Animal Spirits in a Monetary Economy

By Roger E.A. Farmer and Konstantin Platonov*

We integrate Keynesian economics with general equilibrium theory in a new way. Our approach differs from the prevailing New Keynesian paradigm in two ways. First, our model displays steady state indeterminacy. This feature allows us to explain persistent unemployment which we model as movements among the steady state equilibria of our model. Second, our model displays dynamic indeterminacy. This feature allows us to explain the real effects of nominal shocks by selecting a dynamic equilibrium where prices are slow to respond to unanticipated money supply disturbances. Price rigidity arises as part of a rational expectations equilibrium in which the equilibrium is selected by beliefs. To close our model, we introduce a new fundamental that we refer to as the belief function.

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 textbooks, and, in the form of 'dynamic IS-LM analysis', it is used by policy makers

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

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 (2016).

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 the old generation and hire young 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 employed and output produced by each individual firm with the symbols L and Y.[6] To refer to aggregate labor and aggregate output we use the symbols $\bar{L}$ and $\bar{Y}$. L and Y are indexed by $j \in [0, 1]$ where

$$\bar{Y} = \int_j Y(j)dj, \quad \text{and} \quad \bar{L} = \int_j L(j)dj.$$

Since we assume that all firms make the same decisions it will always be true that $L(j) = L$, 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 workers to production and V workers to recruiting where

$$L = X + V.$$

Output is given by the expression

$$Y = K^{\alpha} X^{1-\alpha},$$

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

$$L = qV, \tag{1}$$

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

$$Y = K^{\alpha} \left[\left(1 - \frac{1}{q} \right) L \right]^{1-\alpha}. \tag{2}$$

The profit maximizing firm sets

$$(1-\alpha)\frac{Y}{L} = \frac{W}{P} \quad \text{and} \quad \alpha\frac{Y}{K} = \frac{R}{P},$$

where P is the money price of goods, W is the money wage and R is the money rental rate of capital.

Notice that Equation (2) looks like a classical production function with one exception. The variable, q, which represents labor market tightness, influences total factor productivity. One may show that q is greater than 1 in equilibrium. A low value of q 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 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 $\bar{L}$ as a function of aggregate resources devoted to recruiting, $\bar{V}$, and the aggregate number of unemployed searching workers, $\bar{U}$. This function is given by,

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

where $\bar{U}$ 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 $L = \bar{L}$, we may combine Equations (1), (2) and (3) to find an expression for Y in terms of L and $\bar{L}$

$$Y = K^{\alpha}\left[L\left(1 - \frac{\bar{L}}{\Gamma}\right)\right]^{1-\alpha}, \tag{4}$$

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

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

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

which represents the connection between aggregate output $\bar{Y}$ and aggregate input of capital and labor $\{\bar{K}, \bar{L}\}$.

The social production function exhibits search externalities. For large values of aggregate employment, $\bar{L}$, 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. The social production function achieves a maximum when

$$\bar{L} = \frac{\Gamma}{2}. \tag{6}$$

If employment increases beyond $\Gamma/2$, additional increases in aggregate employment become counter productive.[8] The value of unemployment at the social optimum,

$$U = 1 - \frac{\Gamma}{2}, \tag{7}$$

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

[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 more sense to define the natural rate of unemployment to be the social planning optimum.

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 held in the first period of their life M_t/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,

$$U_t = \log(C_t^y) + \beta \mathbb{E}_t \left[\log \left(C_{t+1}^o \right) \right] + \delta \log \left(\frac{M_t}{P_t} \right). \tag{8}$$

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:

$$P_t C_t^y + M_t + B_{t+1} + P_{K,t} K_{t+1} = W_t L_t, \tag{9}$$

$$P_{t+1} C_{t+1}^o = (R_{t+1} + P_{K,t+1}) K_{t+1} + (1+i_t) B_{t+1} + M_t. \tag{10}$$

