Yang (2011). They estimate their model on US data so as we borrow a lot of their parameter estimates it makes sense to follow also this modelling strategy. A second reason is that we base the fiscal policy stance on the tax rate, so it is more convenient to apply the same tax rate to both labor and capital.

capital. It also follows a simple AR(1) process in its log-linearized form:

$$log(u_t^i) = Const_u^i + \rho_{u^i} log(u_{t-1}^i) + \epsilon_t^{u^i} \tag{7}$$

2.2 Wages:

A composite labor service L_t is produced by labor packers and is given by:

$$L_t = \left[\int_0^1 l_t(l)^{\frac{1}{1+\eta_t^w}} dl \right]^{1+\eta_t^w} \tag{8}$$

The demand functions from the labor packers stems from the profit maximization problem which yields (with L_t^d as the composite demand for labor services).

$$l_t(l) = L_t^d \left(\frac{W_t(l)}{W_t} \right)^{-\frac{1+\eta_t^w}{\eta_t^w}} \tag{9}$$

where η_t^w is an exogenous markup to wages. It follows in its log-linear form an AR(1) process:

$$log(\eta_t^w) = Const_{\eta_w} + \rho_{\eta^w} log(\eta_{t-1}^w) + \epsilon_t^{\eta^w} \tag{10}$$

The nominal aggregate wage evolution is then given by:

$$W_t = \left[(1-\theta_w)\tilde{W}_t^{-\frac{1}{\eta_t^w}} + \theta_w \left(\pi^{1-\chi_w} \pi_{t-1}^{\chi_w} \right)^{-\frac{1}{\eta_t^w}} W_{t-1}^{-\frac{1}{\eta_t^w}} \right]^{-\eta_t^w} \tag{11}$$

The fraction θ_ω of households that cannot re-optimize index their wages to past inflation by the rule

$$W_t(j) = W_{t-1}(j)(\pi_{t-1}^{\chi_{omega}} \pi_{ss}^{1-\chi_\omega}) \tag{12}$$

The first order conditions on the labor market can also be found in the Appendix.

2.3 Firms

The production function of firm i is linear in technology and labor:

$$Y_t(i) = \exp(A_t) K_{t-1}(i)^\alpha L_t(i)^{1-\alpha} \tag{13}$$

where Y_t denotes the output produced with a certain level of technology A_t, labor input $L_t(i)$ and capital K_t. The exogenous process for technology is given by an AR(1):

$$\log(A_t) = \rho_a \log(A_{t-1}) + \epsilon_t^A \tag{14}$$

In terms of price setting we assume that retailers set their prices according to the Calvo (1983) mechanism, i.e. each period the fraction $(1-\theta_i)$ of all firms are able to reset their prices optimally. Furthermore we assume that firms that cannot reoptimize their prices in period t index their prices to the past inflation rate following the equation.

$$P_t(i) = P_{t1}(i)^{\chi_p} \pi_t^{\chi_p} \pi_{ss}^{1-\chi_p} \tag{15}$$

Profits of firm j (in nominal terms) are then equal to

$$\Pi_t(i) = (P_t(j) - MC_t(i)) \left(\frac{P_t(i)}{P_t}\right)^{-\eta_t^p} Y_t(i) \tag{16}$$

with real marginal costs given by:

$$MC_{i,t} = (1-\alpha)^{\alpha-1}\alpha^{-\alpha}(R_t^k)^\alpha W_t^\alpha A_t^{-1}$$

and the demand for good i $Y_t(i)$ as:

$$Y_t(i) = Y_t \left(\frac{p_t(i)}{P_t}\right)^{-\frac{1+\eta_t^p}{\eta_t^p}} \tag{17}$$

where η_t^p is an exogenous markup to the intermediate good's price that also follows an AR(1) process in its log-linear form:

$$log(\eta_t^p) = Const_{\eta_p} + \rho_{\eta^p} log(\eta_{t-1}^p) + \epsilon_t^{\eta^p} \tag{18}$$

2.4 Government

As we allow the government to accumulate debt the budget constraint is not balanced. It therefore takes the following form:

$$B_t = B_{t-1}\frac{R_{t-1}}{\pi_t} - R_t^K K_t \tau_t - W_t L_t \tau_t + G_t + Z_t \tag{19}$$

One of the fiscal policy instruments has to incorporate a response to the past value of debt. Otherwise fiscal policy would follow an active behavior, i.e. debt would not be stabilized and follow an explosive path. In other words the coefficient of any fiscal rule on lagged debt must be bigger then $\frac{1}{\beta} - 1$ so that debt is stationary. We choose the labor tax rule to behave accordingly. All other fiscal rules follow normal AR(1) processes with their respective white noise component. Government spending is given by:

$$\log(G_t) = Const_G + \rho_g \log(G_{t-1}) + \epsilon_t^G \tag{20}$$

Z_t denotes transfers which behave as follows:

$$\log(Z_t) = Const_Z + \rho_z \log(Z_{t-1}) + \epsilon_t^Z, \tag{21}$$

As mentioned above, the tax rate is modelled as a rule with the feedback coefficient ρ_b which the agents do not know for sure and have to infer:

$$\log(\tau_t) = Const_\tau + \rho_b \log(B_{t-1}) + \epsilon_t^\tau \tag{22}$$

The monetary policy is given by simple Taylor type rule, which is only reacting to inflation and not to production. A major difference is that the timing is different from usual models with the interest reaction to lagged inflation instead of contemporaneous or even expected inflation.

$$\log(R_t) = Const_R + \phi_\pi \log(\pi_{t-1}) + \epsilon_t^R \tag{23}$$

The firms and households in our model know the form of the labor tax rule and the monetary policy rule as described above, but they do not know the coefficients, which they have to estimate. They also know that the government budget constraint has to hold in every period.

2.5 Market Clearing

Demand on the part of the government and households in form of investment and consumption in addition to the adjustment costs related to the utilization costs must fully absorb the output of the firm:

$$Y_t = C_t + I_t + G_t + \psi(V_t)K_{t-1}$$

The bond market in our model is simple and market clearing in this market implies that all bonds issued by the government are bought by the households in the economy.

3 Learning Mechanism

Our approach to modelling learning is borrowed from our earlier work Hollmayr and Matthes (2013), which in turn builds on Cogley *et al.* (2011).

The agents in our model observe all relevant economic outcomes and use those observations to estimate the coefficients of the policy rules. They know all other aspects of the model. All private agents share the same beliefs and carry out inference by using the Kalman filter. If we denote by $\mathbf{\Omega_t}$ the vector of coefficients of all policy rules and by $\xi_\mathbf{t}$ the vector of the interest rate and the tax rate at time t then the observation equation for the state space system used by the Kalman filter is given by: We denote by $\mathbf{\Omega_t}$ the vector of policy rule coefficients that agents want to estimate. In order for agents to be able to use the Kalman Filter for inference, we need to build a state space system than encompasses our assumptions on the learning behavior of agents. The observation equation represents the policy rules, whereas the state equation represents the perceived dynamics in policy rule coefficients.
The vector of observations is given by [5]

$$\xi_\mathbf{t} = \begin{bmatrix} \log(R_t) - R_c \\ \log(\tau_t^L) - \tau_c^L \end{bmatrix} \tag{24}$$

$$\xi_\mathbf{t} = \mathbf{X_{t-1}\Omega_t} + \eta_\mathbf{t} \tag{25}$$

where $\eta_\mathbf{t}$ collects the iid disturbances in the policy rules. $\mathbf{X_{t-1}}$ collects the right-hand side variables in the policy rules. What is left to specify then is the perceived law of motion for Ω_t - how do firms and households in the economy think policy rule coefficients change over time? We study two assumptions: agents either know when

[5] For simplicity, we assume that the steady states are known to the private agents (Cogley *et al.* (2011) highlight that the differences between dynamics under learning and the full information case emerge mainly from different views held by agents on policy rule response coefficients, not intercepts).

the policy rule changes and take into account that policy rule coefficients before and after the break date or they suspect that policy changes every period. The following law of motion for the coefficients encodes these assumptions, inspired by the literature on time-varying coefficient models in empirical macroeconomics (such as Cogley and Sargent (2005) or Primiceri (2005)) [6]:

$$\mathbf{\Omega_t} = \mathbf{\Omega_{t-1}} + \mathbf{1}_t \nu_t \tag{26}$$

If we set the variance of $\nu_\mathbf{t}$ to a conformable matrix of zeroes, then the private agents in our model believe that policy rule coefficients do not change and they estimate unknown constant coefficients. The indicator function $\mathbf{1}_t$ selects in what periods agents perceive there to be a change in policy. We will entertain two assumptions on this indicator function: one in which it is always 1, so agents always assume there is a change in parameters and one in which this indicator function is 0 unless the policy rule actually changes [7]. Given beliefs for $\mathbf{\Omega_t}$, agents in our model will adhere to the anticipated utility theory of decision-making: they will act as if $\mathbf{\Omega_t}$ is going to be fixed at the currently estimated level forever onwards [8]. This is a common assumption in the literature on learning, see for example Milani (2007).

