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ANIMAL SPIRITS IN A MONETARY MODEL

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We would like to thank Gauti Eggertsson for his discussion of our work at the Conference in Honor of Michael Woodford's Contibutions to Economics, held at the Federal Reserve Bank of New York on May 19th and 20th of 2016. We also thank the participants at the conference and participants at the UCLA macro and international finance workshops. We have both benefited from conversations with Giovanni Nicoló. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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ABSTRACT

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Animal Spirits in a Monetary Economy

By Roger E.A. Farmer and Konstantin Platonov*

We provide a new theory of the money transmission mechanism. Our model displays steady-state and dynamic indeterminacy. Steady-state indeterminacy helps explain persistent unemployment, which we represent as movements among the steady state equilibria of our model. Dynamic indeterminacy helps explain the real effects of nominal shocks. We resolve indeterminacy by introducing the belief function as a new fundamental. We develop a graphical apparatus, the IS-LM-NAC framework, that explains how monetary policy affects the economy both in the short-run and in the long-run. If beliefs are adaptive, shocks to the money supply may have permanent long-run effects on the unemployment rate.

In the lead-up to the 2008 financial crisis, a consensus developed among academic macroeconomists that the problem of macroeconomic stability had been solved. According to that consensus, the New-Keynesian dynamic stochastic general equilibrium (DSGE) model provides a good first approximation to the way that monetary policy influences output, inflation and unemployment. In its simplest form, the NK model has three equations; a dynamic IS curve, a policy equation that describes how the central bank sets the interest rate, and a New-Keynesian Phillips curve. In its more elaborate form, the New-Keynesian DSGE model is reflected in work that builds on the medium scale DSGE model of Frank Smets and Raf Wouters (2007).

The NK model evolved from post-war economic theory in which the Keynesian economics of the *General Theory*, (Keynes, 1936), was grafted onto the microeconomics of Walrasian general equilibrium theory (Walras, 1899). Paul Samuelson, in the third edition of his undergraduate textbook, (Samuelson, 1955), referred to this hybrid theory as the 'neo-classical synthesis'. According to the neo-classical synthesis, the economy is Keynesian in the short-run, when not all wages and prices have adjusted to clear markets; it is classical in the long-run, when all wages and prices have adjusted to clear markets and the demands and supplies for all goods and for labor are equal.[1].

The neo-classical synthesis is still the main framework taught in economics text-

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[1]This characterization of the history of thought is drawn from Farmer (2010a) and elaborated on in Farmer (2016a).

books, and, in the form of 'dynamic IS-LM analysis', it is used by policy makers to frame the way they think about the influence of changes in fiscal and monetary policy on economic activity.[2] This paper proposes an alternative framework. Building on work by Roger Farmer (2010b) we integrate Keynesian economics with general equilibrium theory in a new way. Our work displays two main differences from the New Keynesian model.

First, the steady state equilibria of our model display dynamic indeterminacy. For every steady state equilibrium, there are multiple dynamic paths, all of which converge to the same steady state. We use that property to explain how changes in the money supply may be associated with immediate changes in real economic activity without invoking artificial barriers to price change.[3]

Second, our model displays steady state indeterminacy. We adopt a labor search model in which the presence of externalties generates multiple steady state equilibria. Unlike classical search models we do not close the model by assuming that firms and workers bargain over the wage.[4] Instead, as in Farmer (2010b; 2012a), firms and workers take wages and prices as given and employment is determined by aggregate demand. We use that feature to explain why unemployment is highly persistent in the data. Persistent unemployment, in our model, represents potentially permanent deviations of the market equilibrium from the social optimum.[5]

To close our model, we assume that equilibrium is selected by 'animal spirits' and we model that idea by introducing a *belief function* as in Farmer (1993, 2002, 2012b). We treat the belief function as a fundamental with the same methodological status as preferences and endowments and we study the implications of that assumption for the ability of monetary policy to influence inflation, output and unemployment.

I. The Model

We construct a two-period overlapping generations model. In every period there are two generations of representative households; the young and the old. The young inelastically supply one unit of labor, but, due to search frictions, a fraction of young individuals remain unemployed in any given period. We assume that there is perfect insurance within the household and that labor income is split between current consumption, interest bearing assets, and money balances.

[2]See, for example, Mankiw (2015).

[3]For earlier papers that invoke that idea see Farmer and Woodford (1984, 1997), Farmer (1991, 1993, 2002, 2000), Matheny (1998), and Benhabib and Farmer (2000). We prefer to avoid the assumption of menu costs or other forms of price rigidity because our reading of the evidence as surveyed by Klenow and Malin (2010), is that prices at the micro level are not sticky enough to explain the properties of monetary shocks in aggregate data.

[4]By classical search models, we mean the literature that builds on work by Peter Diamond, (1982), Dale Mortensen, (1970), and Chris Pissarides (1976).

[5]Olivier Blanchard and Lawrence Summers (1986; 1987) attribute persistent unemployment to models that display hysteresis. Our model has that feature, but for different reasons than the explanation given by Blanchard and Summers. For a recent survey that explains the evolution of models of dynamic and steady state indeterminacy, see Farmer (2016b).

Households hold money, physical capital and financial assets in the form of government bonds. Money is dominated in rate-of-return and is held for transaction purposes. We model this by assuming that real money balances yield utility as in Patinkin (1956). The old generation receives interest on capital and bonds and they sell assets to the young generation. We close the markets for physical capital and labor by assuming that there is one unit of non-reproducible capital and that the labor-force participation rate is constant and equal to one. We also assume that government bonds are in zero net supply.

There is a single good produced by a continuum of competitive firms. Firms rent capital from old generation individuals and hire young generation individuals. Hiring labor is subject to search frictions. Firms take prices and wages as given and they allocate a fraction of labor to recruiting. We assume that every worker allocated to recruiting can hire q new workers, where q is taken as given by firms but determined in equilibrium by the search technology. Every worker allocated to recruiting is one less worker allocated to production.

Search in the labor market generates multiple equilibria. To select equilibrium, we assume that economic agents form beliefs about the real value of their financial wealth using a belief function that is a primitive of our model. Our approach differs from the more usual assumption in the labor search literature where the equilibrium is pinned down by Nash bargaining over the real wage.

