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Adaptive learning and monetary exchange

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ABSTRACT

This paper investigates three classic questions in monetary theory: How can an intrinsically worthless asset, such as fiat money, maintain value as a medium of exchange? What are the short-run and long-run effects of a change in the money supply? What is the social cost of inflation? I answer these questions using a microfounded model of monetary exchange that replaces the rational expectations assumption with an adaptive learning rule. First, I show that monetary exchange is a robust arrangement in the sense that agents are able to learn the stationary monetary equilibrium while the non-monetary equilibrium is unstable under learning. Second, an unanticipated monetary injection has real effects in the short-run because learning the value of money takes time. In the long run, agents successfully learn the value of money, hence money is neutral. Third, under a constant money growth policy, an increase in the growth rate of money increases output in the short-run producing a short-run Phillips curve. A ten percent increase in the money growth rate has a social cost of 0.41 percent of output per year. Alternatively, a ten percent decrease in the money growth rate has a social benefit of 0.37 percent of output per year.

1. Motivation

This paper investigates three classic questions in monetary theory. How can an intrinsically worthless asset, such as fiat money, maintain value as a medium of exchange? What are the short-run and long-run effects of a change in the money supply? What is the social cost of inflation? To answer these questions I use a microfounded model of monetary exchange that replaces the rational expectations assumption with an adaptive learning rule. Random matching models of monetary exchange are well suited to address these questions because the role of money and benefits of monetary exchange are explicit. In particular, the Lagos and Wright (2005) model has become the prominent paradigm in this class of monetary search models due to the tractability and sharp policy predictions. When agents use a simple adaptive learning rule to learn about the value of money in the Lagos and Wright (2005) framework, monetary exchange is a robust arrangement in the sense that the monetary steady state is locally stable and agents never learn the non-monetary steady state. The learning process takes time, however, so a change in the money supply has real effects in the short-run, but is neutral in the long-run because agents eventually learn the lower steady state value of money. The social cost of a money growth policy is lower than previous estimates (e.g. Lucas, 2000 and Lagos and Wright, 2005) because of the short-run benefits associated with the learning dynamics.

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The tenuousness of monetary equilibria, originally discussed by Wallace (1980), is the idea that in a model with fiat money there always exists an equilibrium where fiat money is not valued and that a monetary equilibrium can always break down due to self-fulfilling beliefs. In the Lagos and Wright (2005) model there are two steady states (a monetary and non-monetary steady state) and a continuum of perfect foresight paths that converge to the non-monetary steady state.[1] The monetary steady state in this benchmark model is tenuous in the sense that a small perturbation from the monetary steady-state sends the economy on a path towards the non-monetary steady-state. However, when agents form expectations about the value of money using a simple adaptive learning rule, the monetary steady-state is locally stable and agents never learn the non-monetary steady state. Therefore monetary exchange is a robust arrangement because the monetary steady state is stable when agents use an adaptive learning rule and the non-monetary steady state is not stable.

Another central idea in monetary economics, probably the most central, involves the non-neutrality of money. As Lucas (1996) writes, "this tension between two incompatible ideas—that changes in money are neutral units changes and that they induce movements in employment and production in the same direction—has been at the center of monetary theory at least since Hume wrote." In the absence of price rigidities the Lagos and Wright (2005) model predicts that a one time change in the money supply has no real effects. A monetary injection leads to a proportional decrease in the value of money, hence real balances are unchanged. However, when agents gradually learn about the value of money over time, an unanticipated monetary injection has real effects in the short-run while satisfying long-run neutrality. This occurs because price expectations do not fully adjust following the monetary injection and agents hold more expected real balances. Eventually agents learn the lower steady-state value of money, hence the monetary injection is neutral in the long-run. In an environment of constant money growth where agents learn the inflation rate, an increase in the money growth rate increases output in the short-run. The short-run Phillips curve appears because the money supply initially grows faster than agents' inflation expectations leading to an increase in expected real balances held by agents. While the learning process occurs, the increase in expected real balances increases output until inflation expectations catch up to the money growth rate. The short-run Phillips curve relationship is derived even though prices are fully flexible and agents have all past price information.[2] Alternatively, an unexpected decrease in the money growth rate (disinflation) causes output to decrease in the short-run. Therefore a disinflation is costly in the short-run as agents learn the lower inflation rate.