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 consumption in the second period,

$$\mathbb{E}_t \left[\frac{\beta}{P_{t+1} C_{t+1}^o} \right] (1+i_t) = \mathbb{E}_t \left[\frac{\beta}{P_{t+1} C_{t+1}^o} \cdot \frac{P_{K,t+1} + R_{t+1}}{P_{K,t}} \right]. \tag{11}$$

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

$$S_t = (B_{t+1} + P_{K,t} K_{t+1})/P_t, \tag{12}$$

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

$$S_t = \frac{1}{1+\beta+\delta} \left(\beta - \frac{\delta}{i_t} \right) \frac{W_t L_t}{P_t}, \tag{13}$$

$$\frac{M_t}{P_t} = \frac{\delta}{1+\beta+\delta} \frac{1+i_t}{i_t} \frac{W_t L_t}{P_t}. \tag{14}$$

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 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 birth mother. Beliefs,

[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.

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

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

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

where the expectations operator in Equation (15) 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,

$$\mathbb{E}_t^* \left[\frac{P_{K,t+1}}{P_{t+1}} \right] = \mathbb{E}_t \left[\frac{P_{K,t+1}}{P_{t+1}} \right] = \Theta_t, \tag{16}$$

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

V. The Equations of the Model

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

$$\frac{1-\alpha}{1+\beta+\delta} \left(\beta - \frac{\delta}{i_t} \right) Y_t = \frac{P_{K,t}}{P_t}, \tag{17}$$

$$\frac{M_t}{P_t} = \frac{(1-\alpha)\delta}{1+\beta+\delta} \frac{1+i_t}{i_t} Y_t, \tag{18}$$

$$\mathbb{E}_t \left[\frac{\beta}{P_{t+1} C_{t+1}^o} \right] (1+i_t) = \mathbb{E}_t \left[\frac{\beta}{P_{t+1} C_{t+1}^o} \cdot \frac{P_{K,t+1} + R_{t+1}}{P_{K,t}} \right]. \tag{19}$$

Equation (17) 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 (18) is the money market clearing condition and it is our equivalent of the LM curve. Equation (19) 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

$$Y_t = \left[\left(1 - \frac{L_t}{\Gamma}\right) L_t\right]^{1-\alpha}. \tag{20}$$

Equation (20) 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 (21)

$$\mathbb{E}_t\left[\frac{P_{K,t+1}}{P_{t+1}}\right] = \Theta_t, \tag{21}$$

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 the stock market Θ_t select one equilibrium out of many and they represent the assumption that confidence is an independent driver of business cycles.

Equations (17), (18), (19), and (21) determine aggregate demand. Given beliefs $\{\Theta_t\}$ and monetary policy $\{M_t\}$, these equations select an equilibrium sequence for $\{Y_t, i_t, P_t, P_{K,t}\}$ and Equation (20) determines how much labor firms need to hire to satisfy the demand for goods. Since employment is determined recursively, in the subsequent discussion we dispense with Equation (20) 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 for ever in the presence of pessimistic

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

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:

$$\text{IS:} \quad \frac{1-\alpha}{1+\beta+\delta}\left(\beta - \frac{\delta}{i}\right) Y = \Theta, \tag{22}$$

$$\text{LM:} \quad \frac{M}{P} = \frac{(1-\alpha)\delta}{1+\beta+\delta}\frac{1+i}{i}Y, \tag{23}$$

$$\text{NAC:} \quad i = \frac{\alpha Y}{\Theta}. \tag{24}$$

Equations (22) – (24) 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 1.