Our model provides a microfoundation for the textbook Keynesian cross, in which the equilibrium level of output is determined by aggregate demand. Our labor market structure explains why firms are willing to produce any quantity of goods demanded, and our assumption that beliefs are fundamental determines aggregate demand. In our model, beliefs select an equilibrium and in that equilibrium, the unemployment rate may differ permanently from the social planning optimum.

II. Aggregate Supply

There is a continuum of competitive firms and we represent the labor and capital employed and output produced by each individual firm with the symbols L_t, K_t, and Y_t.[6] To refer to aggregate labor and aggregate output we use the symbols $\bar{L}_t$ and $\bar{Y}_t$. The variables L_t, K_t, and Y_t are indexed by $j \in [0, 1]$ where

$$\bar{L}_t = \int_j L_t(j)dj, \quad \bar{K}_t = \int_j K_t(j)dj, \quad \text{and} \quad \bar{Y}_t = \int_j Y_t(j)dj.$$

Since we assume that all firms make the same decisions it will always be true that $L_t(j) = L_t$, $K_t(j) = K_t$ and $Y_t(j) = Y_t$, hence, we will dispense with the subscript j in the remainder of our exposition.

We assume that all workers are fired and rehired every period.[7] A firm puts for-

[6]The model developed in this section is drawn from Farmer (2012a).

[7]This convenient short-cut means that we are allowing workers to hire themselves and it allows us

ward a production plan in which it proposes to allocate X_t workers to production and V_t workers to recruiting where

$$L_t = X_t + V_t.$$

Output is given by the expression

$$Y_t = K_t^{\alpha} X_t^{1-\alpha},$$

and the total number of workers employed at the firm is equal to

$$L_t = q_t V_t, \tag{1}$$

where the firm takes q_t as given. Puting these pieces together, we may express the output of the firm as

$$Y_t = K_t^{\alpha} \left[\left(1 - \frac{1}{q_t} \right) L_t \right]^{1-\alpha}. \tag{2}$$

The profit maximizing firm sets

$$(1-\alpha) \frac{Y_t}{L_t} = \frac{W_t}{P_t} \quad \text{and} \quad \alpha \frac{Y_t}{K_t} = \frac{R_t}{P_t},$$

where P_t is the money price of goods, W_t is the money wage and R_t is the money rental rate of capital.

Notice that Equation (2) looks like a classical production function with one exception. The variable, q_t, which represents labor market tightness, influences total factor productivity. One may show that q_t is greater than 1 in equilibrium. A low value of q_t corresponds to a tight labor market in which firms must devote a large amount of resources to recruiting and in which productivity is low. A high value of q_t corresponds to a loose labor market in which firms may devote a small amount of resources to recruiting and in which productivity is high.

At the aggregate level, we assume the existence of a matching technology that determines aggregate employment $\bar{L}_t$ as a function of aggregate resources devoted to recruiting, $\bar{V}_t$, and the aggregate number of unemployed searching workers, $\bar{U}_t$. This function is given by,

$$\bar{L}_t = m\left(\bar{V}_t, \bar{U}_t\right) \equiv \left(\Gamma \bar{V}_t\right)^{1/2}, \tag{3}$$

where $\bar{U}_t$ does not appear in the aggregate matching function because the assumption that workers are fired and rehired every period implies that the number of

to abstract from the dynamics of labor market adjustment. Farmer (2013) relaxes this assumption and studies a model in which labor adjusts slowly over time.

searching workers is equal to 1 in every period. The parameter Γ determines the efficiency of the matching technology. In a symmetric equilibrium where $L_t = \bar{L}_t$, we may combine Equations (1), (2) and (3) to find an expression for Y_t in terms of L_t and $\bar{L}_t$

$$Y_t = K_t^{\alpha} \left[L_t \left(1 - \frac{\bar{L}_t}{\Gamma} \right) \right]^{1-\alpha}, \tag{4}$$

where $\bar{L}_t / \Gamma = 1/q_t$.

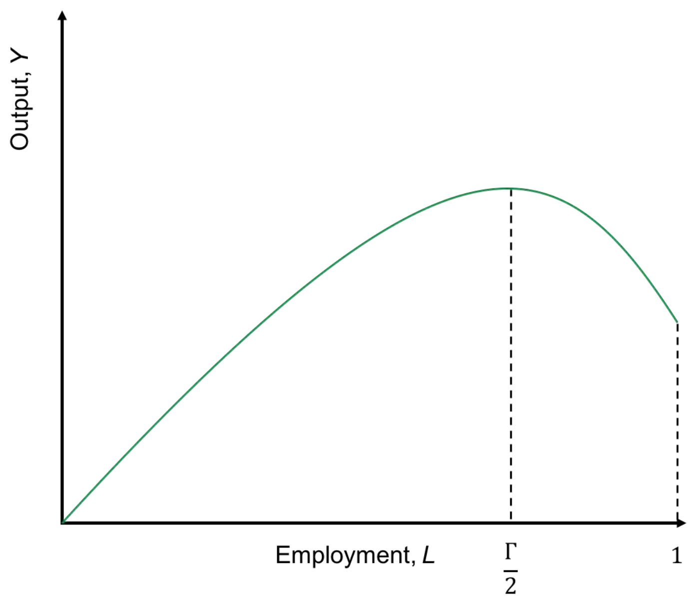

Figure 1. The Social Production Function

Equation (4) is the private production function. This function represents the connection between the output of an individual firm, Y_t, the inputs of labor and capital at the level of the firm, (L_t, K_t), and the labor input of all other firms, $\bar{L}_t$. The private production function is distinct from the social production function, Equation (5),

$$\bar{Y}_t = \bar{K}_t^{\alpha} \left[\bar{L}_t \left(1 - \frac{\bar{L}_t}{\Gamma} \right) \right]^{1-\alpha}, \tag{5}$$

which represents the connection between aggregate output $\bar{Y}_t$ and aggregate input of labor and capital $\left(\bar{L}_t, \bar{K}_t\right)$. We illustrate the properties of the social production function in Figure 1. This figure illustrates that output is increasing in employment up to a maximum that occurs at $\Gamma/2$.

