Discussion on ”Deep Reinforcement Learning in a Monetary Model”

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Disclaimer

- This discussion reflects my own views and not those of the ECB or the Eurosystem

Expectations in macroeconomic models

- Expectations formation is a long-standing issue in economics...
  - ... but unfortunately it is still unresolved - we do not know how people form their expectations and how exactly they might impact their economic decisions
- Solving macroeconomic models requires knowing the expectations formation process...
  - ... at the most, as economists, we can postulate some "laws of motion" for it, and hope for the best - we should be able to solve the model, and there should be an economic interpretation to it
- Consider a (linearised) DSGE model,

$$Ax_t = C + Bx_{t-1} + D\mathbf{E}_t x_{t+1} + F\varepsilon_t$$

How can we compute the reduced form solution to the model? What do we do with the expectations term?

Expectations in macroeconomic models - II

Rational expectations

Under rational expectations, agents know the model, there is perfect information and they understand the different stochastic processes

$$x_t = J + Qx_{t-1} + G\varepsilon_t$$
$$\mathbf{E}_t x_{t+1} = J + Qx_t$$

Adaptive learning

Under adaptive learning, agents form expectation according to some law of of motion, that might converge to the RE case. For example,

$$\mathbf{E}_t x_{t+1} = \mathbf{E}_{t-1} x_t + \phi_t(x_{t-1} - \mathbf{E}_{t-1} x_t)$$

And it is also possible then to find a reduced form solution to the model

Others

Other approaches include those from X. Gabaix, or C. Hommes, which also introduce deviations from rational expectations

Expectations in macroeconomic models - III

- Key point - under those assumptions we can generally find a reduced form solution to the model. Construction of IRFS, policy counterfactuals, and estimation is more or less understood
- In this paper, there is *no explicit law of motion for expectations*, and agents *do not know the model environment* and they have to *learn their optimality conditions* - solution is found assuming that agents use Deep Reinforcement Learning (DRL)

Technical comments

- Paper centers as DRL being an alternative way of forming expectations - but I see it more about a new methodology to solve DSGE models globally
  - We would learn a lot if the methodology was applied to a more standard model (without steady state multiplicity), and compare, for example, IRFS with the RE and AL case
  - In Fernández-Villaverde et al. (2020), they use Deep Learning to solve DSGE models - continuous time, agents still know the probabilities in the model, but breaks the ”curse of dimensionality”. What is the comparison here?

Technical comments - II

- In this framework, agents are ignorant about the model environment (production, market clearing, fiscal and monetary policy...) and also need to learn their own first order conditions (FOC). *What are the implications?*
  - It would be more natural to think that in a representative agent framework, the agent knows its own decisions and constraints
  - There are FOC deviations in the transition to steady state and the agent does not internalise either the market clearing condition nor their own constraints - this seems to mean that the model is not "satisfied", and that by trial and error we converge to the steady state... but is it really a "solution" to the model?
  - ... so how can we compute for example IRFS? Policy counterfactuals? Should we compute it after there is convergence in the policy function and the Bellman equation?
- Why can we learn the steady states that cannot be learned with AL? Expectations formation is critical for the determinacy set
- Can we know ex-post how expectations are formed (more backward or forward looking)? - Policy implications

Food for thought / Policy implications

- Policy makers rely on clear policy communication, and on guidance about the future (forward guidance, announcements of future asset purchases, AIT). Would agents learn these policies in this framework? Are they still somewhat forward looking even if they do not know the state transition functions?
- What is the impact of fiscal policy in this framework? The RA in the model does not fully anticipate (I guess) future taxes, and is also ignorant about the government budget constraint - does fiscal policy become more expansive? Would transfers have a strong effect?
- Optimal policy in standard rational expectations models, in the presence of the ZLB, calls for some type of PLT. This is not so clear under adaptive learning schemes. It would be really interesting to understand the implications of the framework in this paper - especially given the outcomes of the strategy review of the ECB and the Fed

Final summary

- Novel methodology to solve (possibly non-linear) DSGE models without making assumptions about how expectations are formed, and on the information set of the agents using Deep Reinforcement Learning
- With Deep Reinforcement Learning it is possible to learn all possible steady states in a model with different combinations of fiscal and monetary policy (active/passive) - thanks to the global nature of the algorithm
  - Under adaptive learning, only the determinate regimes are learnable
- The proposed methodology allows measuring bounded rationality, and solving the stochastic steady state of DSGE models

My view

This is a great paper! Novel and interesting combination of deep learning with economic models. Very original and promising avenue to solve DSGE models!