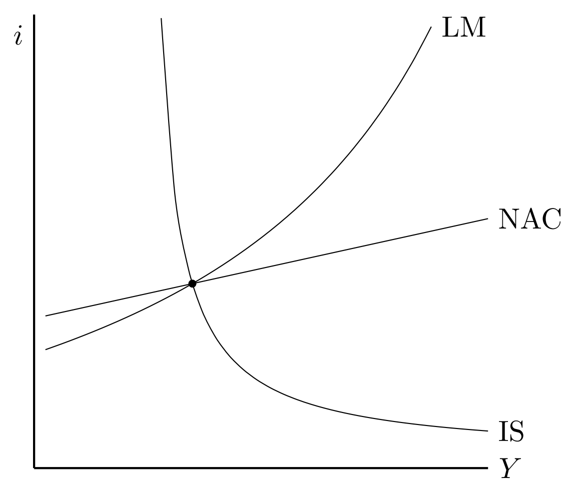

Figure 1. The IS-LM-NAC Representation of the Steady State

The IS curve, Equation (22), is downward sloping and its position is determined by animal spirits, Θ where,

$$\Theta = \mathbb{E}_t\left[\frac{P_{K,t+1}}{P_{t+1}}\right]. \tag{25}$$

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.

A greater value of Θ influences output through two channels. First, since consumers are wealthier, real consumption of goods and services increases. The IS curve shifts to the right. Moreover, higher asset prices reduce the interest rate; the NAC curve becomes flatter and shifts down. These effects are reflected in Figure 2 which shows the effect of an increase in animal spirits. 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 sold NAC to the dashed NAC curve.

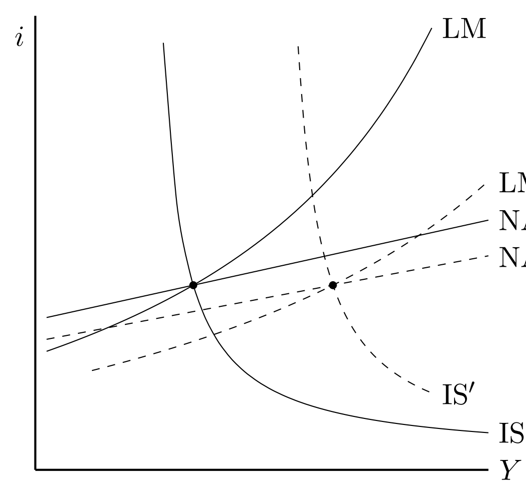

Figure 2. An Increase in Confidence

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 2 by a rightward shift in the LM curve. Because the class of Cobb-Douglas utility functions implies the unitary elasticity of intertemporal substitution and the intertemporal substitution effect and income effect cancel each other, at the new equilibrium the interest rate remains unchanged.[13]

Figure 3 illustrates the steady state implications of our model for an increase in the stock of money. Equations (22) and (24) determine the equilibrium values of output and the interest rate and these equation do not depend on the stock of money. For given values of Y and i, Equation (23) determines the demand for real money balances and the price level, P, adjusts to equate the quantity of real balances supplied equal to the quantity demanded. Changes in the supply of money cause proportional changes in the price level and in the nominal value of the stock market, leaving output and the interest rate unchanged.

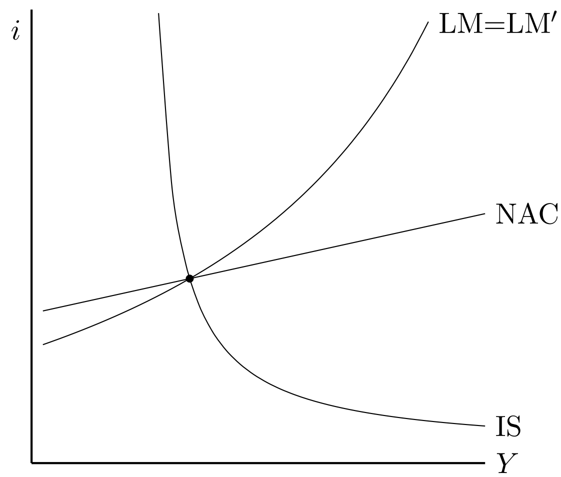

Figure 3. An Increase in the Money Supply

Figure 3 illustrates the neutrality of money graphically. The LM curve after the increase in the money supply, denoted as LM′, is identical with the LM curve before the change, denoted as LM, illustrating the concept that money, in the model, is neutral.

