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Two-sided learning and short-run dynamics in a New Keynesian model of the economy[☆]

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HIGHLIGHTS

- We study asymmetric information and two-sided learning in a New Keynesian model.
- Agents use econometric models to form beliefs about the unknown equilibrium dynamics.
- In simulations, two-sided learning alters the short run dynamics of the model.
- The impact is larger when policymakers' beliefs are still adjusting towards the SCE.

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ABSTRACT

We investigate the role of asymmetric information and learning in a New Keynesian framework in which private agents and the central bank have imperfect knowledge of the economy. We assume that agents employ the data that they observe to form beliefs about the relationships that they do not know, use their beliefs to decide on actions, and revise these beliefs through a statistical learning algorithm as new information becomes available. Using simulations, we show that asymmetric information and learning can significantly change the dynamics of the variables of the model.

1. Introduction

This note studies asymmetric information and two-sided learning in a New Keynesian framework in which private agents do not know the monetary policy rule and do not observe monetary policy shocks, while the central bank has imperfect knowledge about the behavior of private agents. We assume that agents use all the information that they have available to estimate the structural equations of the model that they do not know, and use a statistical learning algorithm to update their beliefs as new data become available. In each period, these beliefs will be the basis for policy decisions (on the side of the central bank) and for production and pricing decisions (on the side of private agents).

The literature on monetary policy in environments characterized by imperfect knowledge and learning is extensive.[1] Two-sided learning was first studied in the seminal work of Marcet and Sargent (1989), upon which most of the ensuing research (including this paper) is built. We employ a framework that departs from the previous literature in this area in two directions. First, we assume that agents are only forming beliefs on the equilibrium relationships that they do not know rather than estimating reduced-form regressions on *all* equilibrium variables (as, for instance, in Dennis and Ravenna, 2008). Second, we assume that both sides of the economy are implementing optimal choices. As a consequence, our analysis does not focus on the ability of the central bank to enforce a particular policy rule or to achieve convergence to a

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1 For a review, see Evans and Honkapohja (2009).

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rational expectations equilibrium (as, for instance, in Evans and Honkapohja, 2003). Instead, the goal of this note is to study the short-run dynamics that the interactions of beliefs and actions can generate.

To what extent can asymmetric information and learning affect the time-series properties of the variables of interest? We address this question by examining the results of simulations performed using a New Keynesian model with parameters calibrated to standard values. Our results indicate that asymmetric information and two-sided learning can significantly alter the dynamics of the model compared to the situation in which the economy is operating at a rational expectations equilibrium (REE).

2. The model

The true model of the economy is a standard New Keynesian framework; the specification is similar to Dennis and Ravenna (2008). The private sector is described by the equations:

$$y_t = E_t^{PA}(y_{t+1}) - \frac{1}{\sigma}\left(i_t - E_t^{PA}(\pi_{t+1}) - r_t^n\right) \quad (1)$$

$$\pi_t = \frac{1}{(1+\beta)}\pi_{t-1} + \frac{\beta}{(1+\beta)}E_t^{PA}(\pi_{t+1}) - \frac{\kappa}{(1+\beta)}y_t + w_t \quad (2)$$

$$r_t^n = \bar{r} + u_t \quad (3)$$

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u \quad (4)$$

$$w_t = \rho_w w_{t-1} + \varepsilon_t^w \quad (5)$$

where y_t is the output gap, π_t the inflation rate, i_t the nominal interest rate, r_t^n the natural rate of interest (which is the sum of its steady state value $\bar{r}$ and a shock u_t), and w_t can be interpreted as a shock to the marginal cost of production. Both u_t and w_t evolve according to an $AR(1)$ process, as described by (4) and (5), with $\varepsilon_t^u \sim i.i.d.(0, \sigma_u^2)$ and $\varepsilon_t^w \sim i.i.d.(0, \sigma_w^2)$. The operator $E_t^{PA}(\cdot)$ in (1) and (2) denotes the fact that private agents form expectations based on their own information set.

The economy is also populated by a central bank, which controls i_t through the policy instrument x_t according to:

$$i_t = x_t + v_t \quad (6)$$

where v_t is a monetary policy shocks, which follows the $AR(1)$ process:

$$v_t = \rho_v v_{t-1} + \varepsilon_t^v. \quad (7)$$

Agents do not have full knowledge of the economy: the central bank does not observe the shocks u_t and w_t, and does not know how private agents form expectations and decide about prices and output, while private agents do not know the policy rule that the central bank uses to set x_t and do not observe the monetary policy shock v_t. We assume that each agent uses the available data to estimate the relationships that they do not know, and employs the perceived model of the economy to make their respective decisions. These steps are updated in each period as new information is observed over time.