Because there are short-run benefits to a money growth policy, previous estimates of the welfare cost of inflation may be overstated and, alternatively, the costs of disinflation understated. Following a 10 percent increase in the money growth rate, buyers hold more expected real balances because inflation expectations are initially lower than the money growth rate. Using standard parameter estimates from a calibration of the model in Craig and Rocheteau (2008), the social cost of 10 percent money growth can range from a social *benefit* of 0.17 percent of output per year to a social *cost* of 1.51 percent of output per year depending on how quickly agents learn.[3] Alternatively, a ten percent decrease in the money growth rate can have a social *cost* of 0.52 percent of output to a social *benefit* of 1.69 percent of output per year. The estimates for the social cost of money growth are smaller than the previous steady-state estimates of Lucas (2000); Lagos and Wright (2005) and Craig and Rocheteau (2008) because of the learning dynamics.

Adaptive learning is an alternative to rational expectations and assumes that agents in the model behave like good econometricians when making their forecasts. That is, agents in the model do not know the "true" model but instead use time-series data to try and estimate the model. As more data become available, the estimates are revised.

Though agents are not fully rational while the learning process occurs, it is possible for agents to eventually learn the rational expectations equilibrium (REE). This has been the focus of much research (e.g. Bray, 1982; Bray and Savin, 1986; Marcet and Sargent, 1989; Woodford, 1990; Guesnerie, 1993; Evans and Honkapohja, 2001, 2009).[4] If agents are able to learn the REE, the REE is said to be learnable or stable under an adaptive learning rule. In models with multiple equilibria, learnability of a single REE gives justification for studying that REE.[5] For example, the baseline OLG model of Samuelson (1958) has a continuum of equilibria that converge to a non-monetary steady state. Lucas (1986) shows that when agents form expectations about the price level using past averages, the monetary REE is stable. Lim et al. (1994) and Marimon and Sunder (1993) test this prediction in an experimental environment and find that agents' forecasts appear to be adaptive and that agents coordinate on the stationary equilibrium where money has value. Duffy and Puzzello (2011) also provide experimental evidence that monetary exchange is a robust social norm in the Lagos and Wright (2005) environment. These theoretical stability results coupled with empirical evidence give justification for studying the equilibrium agents coordinate on when using an adaptive learning rule.

[1] Note that stability of the monetary steady-state depends on the parameter values. See Nosal and Rocheteau (2011) for a discussion of the perfect foresight dynamics.

[2] There is a large literature that focuses on the non-neutrality of money, however this result is typically generated by assuming rigid prices (Clarida et al., 2002) or sticky information (Mankiw and Gregory, 2002). The Lucas (1972) misperceptions theory generates a short-run Phillips curve in an OLG model because agents are confused whether a shock is a demand shock or change in the money supply. Duffy (1994) shows that a monetary injection has real effects in an OLG model where agents use an adaptive learning rule.

[3] Note that the social welfare cost of 1.51 is the perfect foresight estimate from Craig and Rocheteau (2008).

[4] Evans and Honkapohja (1999) provide a survey of macroeconomic models that use adaptive learning.

[5] Lucas (1986) argues "More recently, theorists such as Margaret Bray have begun to develop a stability theory that seems to correspond much more closely to the adaptive behavior documented by Smith (1962) and other experimentalists. The models studied by Smith and Bray have unique equilibria. Their results, experimental and theoretical, have the effect of making us feel more comfortable with the predictions of certain theoretical models…"