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

[13]The constant interest rate is a direct implication of the Cobb-Douglas utility. Allowing for the intertemporal substitution effect to be not equal to the income effect lets the interest rate vary with the level of confidence Θ.

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,

$$x_t \equiv \left[y_t, \tilde{i}_t, p_t, p_{K,t}, \mathbb{E}_t\left[y_{t+1}\right], \mathbb{E}_t\left[p_{t+1}\right], \mathbb{E}_t\left[p_{K,t+1}\right]\right]'. \tag{26}$$

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

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

$$\eta_t^2 \equiv p_{K,t} - \mathbb{E}_{t-1}[p_{K,t}], \tag{28}$$

$$\eta_t^3 \equiv y_t - \mathbb{E}_{t-1}[y_t]. \tag{29}$$

These new variables represent endogenous forecast erros. Next, we log linearize equations (17)–(19) and Equation (21) and we append them to equations (27) – (29). That leads to the following linear system of seven equations in seven unknowns,

$$\Gamma_0 x_t = \Gamma_1 x_{t-1} + \Psi \varepsilon_t + \Pi \eta_t, \tag{30}$$

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 (21), 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 (30).

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.

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

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

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, 1993, 1991).

Following Farmer (2000), we resolve that indeterminacy by assuming that prices are predetermined one period in advance by selecting an equilibrium for which

$$\eta_t^1 \equiv p_t - \mathbb{E}_{t-1}[p_t] = 0. \tag{31}$$

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. Two Dynamic Exercises

In this section we analyze two 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 experiment, we ask how a permanent unanticipated increase in the stock of money affects the economy.

A. A Shock to Confidence

Figure 4 displays the dynamic paths for the variables of this economy in response to the shock to confidence. This shock is reflected in Panel (a) which depicts the exogenous variable Θ, which represents beliefs about the expected future value of a real asset, P_K/P. In our first experiment, we assume that Θ increases by 10 percent and that it remains 10 percent higher for ever after.

Panel (b) shows that the realized value of real wealth increases by 10 percent one period later. That follows from the rational expectations assumption, plus the assumption that the period 1 shock to expected wealth is the only shock to hit the model. Panels (c) and (d) show that output and real balances also increase permanently by 10 percent, beginning in period 2.