The social production function exhibits search externalities. For large values of aggregate employment, $\bar{L}_t$, the labor market becomes tighter and further reduction of unemployment is costly. As firms allocate more workers to the recruiting activity, those workers are withdrawn from production. If employment increases beyond $\Gamma/2$, additional increases in aggregate employment become counter productive.[8] The value of unemployment at the social optimum,

$$U = 1 - \frac{\Gamma}{2}, \tag{6}$$

is our definition of the *natural rate of unemployment.*[9]

III. Aggregate Demand

There is a continuum of households. Each household lives for two periods and derives utility from consumption when young C_t^y, consumption when old C_{t+1}^o, and real money balances purchased in the first period of their life M_{t+1}/P_t. Labor does not deliver disutility, and therefore the participation rate is always equal to 1.

Preferences are given by a logarithmic utility function and we assume that households maximize expected utility,

$$u_t = \log\left(C_t^y\right) + \beta \mathbb{E}_t\left[\log\left(C_{t+1}^o\right)\right] + \delta \log\left(\frac{M_{t+1}}{P_t}\right). \tag{7}$$

In the first period of their life, households earn labor income $W_t L_t$. They use their income to purchase current consumption $P_t C_t^y$, capital goods $P_{K,t} K_{t+1}$ and government bonds B_{t+1}. All prices are in terms of money.

In the second period of life, households rent capital to firms and earn the rental payment $R_{t+1} K_{t+1}$, and interest accrued on their loan to the government $(1 + i_t) B_{t+1}$. In addition, at the end of the period they sell capital and money to the new young generation. Their first and second period budget constraints are given by the following equations:

$$P_t C_t^y + M_{t+1} + B_{t+1} + P_{K,t} K_{t+1} = W_t L_t, \tag{8}$$

$$P_{t+1} C_{t+1}^o = \left(R_{t+1} + P_{K,t+1}\right) K_{t+1} + (1 + i_t) B_{t+1} + M_{t+1}. \tag{9}$$

The no-arbitrage condition implies that the return to government bonds must be equal to the return on physical capital, when evaluated in terms of utility from

[8]In the special case when $\Gamma = 1$, output is maximized when $\bar{L} = 1/2$ and, when $\bar{L} = 1$, aggregate output falls to zero.

[9]Friedman (1968) defined the natural rate of unemployment to be the *equilibrium* rate. That definition only makes sense when equilibrium is unique. In our model, there is a continuum of steady state equilibria. In this framework it makes more sense to define the natural rate of unemployment to be the social planning optimum.

consumption in the second period,

$$\mathbb{E}_t\left[\frac{\beta}{P_{t+1}C^o_{t+1}}\right](1+i_t)=\mathbb{E}_t\left[\frac{\beta}{P_{t+1}C^o_{t+1}}\cdot\frac{P_{K,t+1}+R_{t+1}}{P_{K,t}}\right]. \tag{10}$$

In words, this equation states that the young are indifferent between investing in bonds and capital. Using this condition, and defining real savings as

$$S_t=(B_{t+1}+P_{K,t}K_{t+1})/P_t, \tag{11}$$

we can write the real savings function and the demand for real money balances that solve the utility maximization problem:

$$S_t=\frac{1}{1+\beta+\delta}\left(\beta-\frac{\delta}{i_t}\right)\frac{W_tL_t}{P_t}, \tag{12}$$

$$\frac{M_{t+1}}{P_t}=\frac{\delta}{1+\beta+\delta}\frac{1+i_t}{i_t}\frac{W_tL_t}{P_t}. \tag{13}$$

The savings function is increasing in the money interest rate because money and consumption are substitutes in utility and the money interest rate represents the opportunity cost of holding money. The real interest rate does not enter the equation because of the simplifying assumptions that utility is logarithmic and that labor supply occurs only in youth.[10]

To simplify the exposition of our model we have assumed that government bonds are in zero net supply and we concentrate, in this paper, on the role of monetary policy. In subsequent work we plan to study the role of fiscal interventions.

IV. The Role of Beliefs

Although our work is superficially similar to the IS-LM model and its modern New Keynesian variants; there are significant differences. By grounding the aggregate supply function in the theory of search and, more importantly, by dropping the Nash bargaining assumption, we arrive at a theory where preferences, technology and endowments are not sufficient to uniquely select an equilibrium. Following Farmer (2012a) we close our model by making beliefs fundamental. Farmer studies that assumption in the context of a purely real representative agent model. In the current paper we explore the implications of multiple steady state equilibria in a model where money is used as a means of exchange and

[10] Relaxing the unitary elasticity of intertemporal substitution by considering a utility function of the form $U(C^y,C^o,M/P)=\log(C^y)+\beta\log\left(C^o+\bar{C}\right)+\delta\log(M/P)$ would add the real interest rate as an argument of the savings function. When $\bar{C}>0$, the intertemporal substitution effect dominates the income effect, making the savings function increasing in both money interest rate as the price of money and the real interest rate as the relative price of consumption when old. In this model, we adopt $\bar{C}=0$ for expository purposes.

where the representative agent assumption is replaced by a model of overlapping generations.

The assumption that beliefs are fundamental is not sufficient to explain *how* they are fundamental and the belief function could take different forms. In our view, beliefs are most likely learned and we see the work of George Evans and Seppo Honkapohja (Evans and Honkapohja, 2001) as a promising avenue in describing how a particular belief function may arise. In this respect beliefs are similar to preferences.[11]

Economists assume that a human being is described by a preference ordering and that by the time a person achieves adulthood he or she is able to make choices over any given commodity bundle. But those choices are learned during childhood; they are not inherited. At the age of twenty one, an Italian is likely to choose a glass of wine with a meal; a German is more likely to choose a beer. But a German child, adopted into an Italian family at birth, will grow up with the preferences of his adoptive parents, not with those of his biological parents. Beliefs, in our view, are similar.

During a period of stable economic activity, people learn to make forecasts about future variables by projecting observations of variables of interest on their information from the recent past. When there is a change in the environment, caused by a policy shift or a large shock to fundamentals, they continue to use the beliefs that they learned from the past. That argument suggests that we should treat the parameters of the belief function in the same way that we treat the parameters of the utility function. They are objects that we would expect to remain stable over the medium term and that should be estimated using econometric methods.