If we denote the vector of all variables (plus a constant intercept) in the model economy by $\overline{\mathbf{Y}}_\mathbf{t}$, then we can stack the log-linearized equilibrium conditions (approximated around the perceived steady state) and the estimated policy rules to get the log-linearized perceived law of motion in the economy:

$$\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_\mathbf{t} = \overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})\mathbf{E}^*_\mathbf{t}\overline{\mathbf{Y}}_\mathbf{t+1} + \overline{\mathbf{C}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_\mathbf{t-1} + \overline{\mathbf{D}}\varepsilon^*_\mathbf{t} \tag{27}$$

$\varepsilon^*_\mathbf{t}$contains the actual shocks the innovations that agents observe as well as the perceived policy shocks (the residuals in the estimated policy rules). This system can be solved using a number of algorithms such as gensys (Sims (1994)). The resulting reduced form perceived law of motion is given by:

$$\overline{\mathbf{Y}}_\mathbf{t} = \overline{\mathbf{S}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_\mathbf{t-1} + \overline{\mathbf{G}}(\mathbf{\Omega_{t-1}})\varepsilon^*_\mathbf{t} \tag{28}$$

[6]This assumption has been applied in the learning literature by Sargent *et al.* (2006), for example.

[7]If agents always perceive policy rule coefficients to change even though there is no policy change, their estimators will fluctuate around the true values. The magnitude of those fluctuations is determined by the signal to noise ratio inherent in the state space systems that we will endow agents with.

[8]We use the posterior mean coming out of the Kalman Filter as a point estimate which the agents in the model condition on when forming expectations.

$\mathbf{S}(\mathbf{\Omega_{t-1}})$ solves the following matrix quadratic equation[9]:

$$\overline{\mathbf{S}}(\mathbf{\Omega_{t-1}}) = (\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}}) - \overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{S}}(\mathbf{\Omega_{t-1}}))^{-1}\overline{\mathbf{C}}(\mathbf{\Omega_{t-1}}) \tag{29}$$

and $\overline{\mathbf{G}}(\mathbf{\Omega_{t-1}})$ is given by

$$\overline{\mathbf{G}}(\mathbf{\Omega_{t-1}}) = (\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}}))^{-1}\overline{\mathbf{D}} \tag{30}$$

To derive the ALM, we replace the perceived policy rule coefficients in $\overline{\mathbf{C}}(\mathbf{\Omega_{t-1}})$ with the actual policy rule coefficients and use the actual innovation vector $\varepsilon_{\mathbf{t}}$:

$$\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_{\mathbf{t}} = \overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})\mathbf{E}^*_{\mathbf{t}}\overline{\mathbf{Y}}_{\mathbf{t+1}} + \overline{\mathbf{C}}^{\mathbf{actual}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_{\mathbf{t-1}} + \overline{\mathbf{D}}\varepsilon_{\mathbf{t}} \tag{31}$$

To solve the model, we can plug the PLM into the ALM twice to get

$$\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_{\mathbf{t}} = \overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})(\overline{\mathbf{S}}(\mathbf{\Omega_{t-1}})^{\mathbf{2}}\overline{\mathbf{Y}}_{\mathbf{t-1}} + \overline{\mathbf{S}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{G}}(\mathbf{\Omega_{t-1}})\varepsilon^*_{\mathbf{t}}) + \overline{\mathbf{C}}^{\mathbf{actual}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{Y}}_{\mathbf{t-1}} + \overline{\mathbf{D}}\varepsilon_{\mathbf{t}} \tag{32}$$

Note that there are two types of shocks appearing in the last equation: the true and the perceived shocks. We can solve for the dynamics of $\overline{\mathbf{Y}}_{\mathbf{t}}$ by only inverting $\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}})$ as long as we can derive an expression for the perceived shocks that only depends on pre-determined and exogenous variables. Fortunately enough, this is true in our case.

$$\varepsilon^*_{\mathbf{t}} = \varepsilon_{\mathbf{t}} + \mathbf{I}^{\mathbf{P}}(\overline{\mathbf{C}}^{\mathbf{actual}}(\mathbf{\Omega_{t-1}}) - \overline{\mathbf{C}}(\mathbf{\Omega_{t-1}}))\overline{\mathbf{Y}}_{\mathbf{t-1}} \tag{33}$$

where $\mathbf{I}^{\mathbf{P}}$ denotes a selection matrix that selects those rows of the vector it multiplies that are associated with the policy instruments about whose dynamics the agents are learning.

Plugging that expression into equation (32) we can derive the reduced form actual law of motion:

$$\mathbb{Y}_{\mathbf{t}} = \mathbf{F}(\mathbf{\Omega_{t-1}})\mathbb{Y}_{\mathbf{t-1}} + \mathbf{R}(\mathbf{\Omega_{t-1}})\varepsilon^*_{\mathbf{t}} \tag{34}$$

$$\mathbf{F}(\mathbf{\Omega_{t-1}}) = \overline{\mathbf{A}}^{-1}(\mathbf{\Omega_{t-1}})(\overline{\mathbf{C}}(\mathbf{\Omega_{t-1}}) + \overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{F}}^{\mathbf{2}}(\mathbf{\Omega_{t-1}})) \tag{35}$$

$$+ \overline{\mathbf{A}}^{-1}(\mathbf{\Omega_{t-1}})(\overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{F}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{G}}(\mathbf{\Omega_{t-1}})\mathbf{I}^{\mathbf{P}}(\overline{\mathbf{C}}^{\mathbf{actual}}(\mathbf{\Omega_{t-1}}) - \overline{\mathbf{C}}(\mathbf{\Omega_{t-1}}))) \tag{36}$$

$$\mathbf{R}(\mathbf{\Omega_{t-1}}) = \overline{\mathbf{A}}^{-1}(\mathbf{\Omega_{t-1}})(\overline{\mathbf{B}}(\mathbf{\Omega_{t-1}})\overline{\mathbf{F}}(\mathbf{\Omega_{t-1}}))\overline{\mathbf{G}}(\mathbf{\Omega_{t-1}}) + \overline{\mathbf{D}} \tag{37}$$

This derivation departs from the derivation used in Cogley *et al.* (2011) because we

[9]The perceived law of motion can be derived by assuming a VAR perceived law of motion of order 1 and then using the method of undetermined coefficients.

found our approach of solving for the equilibrium dynamics to be more numerically stable (once we have solved for the ALM, our approach only requires invertibility of $\overline{\mathbf{A}}(\mathbf{\Omega_{t-1}})$).

4 Simulation Exercises

As a first pass to analyze how agents in our economy react to changes in fiscal and monetary policy, we consider a scenario in which monetary policy becomes passive and distortionary taxes react less to the level of debt - we will call this scenario scenario A. In particular, we consider a one time switch in the policy rule coefficients α_π and ρ_b from 1.5 and .1 to .8 and .04. Put differently the economy undergoes a switch from monetary dominance to fiscal dominance. The calibration for all other parameters is given in the appendix. The calibration borrows parameter values from Hollmayr and Matthes (2013) and Traum and Yang (2011). Other parameter values used are standard in the literature.

We run 100 simulations of 100 periods with the policy switch happening in period 10. [10] We analyze different assumptions about the perceived amount of time variation in policy rule coefficients that private agents hold. We assume agents use a covariance matrix of the innovations in the perceived policy rule coefficients of the following form[11]:

$$\mathbf{E}(\nu_\mathbf{t}\nu_\mathbf{t}') = \begin{bmatrix} (scale * (1.5 - 0.8))^2 & 0 \\ 0 & (scale * (0.1 - 0.04))^2 \end{bmatrix} \tag{38}$$

For the case in which $\mathbf{1_t} = 1 \; \forall t$ we consider the following values for *scale*: .01, .05 and .1, while for the case in which the indicator matrix is only non-zero during the actual policy change, we use the values 1/3, 1/2 and 1. We use smaller values for the first case to avoid large swings in beliefs during times when there is no policy change. To clarify the connection between the policy shift and the nature of the equilibria under rational expectations, we summarize the relevant information of scenario A in the following table:

[10] We choose to not put the policy switch at the beginning of the simulations to minimize the effect of the choice of the initial covariance matrix for the Kalman Filter.

