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The Evolution of Endogenous Business Cycles

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Running Head:
Endogenous Business Cycles

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Abstract

This paper distinguishes two kinds of Endogenous Business Cycle models; EBC1 models, which display dynamic indeterminacy, and EBC2 models, which display steady-state indeterminacy. Both strands of the literature have their origins in the sunspot literature that developed at the University of Pennsylvania in the 1980s. I argue that EBC1 models are part of the evolution of modern macroeconomics that has classical roots dating back to the 1920s. EBC2 models provide a microfoundation to one of the most important ideas to emerge from Keynes' (1936) *General Theory*; that high involuntary unemployment can persist as part of the steady-state equilibrium of a market economy.

1 Introduction

In a special issue of the *Journal of Economic Theory*, Benhabib and Farmer (1994) introduced a representative agent business cycle model in which equilibria are indeterminate. Writing in the same issue of the journal, Farmer and Guo (1994) developed a discrete time analog of the Benhabib-Farmer model and added self-fulfilling non-fundamental stochastic shocks to beliefs.

The models developed by Benhabib and Farmer and Farmer and Guo are characterized by a propagation mechanism in which the persistence of business cycles arises endogenously as opposed to the Real Business Cycle (RBC) model in which persistence is explained by an exogenous autocorrelated shock to total factor productivity (TFP). Their work signalled an important departure from the conventional RBC model by demonstrating that business cycles may not be the efficient responses of rational agents to shocks to technology; instead, they may be inefficient fluctuations in employment and GDP, caused by shocks to the self-fulfilling beliefs of households and firms. The 1994 *JET* volume spawned a literature on Endogenous Business Cycles (EBC) that reconciled the Benhabib-Farmer model with a broader range of micro and macro stylized facts.

In the Benhabib-Farmer model there is a unique steady state and a continuum of equilibrium paths that converge to it. I call the class of models that exploit dynamic indeterminacy to explain business cycles, first generation EBC models, or EBC1 models for short.¹ In a recent series of books and

papers, (Brown, 2010; Farmer, 2006, 2008a,b, 2010a,b,c, 2012a,b,c, 2013a; Kashiwagi, 2010; Plotnikov, 2013) my students and I have introduced an endogenous business cycle model in which there is not just dynamic indeterminacy, but also steady-state indeterminacy. Significantly, in Farmer (2006, 2008a, 2012b), I develop a model with a continuum of steady-state unemployment rates. I will refer to this model, and to related models that exploit steady-state indeterminacy to explain business cycles, as second generation EBC models or EBC2 models for short.²

EBC1 models were innovative, but not revolutionary. Although they reintroduced the idea that beliefs may independently influence outcomes, (a concept that was present in the macroeconomic theory of the 1920s), they did not break free from the classical assumption that the labor market is always close to an efficient steady state equilibrium.

This paper explains the evolution from EBC1 models, which display dynamic indeterminacy, to EBC2 models, which display steady-state indeterminacy. Both branches of this literature have their origins with an important idea that was developed at the University of Pennsylvania in the 1980s; *what people believe to be true can independently influence what actually happens*. By combining this revolutionary idea with recent work on labor market search, the EBC2 models developed in my recent books and papers explain how high unemployment can persist indefinitely. In so doing, they offer an explanation for the Great Depression and the Great Recession of 2008 that combines Keynesian and classical ideas in a new way.

2 The History of Macroeconomic Theory

Modern macroeconomics traces its origins to Lucas Jr. (1972), a paper about the role of money in business cycles. Lucas' work was followed by the seminal papers of Kydland and Prescott (1982) and Long and Plosser (1983), which introduced the idea that business cycles are the efficient fluctuations of a competitive economy in response to exogenous persistent technology shocks. This idea, dubbed Real Business Cycle theory, represents a return to classical ideas that characterized business cycle theory in the 1920s (Pigou, 1929).