In this paper we investigate one plausible assumption about the belief function and we study its role as a way of closing our model. We assume that beliefs are determined by the equation

$$\mathbb{E}_t^*\left[\frac{P_{K,t+1}}{P_{t+1}}\right] = \Theta_t, \tag{14}$$

where the expectations operator in Equation (14) is subjective and reflects the beliefs of a representative person of the probabilities of future events. To impose discipline on our analysis we assume that expectations are rational; that is,

$$\mathbb{E}_t^*\left[\frac{P_{K,t+1}}{P_{t+1}}\right] = \mathbb{E}_t\left[\frac{P_{K,t+1}}{P_{t+1}}\right] = \Theta_t, \tag{15}$$

where the expectation $\mathbb{E}$ is taken with respect to the true probabilities in a rational expectations equilibrium.

[11]The discussion in this section closely follows the presentation in Farmer (2016a).

V. The Equations of the Model

The following equations summarize the dynamic competitive equilibrium of our model.

$$\frac{1-\alpha}{1+\beta+\delta}\left(\beta-\frac{\delta}{i_t}\right)Y_t=\frac{P_{K,t}}{P_t}, \tag{16}$$

$$\frac{M_t^*}{P_t}=\frac{(1-\alpha)\delta}{1+\beta+\delta}\cdot\frac{1+i_t}{i_t}Y_t, \tag{17}$$

$$\mathbb{E}_t\left[\frac{\beta}{P_{t+1}C_{t+1}^o}\right](1+i_t)=\mathbb{E}_t\left[\frac{\beta}{P_{t+1}C_{t+1}^o}\cdot\frac{P_{K,t+1}+R_{t+1}}{P_{K,t}}\right]. \tag{18}$$

Equation (16) equates the demand for interest bearing assets by the young to the real value of the single unit of capital. This is our analog of the IS curve. Equation (17) is the money market clearing condition and it is our equivalent of the LM curve. Here M_t^* is the stock of money determined by the central bank and available for the young generation for purchase. Equation (18) is the no-arbitrage relation between the money interest rate and return to capital. This equation represents the assumption that physical capital and government bonds pay the same rate of return and it has no analog in the simplest version of the IS-LM model.

Our model has two additional equations

$$Y_t=\left[\left(1-\frac{L_t}{\Gamma}\right)L_t\right]^{1-\alpha}. \tag{19}$$

Equation (19) is the social production function. This equation serves only to determine employment and it plays the role of the 45 degree line in the Keynesian Cross model.[12]

Finally, Equation (20)

$$\mathbb{E}_t\left[\frac{P_{K,t+1}}{P_{t+1}}\right]=\Theta_t, \tag{20}$$

is the belief function. This equation distinguishes our model from the New Keynesian approach and it replaces the New Keynesian Phillips curve.

The belief function closes our model. Without it, the other four equations do not uniquely determine the five endogenous variables $\{Y_t, P_t, i_t, P_{K,t}, L_t\}$. Beliefs about the future real value of capital, Θ_t, select one equilibrium out of many and they represent the assumption that confidence is an independent driver of business cycles.

Equations (16), (17), (18), and (20) determine aggregate demand. Given beliefs

[12] We have imposed the equilibrium conditions that $L_t=\bar{L}_t$ and $\bar{K}_t=1$.

$\{\Theta_t\}$ and monetary policy $\{M_t^*\}$, these equations select an equilibrium sequence for $\{Y_t, i_t, P_t, P_{K,t}\}$ and Equation (19) determines how much labor firms need to hire to satisfy the demand for goods. Since employment is determined recursively, in the subsequent parts of the paper we dispense with Equation (19) in our discussion of equilibrium.

VI. The IS-LM-NAC Representation of the Steady-State

In this section, we show that the steady-state equilibrium of our model admits a representation that is similar to the IS-LM representation of the *General Theory* developed by Hicks and Hansen.

The IS-LM model is a static construct in which the price level is predetermined. To provide a fully dynamic model, Samuelson closed the IS-LM model by adding a price adjustment equation that later New-Keynesian economists replaced with the New-Keynesian Phillips curve.

We take a different approach. We select an equilibrium by closing the labor market with a belief function. In our model, the IS curve, the LM curve and the NAC curve, intersect to determine the price level, GDP and the interest rate in a steady state equilibrium. Unlike the neo-classsical synthesis, in our model high Pareto inefficient unemployment can persist forever in the presence of pessimistic beliefs. And unlike the interpretation of animal spirits that was popularized by George Akerlof and Robert Shiller (2009), in our model pessimistic animal spirits are fully rational. The people in our model are rational and have rational expectations but they are, sometimes, unable to coordinate on a socially efficient equilibrium.

The following equations characterize the steady-state equilibrium of our model:

$$\text{IS:} \quad \frac{1-\alpha}{1+\beta+\delta}\left(\beta - \frac{\delta}{i}\right) Y = \Theta, \tag{21}$$

$$\text{LM:} \quad \frac{M}{P} = \frac{(1-\alpha)\delta}{1+\beta+\delta} \cdot \frac{1+i}{i} Y, \tag{22}$$

$$\text{NAC:} \quad i = \frac{\alpha Y}{\Theta}. \tag{23}$$

Equations (21) – (23) determine the three unknowns: Y, i and P, for given values of M and Θ. We treat $\Theta = \mathbb{E}[P_K/P]$ as a new exogenous variable that reflects investor confidence about the real value of their financial assets and by making Θ exogenous we provide a new interpretation of Keynes' idea that equilibrium is selected by 'animal spirits'.

In (Y, i) space, the IS and NAC curves determine Y and i and the price level adjusts to ensure that the LM curve intersects the IS and NAC curves at the steady state. We illustrate the determination of a steady state equilibrium in Figure 2.