[11] We have used covariance matrices of this form in our previous work and found them handy to interpret the perceived amount of time variation.

	passive fiscal policy	active fiscal policy
active monetary policy	**unique equilibrium**$\searrow$	no equilibrium
passive monetary policy	multiple equilibria	**unique equilibrium**

In a second scenario B, we leave fiscal policy constant at all times. It is passive in the sense that it stabilizes debt. Monetary policy is assumed to switch from passive to active. This scenario is introduced to mimic the disinflationary stance of the Volcker period in the early eighties in the US. The rest of the simulation setup is identical to scenario A. The covariance matrix in the perceived policy rule coefficients then takes this form:

$$\mathbf{E}(\nu_{\mathbf{t}}\nu_{\mathbf{t}}') = \begin{bmatrix} (scale * (0.8 - 1.5))^2 & 0 \\ 0 & (scale * (0.1 - 0.1))^2 \end{bmatrix} \tag{39}$$

The scaling values are the same as under scenario A. The ensuing equilibrium under rational expectations is once again depicted in the following table:

	passive fiscal policy	active fiscal policy
active monetary policy	**unique equilibrium**	no equilibrium
passive monetary policy	multiple equilibria $\uparrow$	**unique equilibrium**

5 Results

This section discusses the results on the two distinct exercises we carry out. First we describe the equilibria that may arise with a certain probability in the transition after a policy change. Departing from those equilibria and the transition phase we secondly discuss the resulting outcomes and thirdly dynamics that happen along the simulated time path.

5.1 Transition Equilibria

The switch from one unique equilibrium to another one happens immediately under rational expectations. Figure 1 in the appendix shows the probability of a stable equilibrium in scenario A in the rational expectations (RE) case and for the case when agents have imperfect information. Under RE the probability of a unique and stable

equilibrium before and also after the shift from monetary dominance to fiscal dominance is always 100%. As indicated before we run the simulation with three different values in the covariance matrix in the perceived policy rule. Until period 10 everything is exactly the same as under RE. Then irrespective of the value of the covariance matrix the period of transition is marked by a high probability of explosive equilibria. In the case of one standard deviation the probability of having a stable perceived law of motion is zero in period 12 and 13 before converging slowly back to probabilities of around 40% at the end of the simulation horizon. Regarding the two other cases with standard deviations of one half and one fourth the initial dip in the probability is not as extreme with around ten percent and 30 percent respectively. Also the recovery and convergence is a bit faster and at the end of the simulation period probabilities of a stable and unique equilibrium are around 55 and 60 percent. It is significant, however, that once agents do not have full information both the nature of the equilibrium changes and also the duration of this new equilibrium. Despite endowing the agents with substantial information, the transition back to the full information benchmark takes a very long time. Leeper and Davig (2011) estimate the four different policy regimes to US data and also find that a switch from one unique equilibrium to another does not happen right away. It is often interrupted by a short interlude of perceived indeterminacy and also in one or two cases by perceived explosive dynamics.
The result in Figure 1 is obtained with a variety of covariances in the learning setup under the baseline calibration including also the volatilities of the two policy rules. What happens if the learning setup stays constant and the noise in the Kalman Filter changes? In other words, we let the volatility of the monetary and the tax rate shock vary[12]. Figure 2 indicates the probability of the economy being stable once when the monetary policy volatility is very low and the tax rate rate volatility very high, then the other way around and once when both are intermediate. The highest probability of an unstable equilibrium (around 40%) results once the shock on monetary policy is very high and the one on the tax rate quite small. The opposite picture arises if the monetary volatility is low. In this case the probability of a stable equilibrium is over 80%. In Figure 3,however, it becomes obvious that the lower the monetary volatility gets the higher the probability of indeterminate solutions. For both the intermediate and high monetary volatility the probability of determinate solutions is 100%. This is also why one line (the green) lies on top of the other (the red one). This can also be shown for the complete set of volatilities ranging from 0.001 to around 0.7 in the

[12]Due to computational reasons we shorten the simulation horizon to 20 periods and let the break from monetary dominance to fiscal dominance happen in period 5. We simulate the economy 50 times for each of both volatilities.

two panels of Figure 4 that show contour plots for the volatilities. According to both graphs the fiscal volatility is not responsible for the ensuing equilibrium. The smaller the distribution of the monetary policy shock is the higher the probability of a stable solution. Increasing the distribution slightly makes unstable solutions more and more likely. The right panel makes clear that only small values of monetary policy volatilities may give rise to indeterminate solutions before unique solutions dominate the picture. Also Schorfheide (2005) and Leeper and Zha (2003) find that the signal coming from monetary policy is crucial for learning or more general inferring the right state of the policy.

In scenario B we switch from passive to active monetary policy. The development of the equilibrium can be observed in Figure 7. At first as before in scenario A the first ten periods are identical before the switch occurs. The probability of indeterminacy is 100% in the first ten periods under rational expectations before it is zero forever onwards. Here, however, the speed of learning denoted by the different covariance entries in the perceived policy rules does not make a big quantitative difference in terms of probabilities regarding the unique equilibria. The probabilities are converging back relatively fast and in period 25 the probability of the economy displaying a unique equilibrium is around 60% already. At the end of the simulation horizon it is quite stable at around 90% for all three covariance matrices. This tells us that here the persistence is a bit less compared to the situation when two policy rules changed at the same time. But it would nevertheless take the economy three to four years to arrive in the unique equilibrium situation in more than half of all times.

5.2 Transition Outcomes

Agents might hold different priors about what kind of policies the government and central bank can pursue. We therefore analyze a situation in which agents a priori rule out explosive dynamics - they apply a projection facility that makes them choose policy coefficients that are closest to their original estimates, but imply a stable (perceived) equilibrium. Using the projection facility we see in Figure 6 how slightly different the values are if agents discard coefficients that yield purely explosive equilibrium outcomes and choose values for those coefficients that are nearby. As a simple measure of differences between the learning and the RE approach we accumulate the difference of the respective key macro variables under both forms of expectations formation. The formula for this approach looks like this:

$$Diff_j^W = \sum_{t=1}^{j} \frac{(W_t^{learning} - W_t^{RE})}{W} \tag{40}$$

where W_t denotes the median of any macro variable in levels and W is the respective steady state level. The superscript decides what simulation outcome (learning or RE) we look at. The cumulated outcome gains or losses over the whole horizon are for example depicted in Figure 5 in the top panel. In the medium panel we show the respective width of error bands of the simulated macro variables under learning and RE over the simulation horizon. This represents the volatility of learning versus RE. The bottom panel shows the coefficients in the two policy rules. The actual path is shown in green while the estimated beliefs are given in red.

What are the outcomes of scenario A if one compares learning to RE [13]? In the lower panel of Figure 5 the paths of the beliefs indicate that agents pick up on the coefficient in the tax rate rule very quickly whereas it takes them a long time to apprehend that monetary policy has changed. This means that households observe an explosive fiscal policy (passive stance) while monetary is for a long time still behaving actively. Incorporating the projection facility to avoid huge differences in outcomes, one can nevertheless see that dynamics are pretty distinct. In terms of volatilities the business cycle under learning exhibits considerable higher and also much more persistent amplification. All major macro variables are up to 50% more volatile under imperfect information. The upside to this, however, is that GDP, capital etc. are also persistently higher under learning compared to RE. The outcomes of scenario B are shown in Figure 8. The lower panel once again shows the convergence in beliefs to the true parameter(s). It takes the full simulation horizon to converge to the value 1.5 but as discussed above once the threshold of approximately 1 (which denotes the Taylor principle) is cleared the economy is in a unique equilibrium. The standard deviation in the learning case is higher compared to the rational expectations case with around 20% for consumption and GDP and only short-lived 10% more volatility in the case of capital. As there is uncertainty surrounding monetary policy above all inflation is much more volatile with a spike at around 300% in the initial periods after the policy switch. In terms of outcomes the transition period is rather negative compared to the full information case. GDP and capital suffer small losses, while inflation and debt are slightly higher under imperfect information. The magnitudes are significant but not very big, however.