Although the Real Business Cycle model is grounded in classical economics, it is mathematically more sophisticated. Because the math was hard, the initial RBC model was simple. In place of the rich panoply of shocks that drive business cycles in Pigou's work, the RBC model is driven by a single random shock; innovations to total factor productivity. The next twenty five years were characterized by a research agenda in which the business cycle shocks of the 1920's were brought back, one by one, into the classical model. The models developed over this period are referred to as DSGE, or dynamic stochastic general equilibrium models. EBC1 models were an important part of this DSGE agenda.

Like the RBC model, DSGE models have a general equilibrium core. They differ from it by adding nominal frictions as in Christiano, Eichenbaum, and Evans (2005), additional shocks as in Hall (1997) and Beaudry and Portier (2006) or by making small departures from the core assumptions that provide

a richer propagation mechanism as in Farmer and Guo (1994). By the onset of the Great Recession in 2007, Smets and Wouters (2007) had managed to replicate the verbal theory of Pigou using the language of dynamic stochastic general equilibrium theory. They showed that a DSGE model, loaded up with enough frictions and multiple shocks, does a credible job of replicating the dynamics of post-war U.S. business cycles.

RBC models were developed in response to the failure of Keynesian theory to explain economic events of the 1970s. It now appears that Keynesian economics was discarded prematurely as the classical models that replaced Keynesian theory are themselves unable to explain either the Great Depression or its recent reincarnation on a smaller scale, the Great Recession of 2008. The Great Depression shattered the classical view and in response to the depression, Keynes (1936) argued instead that the economy can get stuck in a state of involuntary unemployment and that any unemployment rate can be an equilibrium. In my work on EBC2 models, I capture this concept by adding a theory of labor market search to an otherwise standard general equilibrium model. In so doing, I reconcile the economics of involuntary unemployment with microeconomic theory in a new way.

3 Indeterminacy, Sunspots and Self-fulfilling Prophecies: Macro at Penn in the 1980's

EBC models of both generations are based on an idea developed at the University of Pennsylvania in the early 1980's with the work of Cass and Shell (1983), Azariadis (1981), and Farmer and Woodford (1984); that indeterminacy can be combined with self-fulfilling beliefs to create a positive model of business cycles. Indeterminacy acts as the propagation mechanism and shocks to beliefs, caused by non-fundamental uncertainty, act as the impulse.

Using the term 'sunspots' to refer to non-fundamental uncertainty, Cass and Shell (1983) were the first to show that sunspots can have real effects on consumption, even in the presence of a complete set of financial markets. Using the term, 'self-fulfilling prophecies' to refer to non-fundamental uncertainty, Azariadis (1981) was the first to show that non-fundamental shocks could be added to a dynamic stochastic general equilibrium model to drive business cycles. The models of Cass and Shell and Azariadis were two-period lived overlapping generations models with a finite number of determinate steady states.

Indeterminacy as a positive explanation of business cycles was first introduced by Farmer and Woodford (1984), (published later as Farmer and Woodford (1997)) who combined self-fulfilling prophecies with indeterminacy to generate a model in which sunspot shocks generate endogenous autocorrelated responses of GDP and employment. Up to this point, models of

indeterminacy and sunspots, or self-fulfilling prophecies, were recognized as theoretical possibilities, but because they were constructed in static models or in models where agents live for only two periods, they remained disconnected with quantitative models of the business cycle.

That changed with the 1994 JET volume in which Benhabib and Farmer (1994) demonstrated that indeterminacy occurs in models that are similar to the RBC model and Farmer and Guo (1994) provided a framework where, for the first time, sunspot theory could be taken seriously as a positive explanation of the business cycle.

4 EBC1: Multiple Dynamic Equilibria and Increasing Returns-to-Scale

The Benhabib-Farmer model alters the RBC model by adding a technology with increasing returns-to-scale. The key idea of this model is to exploit a production externality that reconciles increasing returns-to-scale with the neoclassical theory of distribution. The model has been successful because it is simple and closely related to the RBC model that by 1994, had become the industry standard.