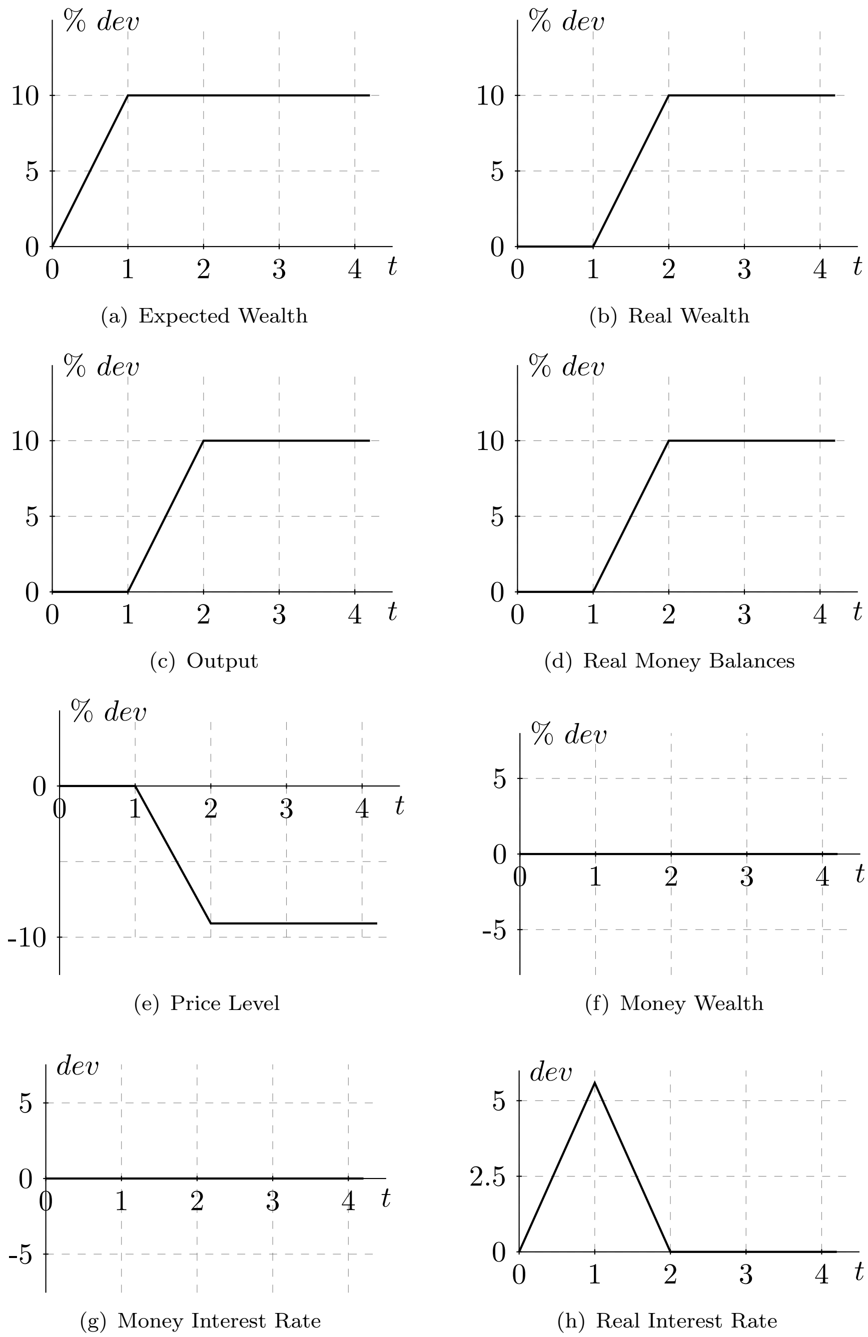

FIGURE 4. A PERMANENT SHOCK TO CONFIDENCE

Panel (e) shows that the price level falls in period 2 and stays permanently lower and, from panels (f) and (g), we see that money wealth and the money interest rate do not respond at all to the confidence shock.

Panel (h) shows that the only variable that responds in period 1, to a shock to expected wealth, is the real interest rate. Because the price level and the money interest rate do not adjust in the the first period, the real interest rate adjustment must be achieved entirely by a self-fulling adjustment in 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. That follows from our equilibrium selection: we picked an equilibrium with this property.

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. 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. A Shock to the Money Supply

Figure 5 displays the dynamic paths for the variables of this economy in response to the shock to the money supply. This shock is reflected in Panel (a) which depicts the exogenous variable M. In our second experiment, we assume that M increases by 10 percent and that it remains 10 percent higher for ever after.

Panel (b) shows that the realized value of the capital stock is unchanged in this experiment. Panels (c) and (d) show that output and real balances also increase temporarily in the first period by 10 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.

Panel (e) shows that the price increases by 10 percent in period 2 and stays permanently higher. This increase neutralizes the increase in the money supply and is consistent with the return to steady state of real balances reflected in panel (d).

From panel (g) we see that the money interest rate remains constant during the entire exercise and panel (h) shows that the real interest rate responds to the money shock in period 1. The real interest rate falls because people rationally anticipate that the price level will be permanently higher from period 2 on.