All agents use the same vector z_t^R to estimate the unknown structural relationships of the model[2] :

$$z_t^R = \begin{bmatrix} y_t & \pi_t & i_t & 1 \end{bmatrix}'. \quad (8)$$

Private agents estimate the unknown monetary policy rule as:

$$i_t = z_{t-1}^{R\prime}\psi_t + \omega_t^{PA}. \quad (9)$$

Similarly, the monetary authorities estimate the unknown private side of the economy as:

$$y_t = z_{t-1}^{R\prime}c_{yt} + \omega_{yt}^{CB} \quad (10)$$

$$\pi_t = z_{t-1}^{R\prime}c_{\pi t} + \omega_{\pi t}^{CB}. \quad (11)$$

We assume that agents use a standard recursive least squares algorithm (see Evans and Honkapohja, 2001) to update ψ_t, c_{yt} and $c_{\pi t}$. The linear relationships in (9), (10) and (11), can be written in a general form as:

$$q_t = z_{t-1}^{R\prime}\phi_t + \eta_t$$

where q_t is either i_t, y_t, or π_t, ϕ_t is the vector of parameters, and η_t the residual. Using this notation, the learning algorithm is written as:

$$R_t = R_{t-1} + g_t\left(z_{t-1}^R z_{t-1}^{R\prime} - R_{t-1}\right)$$

$$\phi_t = \phi_{t-1} + g_t R_t^{-1} z_{t-1}^R\left(q_t - z_{t-1}^{R\prime}\phi_{t-1}\right). \quad (12)$$

Our simulations focus on Recursive Least Squares (RLS) learning, in which $g_t = \frac{1}{t_0 + t}$.

In our framework, the error ω_t^{PA} affects private agents' expectations and perceived law of motion (PLM), and we assume that private agents estimate its variance as[3] :

$$\widehat{\sigma}_{\omega t}^2 = \widehat{\sigma}_{\omega t-1}^2 + g_t\left[(i_t - \psi_t z_{t-1}^R)^2 - \widehat{\sigma}_{\omega t-1}^2\right]. \quad (13)$$

We augment our learning algorithm with a projection facility. More specifically, we allow private agents to disregard estimates of (9) for which the solution of the expectational difference equation implied by (1) and (2) does not exist, and policymakers to rule out estimates of (10) and (11) for which the central bank's perceived law of motion for y_t, i_t, and π_t is not stable.[4] In practice, this projection facility is never invoked in our simulations.

Policymakers and private agents base their decisions on their respective PLMs. All agents are assumed to behave as anticipated utility decision makers (Kreps, 1998), so they treat parameter estimates as true values, and disregard parameter uncertainty and the effects of learning.

The PLM for private agents is obtained from (1)–(5) and (9). We assume the same timing as Cogley et al. (2011): private agents first estimate the parameters of (9) using data up to time $t-1$, then observe current period shocks (except for the monetary policy shock) and the value of the policy instrument, and finally use all this information to solve the expectational difference equation implied by the equilibrium conditions and the estimated policy rule. We use Sims'(2001) Gensys program to find this solution, and we do not rule out the possibility of indeterminate equilibria.

The central bank, on the other hand, decides the value of the policy instrument x_t by minimizing the quadratic loss function:

$$E_{t-1}^{CB}\sum_{j=0}^{\infty}\beta^j[(\pi_{t+j})^2 + \lambda_y(y_{t+j})^2 + \lambda_i(i_{t+j} - i_{t+j-1})^2] \quad (14)$$

given (10) and (11), and the estimated values of c_{yt} and $c_{\pi t}$. The operator E_{t-1}^{CB} indicates that expectations are formed with respect

[2] The results do not change if we allow private agents to use u_t and w_t, and the central bank to use v_t, when estimating the unknown relationships of the model. The learning algorithm typically ends up attaching a coefficients of zero to the variables that are only observed by one side and not the other.

[3] An online Appendix explains why the estimated variance of the policy shocks enters the PLM (and thus the actual law of motion, ALM) in our case.

[4] If the projection facility is active, we assume that agents will use their estimates from the previous periods as beliefs.