The IS curve, Equation (21), is downward sloping and its position is determined

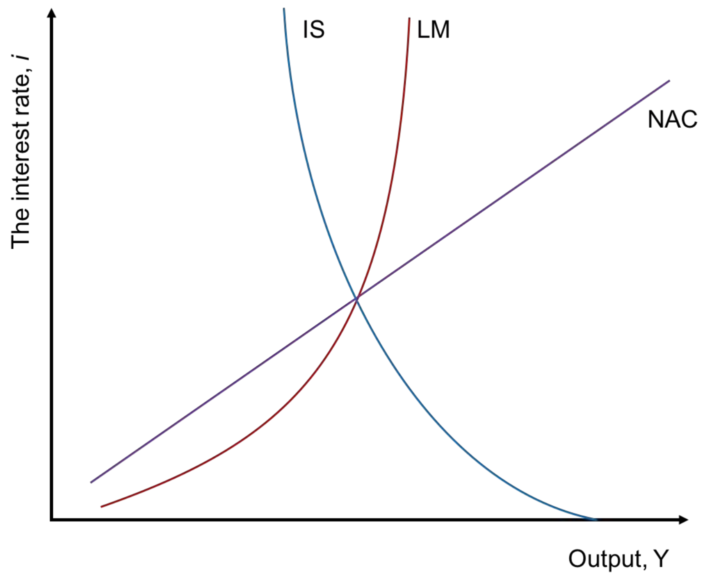

FIGURE 2. THE IS-LM-NAC REPRESENTATION OF THE STEADY STATE

by animal spirits, Θ where,

$$\Theta = \mathbb{E}_t \left[\frac{P_{K,t+1}}{P_{t+1}} \right]. \tag{24}$$

In a steady state equilibrium, beliefs about future wealth are self-fulfilling. When people feel wealthy, they *are* wealthy. Increased confidence shifts the IS curve to the right and it shifts the NAC curve down and to the right. The economy arrives eventually at a new steady state equilibrium with higher output, but the path by which the economy arrives at this steady state depends on how people form expectations about future prices. We analyze the movement between equilibria in Section VII.

VII. Two Comparative Statics Exercises

In this section we consider how two comparative static exercises affect the equilibrium values of Y, i and P. The first is a change in self-fulfilling beliefs about wealth and the second is an increase in the money stock. In the first of these exercises we assume that Θ increases from a low value to a higher value at some date, $t = 1$, and that it remains constant thereafter. In the second exercise, we hold Θ fixed forever. In section IX we will consider an alternative model of expectation formation in which the belief about the future value of capital is equal to its current realized value.

Consider first, the experiment of an increase in the belief about the value of financial wealth. A greater value of Θ influences output through two channels. Firstly, since consumers believe, correctly, that they are wealthier, real consumption of goods and services increases. The IS curve shifts to the right. Moreover, higher asset prices reduce the interest rate and the NAC curve becomes flatter. These effects are illustrated in Figure 3. As people become more confident, the IS curves shifts to the right beginning at the solid IS curve and ending at the dashed IS curve. At the same time, the NAC curve shifts down and to the right, from the solid NAC to the dashed NAC curve.

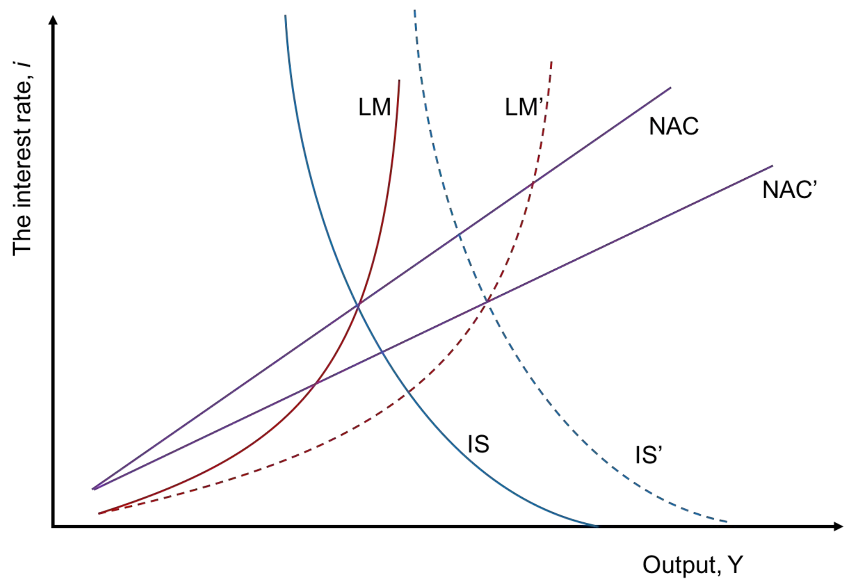

Figure 3. An Increase in Confidence

Because output increases, the demand for real money balances increases, and the price level must be lower in the new steady state equilibrium. This is reflected on Figure 3 by a rightward shift in the LM curve. Because the class of Cobb-Douglas utility functions implies a unitary elasticity of intertemporal substitution, the intertemporal substitution effect and the income effect cancel each other out, and the new equilibrium the interest rate remains unchanged.

Consider next, the effect of an increase in the stock of money. Figure 4 illustates the steady state implications of our model for this experiment. Equations (21) and (23) determine the equilibrium values of output and interest rate independently of the stock of money. Once Y and i and therefore the demand for real money balances have been determined, the price level P adjusts to set the supply of real money equal to the demand for real money balances. It follows that changes in the supply of money will cause proportional changes in the price level and the nominal value of the stock market, leaving output and the interest rate unchanged.

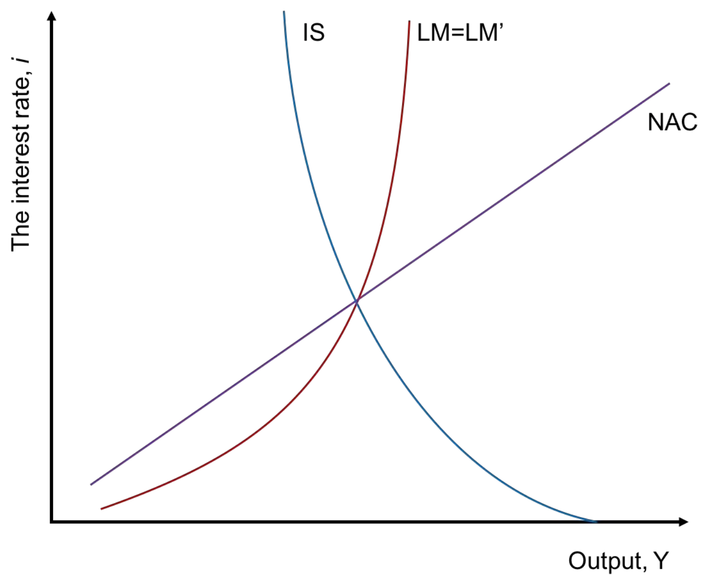

FIGURE 4. AN INCREASE IN THE MONEY SUPPLY

Figure 4 illustrates the neutrality of money graphically. The LM curve after the increase in the money supply is identical with the LM curve before the change, illustrating the concept that money, in our model, is neutral. However, as we will show in Section IX, this result depends on the form of the belief function. If beliefs about the future value of capital depend on the current realized value of capital, an increase in the money supply may have a permanent real effect on output through its effect on business and consumer confidence.