[13] Here we focus on our baseline calibration of half a standard deviation in the covariance matrix.

5.3 Transition Dynamics

!!! To be done!

5.4 Further Results/Robustness checks

DISCRETION VS COMMITMENT

The fact that agents have only incomplete knowledge about the policy stance might open up some additional leeway for the fiscal and monetary authorities. They could contemplate "fooling" the agents by using discretionary measures that are not feasible or desirable under full information. In the rational expectations framework agents know immediately the full functional form of the policy rule so discretion on the monetary side would lead to indeterminacy in the period that monetary policy changes from an active to a passive stance. Under learning, however, it takes some time for the households to apprehend that something has changed (although the agent receives the same signal as explained and shown above). In the following, we assume that technology is exogenously decreased by 2.5% in period 9. Monetary Policy reacts in period 10 by decreasing its interest rate reaction to inflation from 1.5 to 0.8 thereby violating the Taylor principle. This policy is followed for 10 consecutive periods until period 20. The motive behind this discretionary move is to stabilize the business cycle by not raising nominal interest enough after a spike in inflation or vice versa after a decrease in inflation. This would lower real interest rates and induce agents to consume and invest more than they would have done otherwise. Figure 9 depicts this move by the central bank and the comparison with the rational expectations case, where no policy shift occurs ie. the monetary authority honors its commitment. In terms of economic outcomes the change is minor but for GDP and Inflation a little positive. A discrete move under learning yields a slightly higher GDP (about 0.2%) and a bit less inflation than under rational expectations. On the downside the standard deviation is slightly higher for all macro-variables and ranges from 1% in the case of inflation up to 4% for consumption. In the lower panel we depict once again the beliefs and actual coefficients of both policy rules. As can be seen, the beliefs for those critical 10 periods are fully stable and do not follow the actual path of the monetary policy coefficient. Up until period 20 agents do not realize that the true coefficient was shifted although they got a signal in period 10 that something is about to change. As explained in the previous sections the actual law of motion is, however, a combination of beliefs and actual coefficients so although agents might be misled for a while the actual policy is still contributing to a significant stabilization of the business cycle.

6 Conclusion

The interaction between monetary and fiscal policy is crucial in modern macroeconomics. In our paper we depart from rational expectations in so far as agents have to estimate the reaction coefficient in the respective policy rule. By doing so a switch in one of the policy stances may have far reaching consequences for the whole economy in terms of equilibria, outcomes and dynamics. Hence, under a reasonable calibration, a switch from monetary dominance to fiscal dominance leads to unstable equilibria for a considerable amount of time. Compared to the full information setup this triggers large deviations in outcomes for key macroeconomic variables such as output, consumption and inflation. For the existing model we quantitatively pin down the nature of the equilibria depending on the volatility in the interest rate rule. For low exogenous volatility in the monetary rule indeterminacy is more probable while the higher the volatility gets the higher the probability for explosiveness is. Using the insight that agents face uncertainty about key policies, the monetary authority may also benefit from households' imperfect information and counteract a recession with highly discretionary measures in order to stabilize the economy. This would not be possible under rational expectations as the agents are always fully aware of the current policy stance.

References

Bianchi, F. (2013). Regime Switches, Agents Beliefs, and Post-World War II U.S. Macroeconomic Dynamics. *Review of Economic Studies*, **80**(2), 463–490.

Bianchi, F. and Ilut, C. (2013). Monetary/Fiscal Policy Mix and Agents' Beliefs. Cepr discussion papers, C.E.P.R. Discussion Papers.

Bianchi, F. and Melosi, L. (2013). Dormant shocks and fiscal virtue. In *NBER Macroeconomics Annual 2013, Volume 28*, NBER Chapters. National Bureau of Economic Research, Inc.

Calvo, G. (1983). Staggered Prices in a Utility Maximizing Framework. *Journal of Monetary Economics*, **12**, 383–398.

Christiano, L., Eichenbaum, M., and Evans, C. L. (2005). Nominal Rigidities and the Dynamic Effects of a shock to Monetary Policy. *Journal of Political Economy*, **113**(1), 1–45.

Cogley, T. and Sargent, T. J. (2005). Drift and volatilities: Monetary policies and outcomes in the post WWII U.S. *Review of Economic Dynamics*, **8**(2), 262–302.

Cogley, T., Matthes, C., and Sbordone, A. M. (2011). Optimal disinflation under learning. Technical report.

Curdia, V. and Finocchiaro, D. (2013). Monetary regime change and business cycles. *Journal of Economic Dynamics and Control*, **37**(4), 756–773.

Hollmayr, J. and Matthes, C. (2013). Learning about fiscal policy and the evolution of policy uncertainty. *Bundesbank Discussion Paper No 51*.

Kreps, D. (1998). *Anticipated Utility and Dynamic Choice*, pages 242–274. Frontiers of Research in Economic Theory. Cambridge University Press.

Leeper, E. M. (1991). Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics*, **27**(1), 129–147.

Leeper, E. M. and Davig, T. (2011). Monetary-Fiscal policy interactions and fiscal stimulus. *European Economic Review*, **55**, 211–227.

Leeper, E. M. and Zha, T. (2003). Modest policy interventions. *Journal of Monetary Economics*, **50**(8), 1673–1700.

Liu, Z., Waggoner, D. F., and Zha, T. (2011). Sources of macroeconomic fluctuations: A regimeswitching DSGE approach. *Quantitative Economics*, **2**(2), 251–301.

Lubik, T. A. and Schorfheide, F. (2004). Testing for Indeterminacy: An Application to U.S. Monetary Policy. *American Economic Review*, **94**(1), 190–217.

Milani, F. (2007). Expectations, learning and macroeconomic persistence. *Journal of Monetary Economics*, **54**(7), 2065–2082.

Primiceri, G. (2005). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies*, **72**(3), 821–852.

Sargent, T., Williams, N., and Zha, T. (2006). Shocks and government beliefs: The rise and fall of American inflation. *American Economic Review*, **96**(4), 1193–1224.

Schorfheide, F. (2005). Learning and Monetary Policy Shifts. *Review of Economic Dynamics*, **8**(2), 392–419.

Sims, C. A. (1994). A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy. *Economic Theory*, **4**(3), 381–99.

Smets, F. and Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review*, **97**(3), 586–606.

Traum, N. and Yang, S.-C. S. (2011). Monetary and fiscal policy interactions in the post-war U.S. *European Economic Review*, **55**(1), 140–164.

Appendix

FOCs and Log-linearized Equation

A First-Order Conditions

Households:

$$\begin{aligned}
\lambda_t &= U_t^b \left(C_t - hC_{t-1}\right)^{-\sigma} \\
\lambda_t &= \beta R_t E_t \frac{\lambda_{t+1}}{\pi_{t+1}} \\
(1-\tau_t)R_t^k &= \psi'(V_t) \\
Q_t &= \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[(1-\tau_{t+1})R_{t+1}^k V_{t+1} - \psi(V_{t+1}) + (1-\delta)Q_{t+1}\right] \\
1 &= Q_t\left[1 - \Gamma\left(\frac{I_t}{I_{t-1}}\right) - \Gamma'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] \\
&+ \beta E_t\left[Q_{t+1}\frac{\lambda_{t+1}}{\lambda_t}\Gamma'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]
\end{aligned}$$

Firms:

$$\begin{aligned}
W_t &= (1-\alpha)\frac{Y_t MC_t}{L_t} \\
R_t^k &= \alpha\frac{Y_t MC_t}{K_t} \\
\tilde{P}_t &= \frac{\psi}{\psi-1}\frac{\left[\lambda_t MC_t Y_t + \beta\theta E_t \lambda_{t+l} MC_{t+1} Y_{t+l}\left(\frac{\pi}{\pi_{t+1}}\right)^{-\psi}\right]}{\left[\lambda_t Y_t + \beta\theta E_t \lambda_{t+l} MC_{t+1} Y_{t+l}\left(\frac{\pi}{\pi_{t+1}}\right)^{1-\psi}\right]} \\
P_t^{1-\psi} &= \theta(\pi P_{t-1})^{1-\psi} + (1-\theta)\tilde{P}_t^{1-\psi} \\
0 &= E_t\left[\sum_{t=0}^{\infty}(\beta\theta_w)^s \lambda_{t+s}\bar{L}_{t+s}\left[\tilde{w}_t \prod_{k=1}^{s}\left(\frac{\pi_{ss}}{\pi_{t+k}}\right) - \frac{(1+\eta_t^w)\psi \bar{L}_{t+s}^{\xi}}{(1-\tau_{t+s})\lambda_{t+s}}\right]\right] \\
\bar{L}_{t+s} &= \left[\tilde{w}_t \prod_{k=1}^{s}\left(\frac{\pi_{ss}}{\pi_{t+k}}\right)\right]^{-\frac{1+\eta_t^w}{\eta_t^w}} L_{t+s} \\
w_t^{\frac{1}{\eta_t^w}} &= (1-\theta_w)\tilde{w}_t^{\frac{1}{\eta_t^w}} + \theta_w\left[\left(\frac{\pi_{ss}}{\pi_t}\right)w_{t-1}\right]^{\frac{1}{\eta_t^w}}
\end{aligned}$$