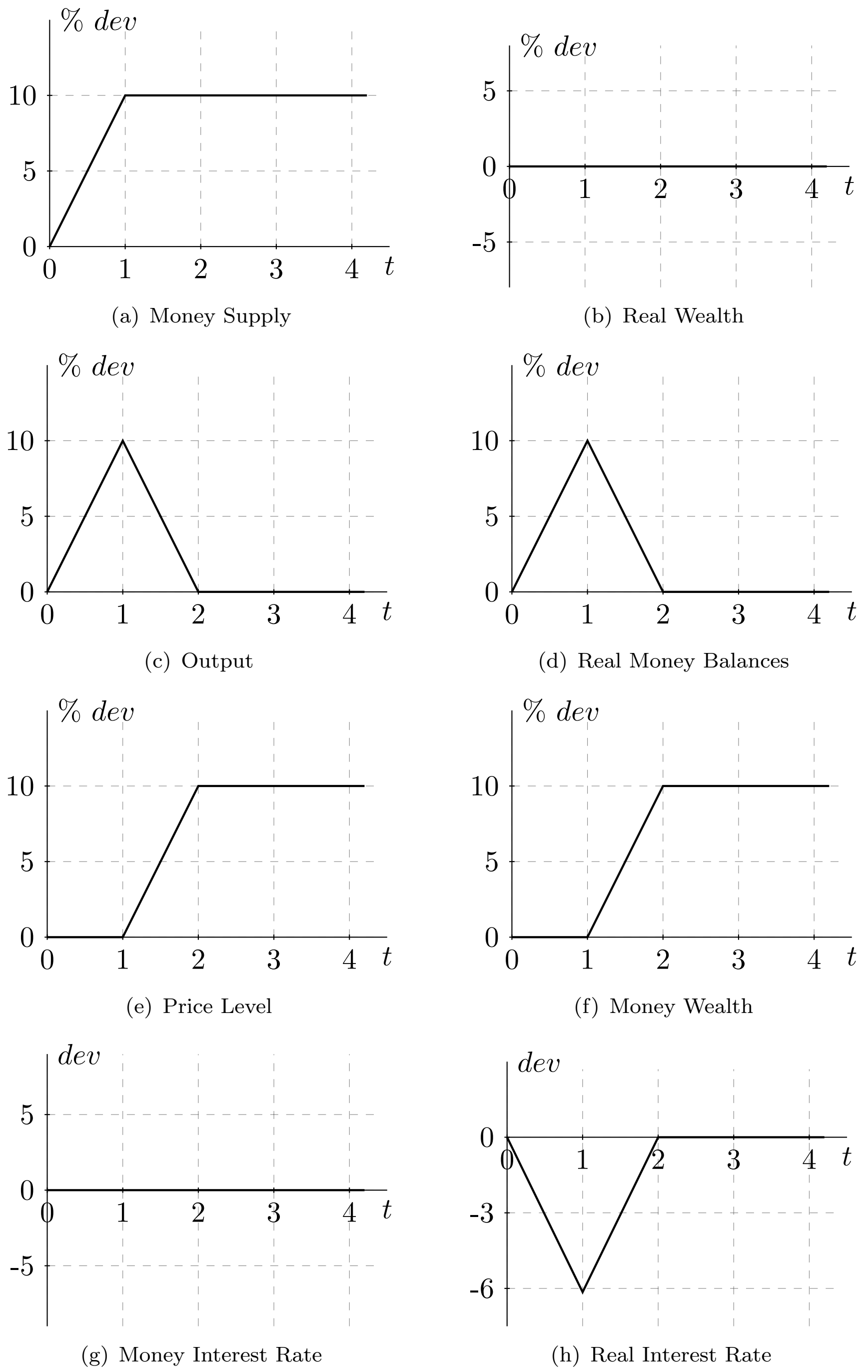

Figure 5. A Permanent Shock to the Supply of Money

X. Conclusion

We have proposed a new way of thinking about the money transmission mechanism. By integrating Keynesian economics with general equilibrium in a new way, we have provided an alternative narrative that, we hope, will help understand 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. We believe that this idea may help to understand why the unemployment rate is so persistent in real world data.

Finally, we have presented a simple graphical apparatus that may 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 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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