VIII. Dynamic Equilibria

In this section we shift from a comparison of steady states to a description of complete dynamic equilibria. To study the equilibria of the complete model, we use the algorithm, GENSYS, developed by Christopher Sims (2001). First, we choose a constant sequence $\{M, \Theta\}$ to describe policy and we log-linearize the dynamic equations around a steady state. Let

$$x_t \equiv \left[y_t, \tilde{i}_t, p_t, p_{K,t}, \mathbb{E}_t\left[y_{t+1}\right], \mathbb{E}_t\left[p_{t+1}\right], \mathbb{E}_t\left[p_{K,t+1}\right]\right]' \tag{25}$$

be log deviations of the variables from their steady state values and define three new variables,

$$\eta_t^1 \equiv p_t - \mathbb{E}_{t-1}[p_t], \tag{26}$$

$$\eta_t^2 \equiv p_{K,t} - \mathbb{E}_{t-1}[p_{K,t}], \tag{27}$$

$$\eta_t^3 \equiv y_t - \mathbb{E}_{t-1}[y_t]. \tag{28}$$

These new variables represent endogenous forecast errors. Next, we log-linearize equations (16) – (18) and Equation (20) and we append them to equations (26) – (28). That leads to the following linear system of seven equations in seven unknowns,

$$\Gamma_0 x_t = \Gamma_1 x_{t-1} + \Psi \varepsilon_t + \Pi \eta_t, \tag{29}$$

where ε_t is a vector of shocks to the fundamentals. These might include, for example, shocks to $\{M_t\}$ and shocks to $\{\Theta_t\}$. The matrix Ψ is derived from the linearized equations and it explains how shocks to M and shocks to Θ influence each of the equations of the model.

Once we have provided a model of beliefs, the steady state of our system is determinate. For every specification of the belief function, Equation (20), there is a unique steady state. In this sense, our animal spirits model is similar to any dynamic stochastic general equilibrium model. For a given specification of fundamentals, there is a unique predicted outcome.

But the fact that the model, augmented by a belief function, has a unique steady state, is not enough to uniquely determine a dynamic equilibrium. To establish uniqueness of a dynamic equilibrium, we must show that, for every representation of fundamentals, where fundamentals now include beliefs, there is a unique dynamic path converging to the steady state. The uniqueness, or non-uniqueness, of dynamic equilibria is determined by the properties of the matrices Γ_0 and Γ_1, in Equation (29).

To establish the properties of a dynamic equilibrium, we must provide a calibrated version of the model since determinacy of equilibrium is, in general, a numerical question. To study determinacy, we used the calibration from Table 1.

Table 1—Calibration

Parameter	Definition	Value
α	Share of capital in output	.33
β	Subjective discount rate	.50
δ	Coefficient on real money balances in utility	.05

For this calibration, we found that our model has one degree of indeterminacy. In words, that implies that for any set of initial conditions there is a one dimensional continuum of dynamic paths, all of which converge to a given steady state. In practice, it means that the rational expectations assumption is not sufficient to uniquely determine all three of the forecast errors, η_t, as functions of the fundamental shocks, ε_t. When the model displays dynamic indeterminacy, there are many ways that people may use to forecast the future, all of which are consistent with a rational expectations equilibrium (Farmer, 1991, 1993).

Following Farmer (2000), we resolve this indeterminacy by selecting an equilibrium for which

$$\eta_t^1 \equiv p_t - \mathbb{E}_{t-1}[p_t] = 0. \tag{30}$$

In words, this assumption means that money prices are set one period in advance. It is important to note that price stickiness does not violate the property of rational expectations. The equilibrium with sticky prices is one of many possible equilibria of the economy where agents form self-fulfilling beliefs about wealth and it is an equilibrium that explains an important property of the data; that unanticipated monetary shocks have real short run effects and they feed only slowly into prices.

IX. Three Dynamic Experiments

In this section we analyze three dynamic experiments. In the first experiment, we begin from a steady state, and we ask how a permanent unanticipated increase in confidence affects the endogenous variables of the model. In the second and third experiments, we ask how a permanent unanticipated increase in the stock of money affects the economy. In our second experiment, the belief of households about the future value of capital is invariant to their observations of its current realized value. In our third experiment, households expect the future value of capital to be equal to its current value. We refer to these two cases as fixed and adaptive beliefs.

The experiment of increasing the money supply, in the case of fixed beliefs, resembles a classical model in which output is supply determined. In this experiment, money is neutral. In contrast, if households form their beliefs adaptively, a permament increase in the money supply has a permanent effect on output. Money is non-neutral because it increases the real value of capital and that increase is translated, through a confidence effect, into a permanent increase in beliefs about the value of future capital.

Is it reasonable to think that a change in a nominal variable may have real effects? We think so. Farmer (2012b) and Farmer and Nicoló (2016) have estimated a model of the US economy in which beliefs about future income growth are equal to current income growth and they have shown that a belief function of this kind outperforms standard New-Keynesian models closed by a Phillips curve. In their model, the central bank sets the money interest rate and changes in the interest rate have a permanent effect on the unemployment rate by shifting the economy from one equilibrium to another. Our third experiment exhibits the same transmission mechanism in a model where the central bank sets the money stock, rather than following an interest rate rule.

A. *Experiment 1: A Shock to Confidence*

Figure 5 displays the dynamic paths of eight variables in response to a one time increase in beliefs about the future value of capital. We call this a shock to confidence.