B Log-Linearized Model

Households:

$$\begin{aligned}
log(\lambda_t) &= Const_C + log(u_t^b) - \frac{1}{1-h}log(c_t) + \frac{h}{1-h}log(c_{t-1}) \\
log(\lambda_t) &= Const_\lambda + log(R_t) + E_t log(\lambda_{t+1}) - E_t log(\pi_{t+1}) \\
log(r_t^k) &= Const_V + \frac{\psi}{1-\psi}log(v_t) + \frac{\tau_{ss}}{1-\tau_{ss}}log(\tau_t) \\
log(q_t) &= Const_Q + E_t log(\lambda_{t+1}) - log(\lambda_t) + \beta(1-\tau_{ss})R_{ss}^k E_t log(r_{t+1}^k) - \beta\tau_{ss}R_{ss}^K E_t log(\tau_{t+1}) \\
&\quad +\beta(1-\delta)E_t log(q_{t+1}) \\
log(k_t) &= Const_K + log(v_t) + log(k_{t-1}) \\
log(\bar{k}_t) &= Const_{\bar{K}} + (1-\delta)log(\bar{k}_{t-1}) + \delta(log(u_t^i) + log(i_t)) \\
(1+\beta)log(i_t) &- \frac{1}{s}(log(q_t) + log(u_t^i)) - \beta E_t log(i_{t+1}) = log(i_{t-1})
\end{aligned}$$

Firms:

$$\begin{aligned}
log(y_t) &= Const_{Agg} + \frac{C_{ss}}{Y_{ss}}log(c_t) + \frac{I_{ss}}{Y_{ss}}log(i_t) + \frac{G_{ss}}{Y_{ss}}log(g_t) + \frac{\psi'(1)K_{ss}}{Y_{ss}}log(v_t) \\
log(y_t) &= Const_Y + log(a_t) + \alpha log(k_t) + (1-\alpha)log(l_t) \\
log(\pi_t) &= Const_\pi + \frac{\beta}{1+\chi^p\beta}E_t log(\pi_{t+1}) + \frac{\chi^p}{1+\chi^p\beta}log(\pi_{t-1}) + \kappa_p log(mc_t) + \kappa_p log(\eta_t^p) \\
log(mc_t) &= Const_{MC} + \alpha log(r_t^k) + (1-\alpha)log(w_t) - log(a_t) \\
log(r_t^k) &= Const_{R^K} + log(l_t) - log(k_t) + log(w_t) \\
log(w_t) &= Const_W + \frac{1}{1+\beta}log(w_{t-1}) + \frac{\beta}{1+\beta}E_t log(w_{t+1}) \\
&- \kappa_w \left[log(w_t) - \nu log(l_t) - log(u_t^b) + \log(\lambda_t) - \frac{\tau_{ss}}{1-\tau_{ss}}log(\tau_t)\right] + \frac{\chi^w}{1+\beta}log(\pi_{t-1}) \\
&- \frac{1+\chi^w\beta}{1+\beta}log(\pi_t) + \frac{\beta}{1+\beta}E_t log(\pi_{t+1}) + \kappa_w log(\eta_t^w)
\end{aligned}$$

Policy Rules and Shocks:

$$
\begin{aligned}
log(b_t) &+ \tau_{ss}\frac{W_{ss}L_{ss}}{B_{ss}}\left(log(\tau_t)+log(w_t)+log(l_t)\right)+\tau_{ss}\frac{R^k_{ss}K_{ss}}{B_{ss}}\Big(log(\tau_t)+log(r^k_t)+log(k_t)\Big)\\
&= Const_B+\frac{1}{\beta}log(R_{t-1})+\frac{1}{\beta}log(b_{t-1})-\frac{1}{\beta}log(\pi_t)+\frac{G_{ss}}{B_{ss}}log(g_t)+\frac{Z_{ss}}{B_{ss}}log(z_t)\\
log(g_t) &= Const_G+\rho_G log(g_{t-1})+\epsilon^G_t\\
log(z_t) &= Const_Z+\rho_Z log(z_{t-1})+\epsilon^Z_t\\
log(\tau_t) &= Const_\tau+\rho_b log(b_{t-1})+\epsilon^\tau_t\\
log(R_t) &= Const_R+\alpha log(\pi_{t-1})+\epsilon^R_t\\
log(a_t) &= Const_A+\rho_A log(a_{t-1})+\epsilon^A_t\\
log(u^i_t) &= Const_u i+\rho^i_u log(u^i_{t-1})+\epsilon^{ui}_t\\
log(u^b_t) &= Const_u b+\rho^b_u log(u^b_{t-1})+\epsilon^{ub}_t\\
log(\eta^p_t) &= Const_{\eta_p}+\rho_{\eta^p} log(\eta^p_{t-1})+\epsilon^{\eta^p}_t\\
log(\eta^w_t) &= Const_{\eta_w}+\rho_{\eta^w} log(\eta^w_{t-1})+\epsilon^{\eta^w}_t
\end{aligned}
$$

with the constants given by:

Constant	Expression
$Const_G$	$log(G_{ss})(1-\rho_G)$
$Const_Z$	$log(Z_{ss})(1-\rho_Z)$
$Const_\tau$	$log(\tau^L_{ss}) - \rho_b log(B_{ss})$
$Const_R$	$log(R_{ss}) - \phi_\pi log(\pi_{ss})$
$Const_B$	$log(B_{ss})(1-\frac{1}{\beta}) + \tau_{ss}\frac{L_{ss}W_{ss}}{B_{ss}}(log(\tau_{ss}) + log(W_{ss}) + log(L_{ss})) + \tau_{ss}\frac{K_{ss}R^k_{ss}}{B_{ss}}(log(\tau_{ss}) + log(R^k_{ss})+$ $log(K_{ss})) - \frac{1}{\beta}log(R_{ss}) + \frac{1}{\beta}log(\pi_{ss}) - \frac{G_{ss}}{B_{ss}}log(G_{ss}) - \frac{Z_{ss}}{B_{ss}}log(Z_{ss})$
$Const_Y$	$log(Y_{ss}) - log(A_{ss}) - (1-\alpha)log(L_{ss}) - \alpha log(K_{ss})$
$Const_A$	$log(A_{ss})(1-\rho_A)$
$Const_{Agg}$	$log(Y_{ss}) - \frac{C_{ss}}{Y_{ss}}log(C_{ss}) - \frac{G_{ss}}{Y_{ss}}log(G_{ss}) - \frac{I_{ss}}{Y_{ss}}log(I_{ss}) - \frac{R^k_{ss}(1-\tau_{ss})K_{ss}}{Y_{ss}}log(v_t)$
$Const_\pi$	$(1 - \frac{\beta}{(1+\chi^p beta)} - \chi^p(1+\beta\chi^p))log(\pi_{ss}) - \kappa_p log(mc_{ss}) - \kappa_p log(\eta^p_{ss})$
$Const_{Lam}$	$-log(R_{ss}) + log(\pi_{ss})$
$Const_Q$	$(1-\beta(1-\delta))log(Q_{ss}) - \beta(1-\tau_{ss})R^K_{ss}log(R^K_{ss}) + \beta\tau_{ss}R^K_{ss}log(\tau_{ss})$
$Const_{R^K}$	$log(R^K_{ss}) - log(W_{ss}) - log(L_{ss}) + log(K_{ss})$
$Const_W$	$(1+\kappa_w - \frac{1}{(1+\beta)} - \beta(1+\beta))log(W_{ss}) - \kappa_w\nu log(L_{ss}) - \kappa_w log(U^b_{ss}) + \kappa_w log(\lambda_{ss}) -$ $-\kappa_w\frac{\tau_{ss}}{(1-\tau_{ss})}log(\tau_{ss}) - \kappa_w log(\eta^w_{ss}) - (\frac{\chi^w}{(1+\beta)} - \frac{(1+\beta\chi_w)}{(1+\beta)} + \frac{\beta}{(1+\beta)})log(\pi_{ss})$
$Const_I$	$-\frac{1}{s}log(Q_{ss}) - \frac{1}{s}log(U^i_{ss})$
$Const_M C$	$log(mc_{ss}) - \alpha log(R^K_s s) - (1-\alpha)log(W_{ss}) + log(A_{ss})$
$Const_L$	$(1-\alpha)log(L_{ss}) + \alpha log(K_{ss}) + log(A_{ss}) - log(Y_{ss})$
$Const_C$	$(\frac{\sigma}{1-h} - \frac{\sigma h}{1-h})log(C_{ss}) + log(\lambda_{ss}) - log(U^b_{ss})$
$Const_V$	$\frac{\psi}{1-\psi}log(V_{ss}) - log(R^K_{ss}) + \frac{\tau_{ss}}{(1-\tau_{ss}}log(\tau_{ss})$
$Const_K$	$log(K_{ss}) - log(V_{ss}) - log(\bar{K}_{ss})$
$Const_{\bar{K}}$	$\delta log(\bar{K}_{ss}) - \delta log(U^i_{ss}) - \delta log(I_{ss})$