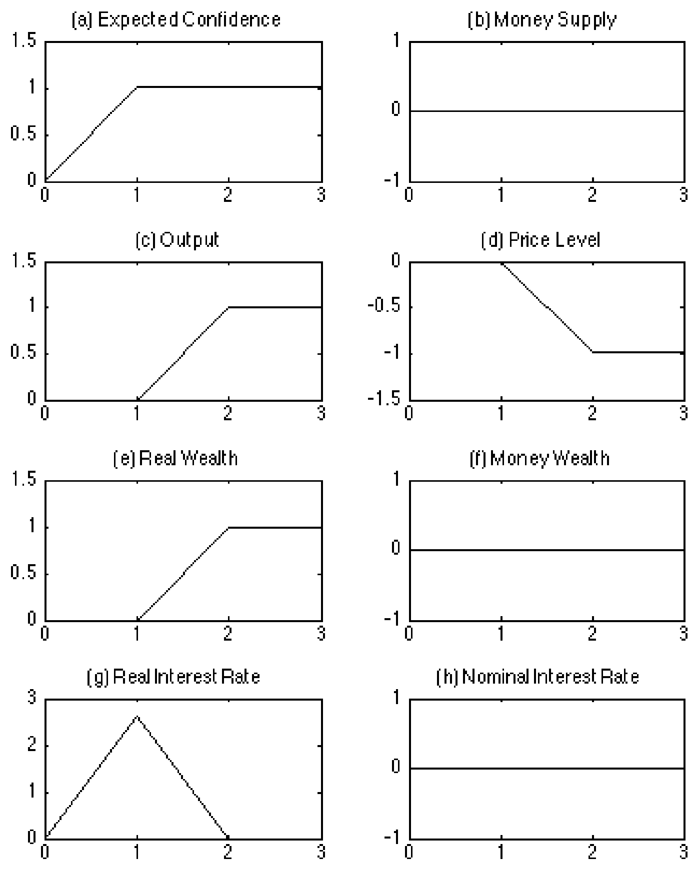

Figure 5. A Permanent Shock to Confidence

Panel (a) depicts the value of beliefs about the value of future capital, $\mathbb{E}_t\left[\frac{P_{K,t+1}}{P_t}\right]$. This is the variable we refer to as Θ. In our first experiment, Θ increases by one percent and it remains one percent higher for ever after. Panel (b) shows the value of the money supply, which we hold fixed for this experiment.

Panel (c) shows that, in period 2, output increases and remains permanently higher by one percent. This occurs beause rational forward-looking consumers increase their spending on goods and services and firms respond by hiring additional workers to produce these goods. Panel (d) shows that the price level falls and stays permanently lower. Greater output increases the demand for real money balances and the price level must fall to equate the demand and supply of money.

Panel (e) shows that, in period 2, the realized value of real wealth increases by one percent. That follows from the rational expectations assumption; people expected the value of capital to increase and, in a rational expectations equilibrium, that belief is supported by the way that people form their beliefs in period 2 and in all subsequent periods. From panel (g), we see that the real interest rate jumps up in period 1 and reverts to its steady-state value thereafter. Because the price level and the money interest rate do not adjust in the first period, the real interest rate adjustment is achieved by a self-fulfilling adjustment to the expected future price level.

We want to draw attention to several features of these impulse responses. First, although adjustment to a confidence shock is delayed, the delay lasts for only one period. That follows from the stylized nature of a model in which there are no endogenous propagation mechanisms. Second, prices do not respond at all in the first period. Unlike the New-Keynesian model, prices are not sticky because of adjustment costs or restrictions on choice. They are fixed because people rationally anticipate that output, not prices, will respond to unanticipated shocks.

If models in this class are to be taken seriously as descriptions of data, they must be tied down by an assumption about how beliefs are formed. To give the model empirical content, one must assume that the belief function remains time invariant at least over the medium term. If that assumption holds, the parameters of the belief function can be estimated in the same way that econometricians estimate preference parameters.[13] We propose to tie down our model by assuming that the covariance of prices with contemporaneous variables should be treated as a separate parameter of the belief function and that this parameter should be estimated using standard econometric methods.

B. *Experiment 2: A Shock to the Money Supply with Fixed Beliefs*

In subsections IX.B and IX.C we show that the way economic agents form beliefs about the future, matter for the long-term effect of monetary shocks. In subsection IX.B, we consider the case of fixed beliefs, which we model with Equation (31),

$$\mathbb{E}_t \left[\frac{P_{K,t+1}}{P_{t+1}} \right] = \Theta. \tag{31}$$

[13]See Farmer (2012b) and Farmer and Nicoló (2016) for examples of empirical exercises that estimate a version of this model on U.S. data.

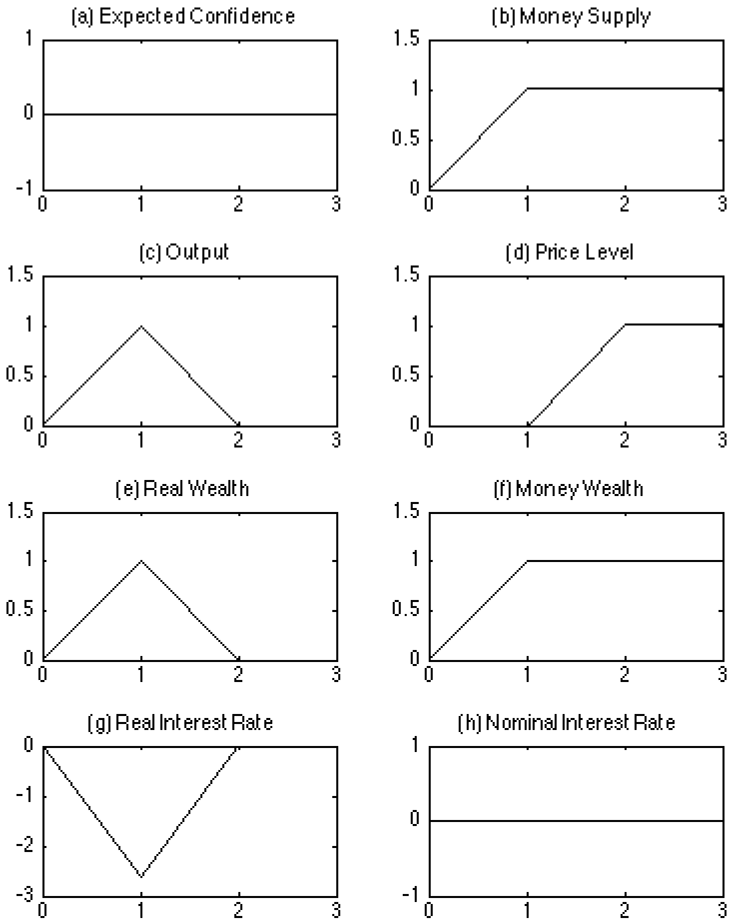

Figure 6. A Permanent Shock to the Supply of Money under Fixed Beliefs

Figure 6 displays the dynamic paths for the variables of this economy in response to a shock to the money supply when we keep beliefs fixed. This shock is reflected in Panel (b) which depicts the exogenous variable M. We assume that M increases by one percent and that it remains one percent higher forever after. Panel (a) shows that beliefs are kept fixed in this experiment.