C Parameters

Calibrated Parameters of simple model

Description	Parameter	Value
impatience	β	0.99
CES utility Consumption	σ	1
CES utility Labor	ν	3.19
Level Shifter labor	ϕ	1.4
habits	h	0.8
Capital intensity	α	0.33
Depreciation rate	δ	0.025
Price Indexation	χ_P	0.26
Wage Indexation	χ_W	0.35
Calvo Prices	ω_p	0.9
Calvo Wages	ω_w	0.79
Inv. Adjustment Cost Parameter	γ	4
Capital Utilization Cost Param.	ψ	0.34
Steady State Tax Rate	τ_{ss}	0.32
coeff. on inflation in TR	$\phi\pi$	1.5
coeff. on B in labor tax rule	ρ_b	0.05
AR parameter Transfer rule	ρ_z	0.34
AR parameter gov. Spending	ρ_g	0.97
AR parameter technology	ρ_a	0.35
AR parameter Indexation Prices	ρ_{η^p}	0.69
AR parameter Indexation Wages	ρ_{η^w}	0.42
AR parameter Preference	ρ_{u^b}	0.86
AR parameter Investment	ρ_{u^i}	0.87
Std.deviation technology	σ_a	0.69
Std.deviation gov. spending	σ_g	0.15
Std.deviation transfers	σ_z	0.91
Std.deviation tax	σ_τ	0.24
Std.deviation interest rate	σ_r	0.14
Std.deviation investment	σ_{u^i}	0.35
Std.deviation preference	σ_{u^b}	0.38
Std.deviation index.prices	σ_{η^p}	0.065
Std.deviation index.wages	σ_{η^w}	0.21

Table 1: Calibrated Parameters of the model

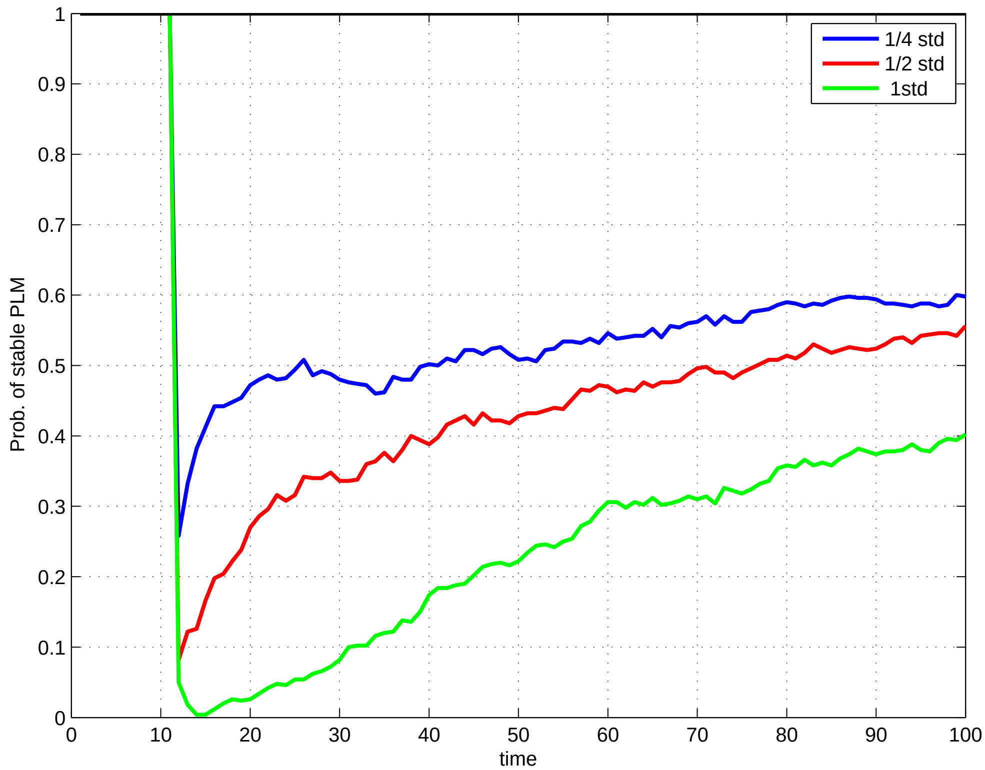

Figure 1: Probability of stable equilibria depending on speed of learning

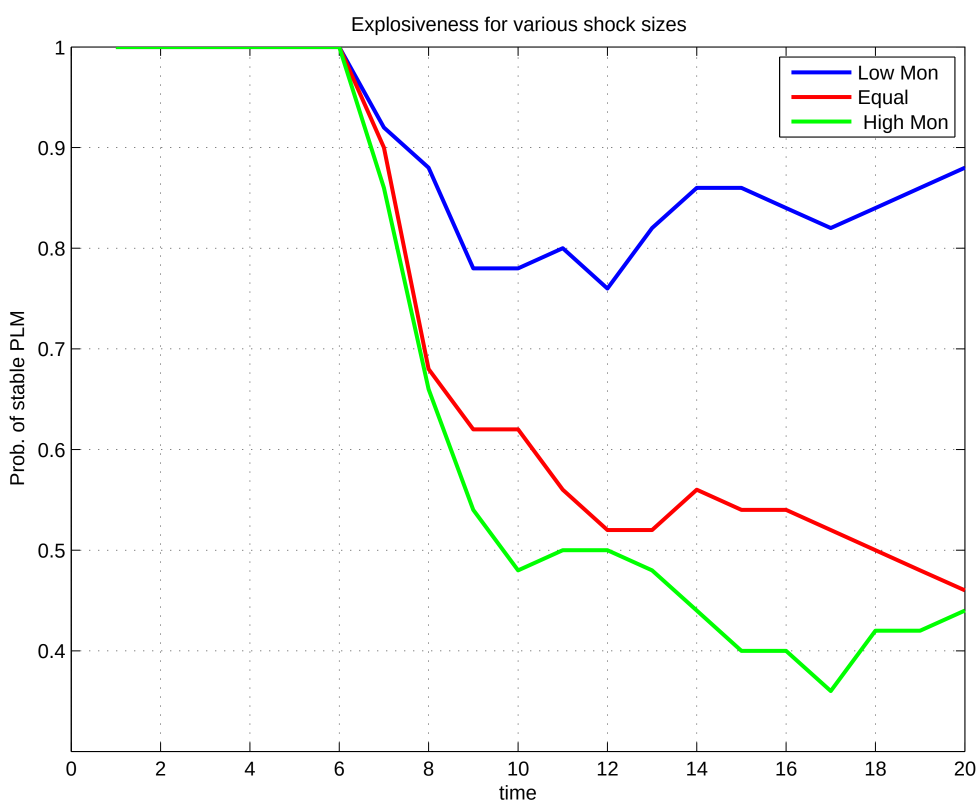

Figure 2: Probability of stability depending on shock sizes:

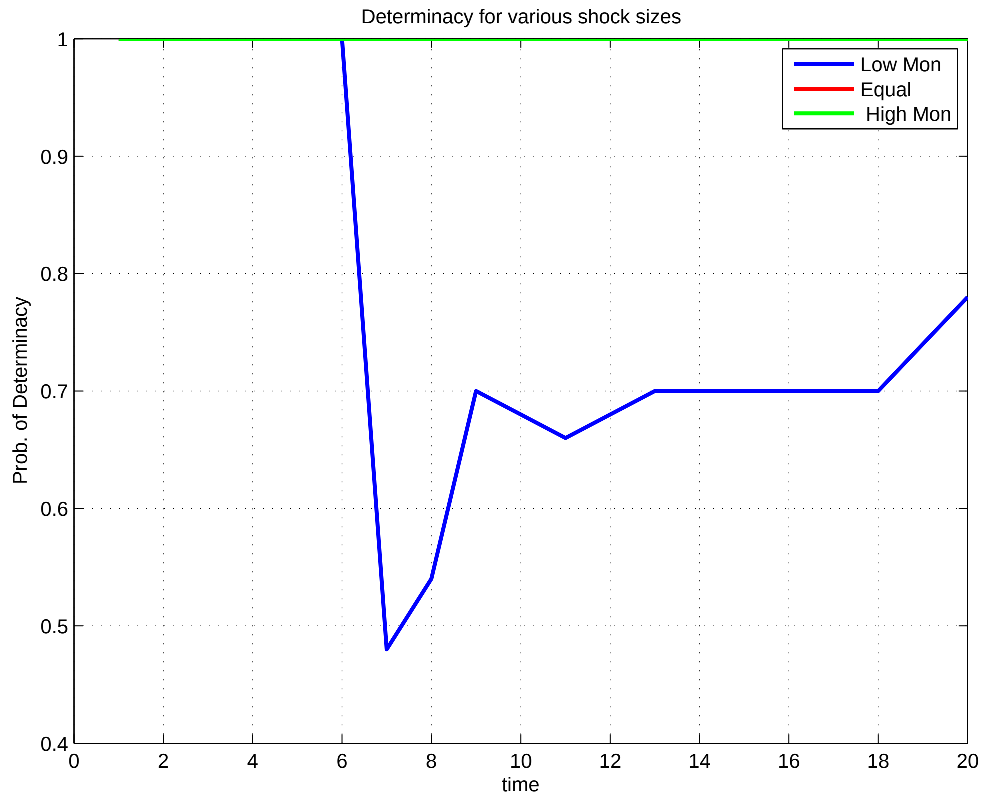

Figure 3: Probability of Indeterminacy depending on shock sizes

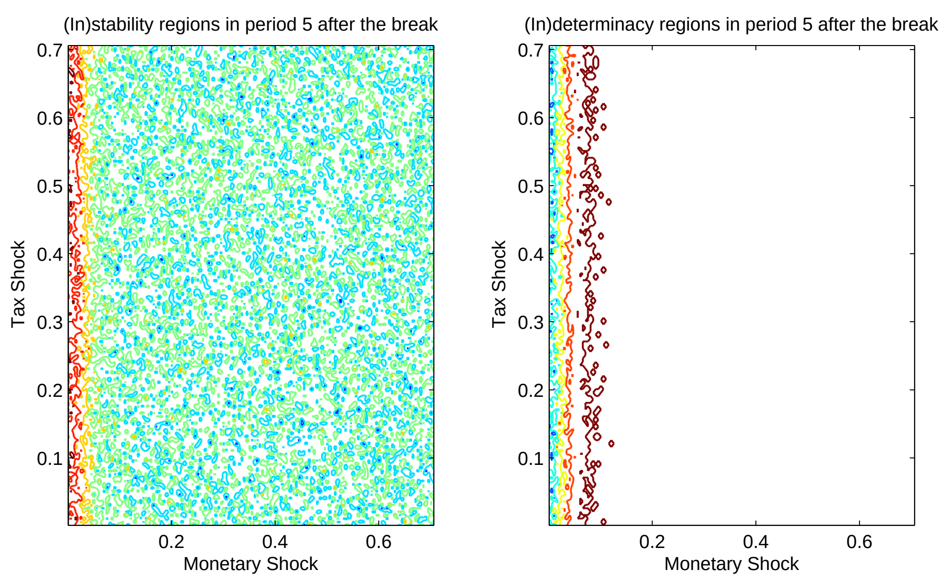

Figure 4: Contour Regions depicting equilibria depending on shock sizes

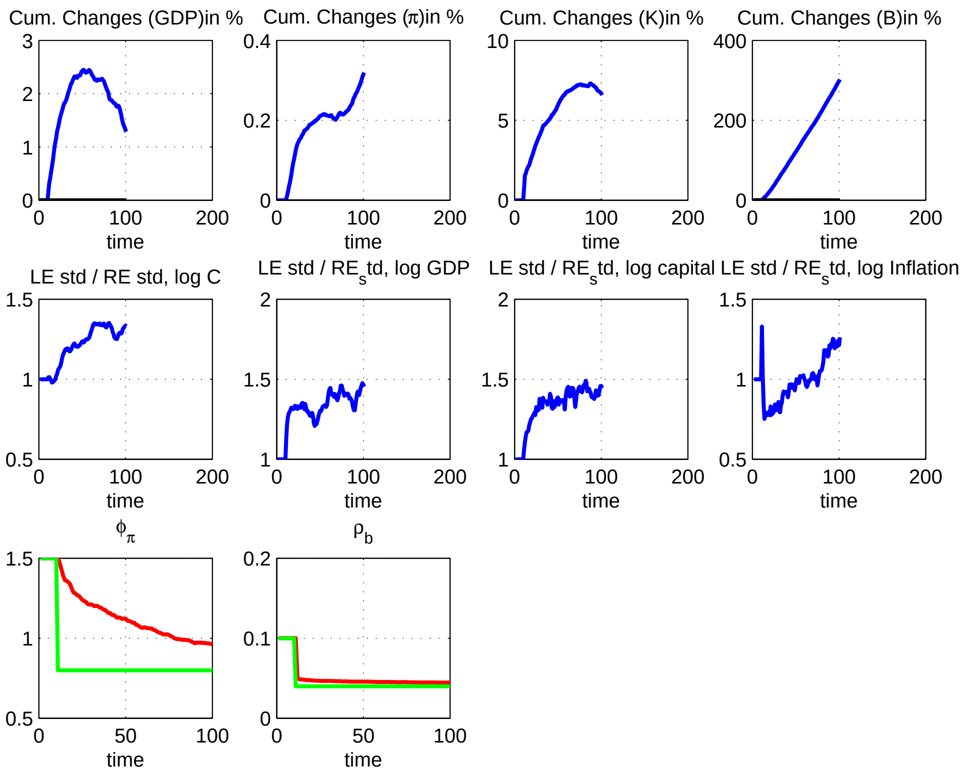

Figure 5: Summary of Outcomes under Scenario A (with Projection Facility)