Panel (c) shows that output increases temporarily in the first period by one percent. This happens because prices are predetermined and are unable to adjust until period 2. Instead, the increase in the money supply causes an increase in aggregate demand that is met by a corresponding temporary increase in output and employment. Firms hire more workers to satisfy the increased aggregate demand.

Panel (d) shows that prices respond in period 2 and remain 1 percent higher. This increase neutralizes the increase in the money supply and is consistent with the return to steady state of output reflected in panel (c). Panels (e) and (f) show that the realized value of capital goes up by one percent. As prices increase in period 2, the real value of capital goes back to its original steady-state level, whereas the money value remains permanently higher. From panel (g) we see that the real interest rate falls in period 1 and panel (h) shows that the money interest rate remains constant during the entire exercise.

C. *Experiment 3: A Shock to the Money Supply with Adaptive Beliefs*

To model adaptive beliefs, we replace Equation (31), with Equation (32),

$$\mathbb{E}_t\left[\frac{P_{K,t+1}}{P_{t+1}}\right] = \frac{P_{K,t}}{P_t}. \tag{32}$$

In this case, households expect the future value of capital to be equal to its current value. This is a special case of a more general model in which beliefs are formed by the following adaptive expectations equation,

$$\mathbb{E}_t\left[\frac{P_{K,t+1}}{P_{t+1}}\right] = \lambda\left(\frac{P_{K,t}}{P_t}\right) + (1-\lambda)\mathbb{E}_{t-1}\left[\frac{P_{K,t}}{P_t}\right], \quad \lambda \in [0,1].$$

We have restricted ourselves to the special case of $\lambda = 1$ because Farmer (2012b) estimated a model that allows λ to lie in the interval $[0,1]$ and found that empirically, the data favors a model where $\lambda = 1$.

Figure 7 displays the dynamic paths for the variables of this economy in response to a shock to the money supply when economic agents form adaptive beliefs. We assume that M increases by one percent and that it remains one percent higher for ever after. The shock to the money supply is reflected in Panel (a).

The increase in the stock of money causes an increase, in period 1, of the money price of capital; this is shown in Panel (f). Because the price of goods is predetermined, the increase in the nominal price of capital is also an increase in its real price as shown in Panel (e). Panel (b) shows that beliefs about the future value of capital respond to this monetary shock and they remain permanently one percent higher. Panel (c) shows that the increase in the value of capital triggers an increase in output that is sustained because of the effect of the increase in the money supply on beliefs, as reflected in Panel (b). Panels (d), (g) and (h) show that the price level, and the real and nominal interest rates do not respond at all to a one off permanent increase in the money supply which is reflected entirely in changes to output and the real price of capital.

X. Conclusion

We proposed a fresh way of thinking about the money transmission mechanism. By integrating Keynesian economics with general equilibrium in a new

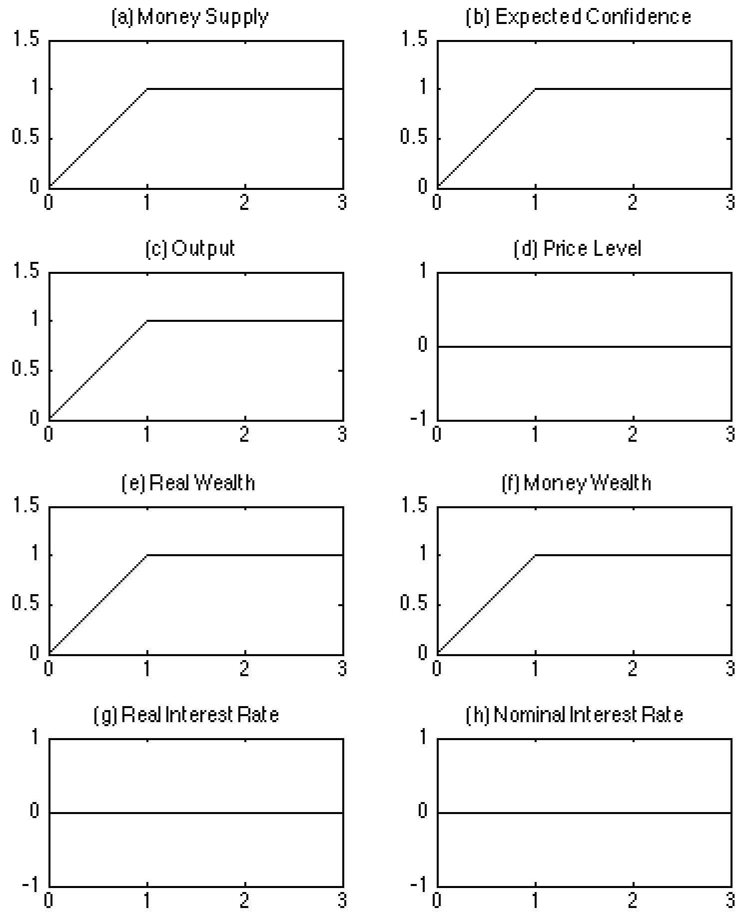

Figure 7. A Permanent Shock to the Supply of Money under Adaptive Beliefs

way, we provided an alternative model and an alternative narrative to explain how macroeconomic policy influences prices and employment.

Our approach differs from New Keynesian economics in two fundamental ways. First, our model displays dynamic indeterminacy. We focus on a dynamic path with predetermined prices to show that changes in the money supply may affect real economic activity even if all nominal prices are perfectly flexible. Second, our model displays steady state indeterminacy that arises as a consequence of search frictions in the labor market. Instead of assuming that firms and workers bargain over the wage, we allow beliefs about the future value of wealth to select a steady-state equilibrium. In our view, beliefs should be treated as a new fundamental of the model. The belief function advances our understanding of why the unemployment rate is so persistent in real world data.

Finally, we have presented a simple graphical apparatus that can be used by policy makers to understand how policy affects the economy. The steady-state equilibria of our model can be explained with our IS-LM-NAC framework in which the NAC curve connects the interest rate to current and expected future values of the stock market. This framework provides a rich new framework for policy analysis and explains the short-run and long-run effects of policy, without the assumption that prices are prevented from moving by artificial barriers to price adjustment.

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