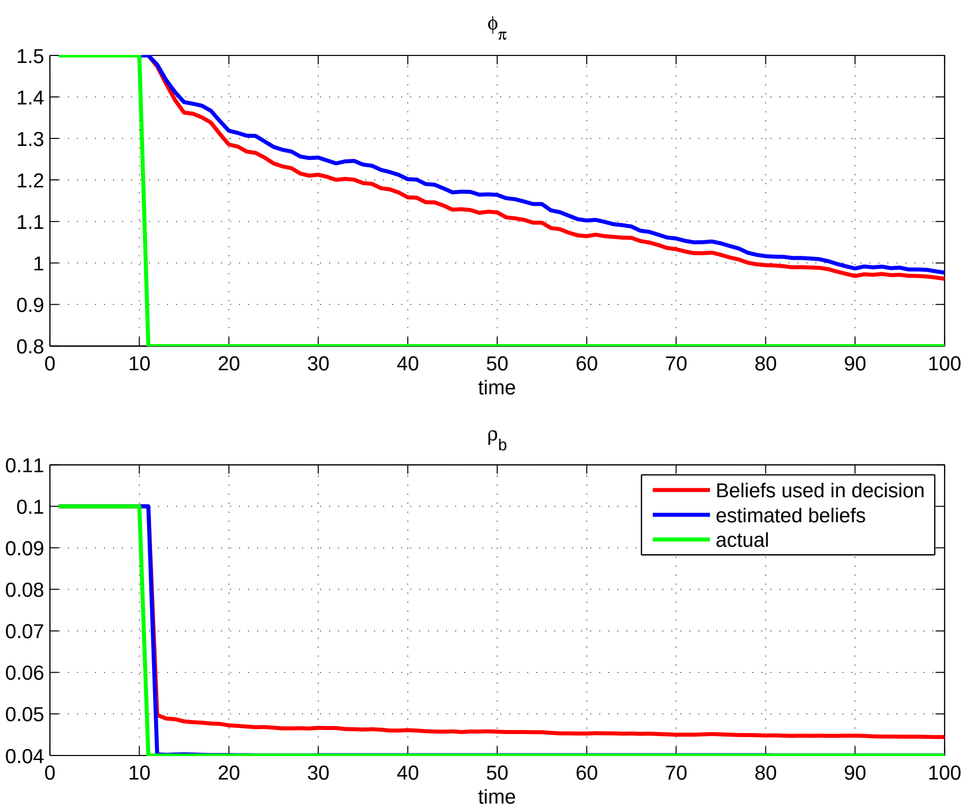

Figure 6: Estimated and used beliefs due to Projection Facility

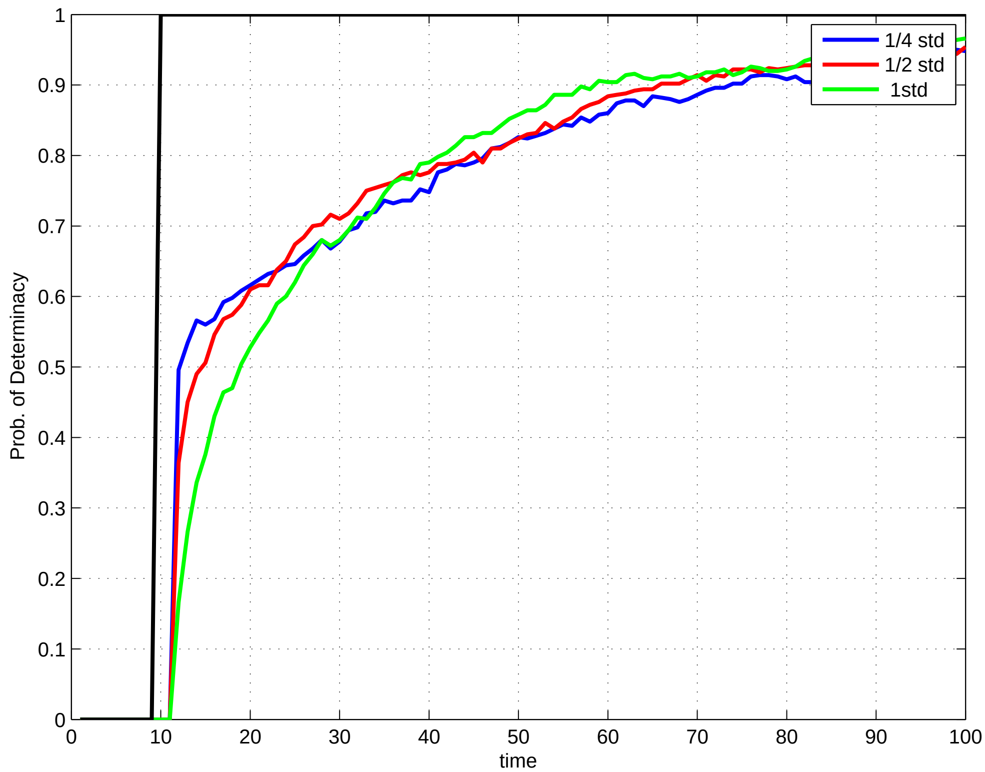

Figure 7: Probability of Determinacy for Scenario B

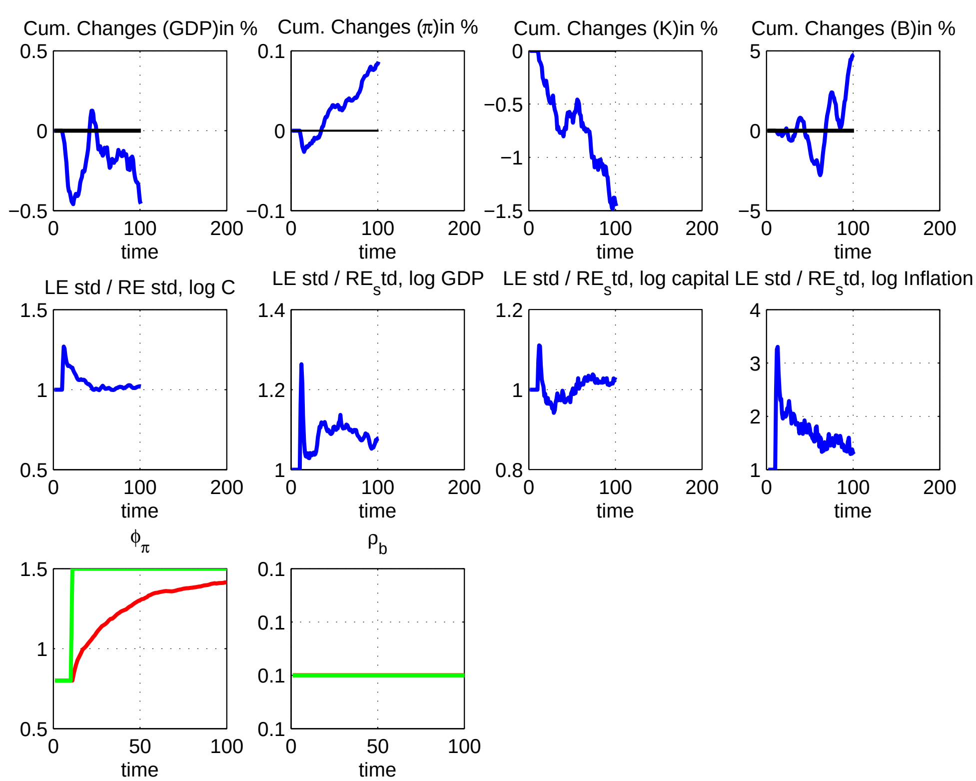

Figure 8: Summary of outcomes under Scenario B

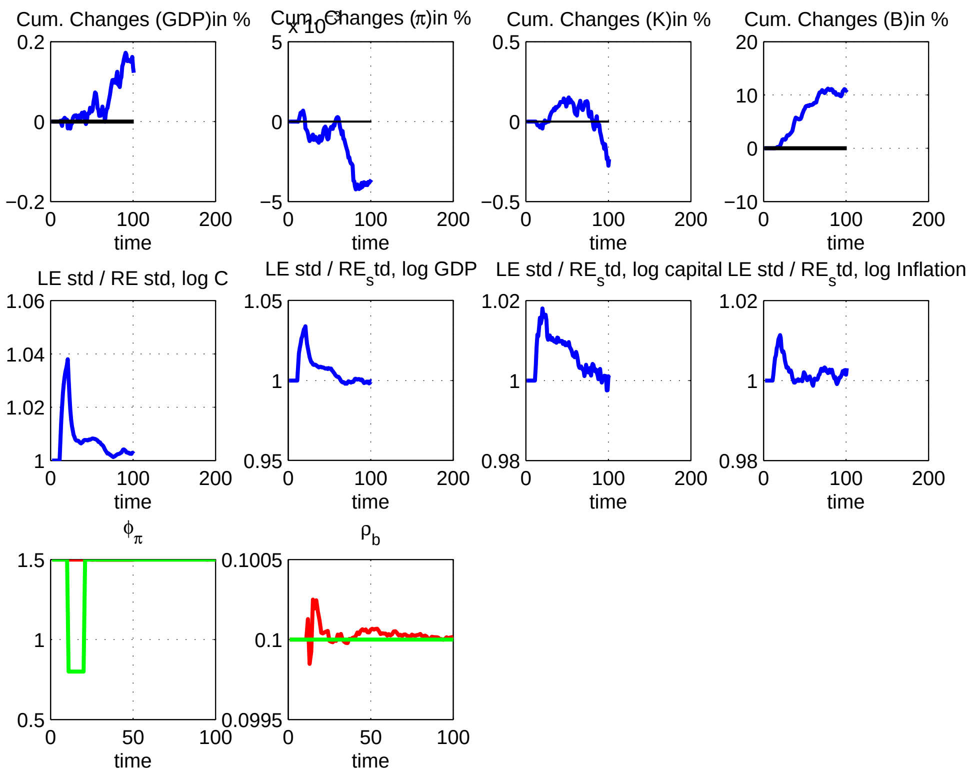

Figure 9: Summary of outcomes under Discretion (Learning) vs. Commitment (RE)