The canonical RBC model (King, Plosser, and Rebelo, 1988) consists of five equations and three boundary conditions to explain the time paths of five variables; GDP Y_t , consumption C_t , capital K_t , labor supply L_t , and

total factor productivity S_t . These five equations are,

$$(1) \quad Y_t = S_t K_{t-1}^a L_t^{1-a},$$

$$(2) \quad K_t = K_{t-1} (1 - \delta) + Y_t - C_t,$$

$$(3) \quad \frac{1}{C_t} = E_t \left\{ \frac{1}{1 + \rho} \frac{1}{C_{t+1}} \left(1 - \delta + \frac{aY_{t+1}}{K_t} \right) \right\},$$

$$(4) \quad C_t L_t^\gamma = (1 - a) \frac{Y_t}{L_t},$$

$$(5) \quad S_t = S_{t-1}^\lambda \exp(e_t),$$

and the three boundary conditions are given by,

$$(6) \quad K_0 = \bar{K}_0,$$

$$(7) \quad S_0 = \bar{S}_0,$$

$$(8) \quad \lim_{T \rightarrow \infty} E_t \left\{ \left(\frac{1}{1 + \rho} \right)^T \frac{K_T}{C_T} \right\} = 0.$$

Equation (1) is a production function, (2) is the capital accumulation equation, (3) is the representative agent's Euler equation, (4) is the first order condition for labor and (5) describes the evolution of TFP as a geometric first order autoregressive process, hit by an iid innovation. The innovation to TFP has a distribution function $D(\cdot)$ with mean 0 and variance σ^2 ,

$$(9) \quad e_t \sim D(0, \sigma^2).$$

The boundary conditions are the initial conditions for capital, (6) and TFP, (7), and the transversality condition, (8). The model has five parameters; these are the rate of time preference ρ , the capital elasticity a , the labor supply parameter γ , the autocorrelation parameter λ and the standard deviation of the innovation to TFP, σ .

The Benhabib-Farmer model has an almost identical structure to the canonical RBC model but it differentiates between the private technology

$$(10) \quad Y_t = S_t A_t K_{t-1}^a L_t^{1-a},$$

and the social technology,

$$(11) \quad Y_t = S_t \bar{K}_{t-1}^\alpha \bar{L}_t^\beta,$$

where the two are related by the identity

$$(12) \quad A_t \equiv \bar{K}_{t-1}^{\alpha-a} \bar{L}_t^{\beta-1+a}.$$

Here, \bar{K}_{t-1} and \bar{L}_t refer to the economy-wide average use of capital and labor and A_t is a productive externality. In a symmetric equilibrium, $\bar{K} = K$ and $\bar{L} = L$ at all dates. An equilibrium of the model is a time path for the variables which satisfies the dynamic equations (1)-(5), the initial conditions (6) and (7) and the transversality condition, Equation (8).

In addition to the parameters of the RBC model, the Benhabib-Farmer

model has two new parameters, α and β . When $\beta > 1 + \gamma$, the social technology exhibits increasing returns-to-scale. In this case, Benhabib and Farmer show that the model has multiple dynamic equilibria. Each of them is represented by a different path for capital, labor, consumption and GDP and all of these paths converge back to the same steady state. Which of the equilibrium paths prevails is determined by the self-fulfilling beliefs of the agents in the model.

5 EBC2: Multiple Steady-State Equilibria as a Microfoundation for Keynesian Economics

My version of an EBC2 model (Farmer, 2006, 2008a, 2012b) alters the RBC model by adding a theory of labor market search. I assume that workers and firms act competitively and take prices and wages as given and I demonstrate that this assumption leads to a model that displays what I call *incomplete factor markets*.³ The key idea of this model is to exploit the fact that, when a worker meets a firm, there are many possible ways of splitting the surplus that arises from the meeting. My reason for developing this model is that EBC1 models provide an inadequate description of major recessions like the Great Depression or the Great Recession of 2008.

As with other DSGE models that enhanced the RBC framework, first generation EBC1 models represent employment fluctuations as small deviations from a unique full employment steady-state equilibrium. Because the

economy is never far from a Pareto Optimal steady state, the welfare costs of business cycles in these models are small.⁴ This characteristic is undesirable because it is inconsistent with the fact that recessions appear to be hugely costly to unemployed workers. The EBC2 model I have developed solves this problem by explaining high persistent unemployment as a socially inefficient equilibrium that arises as a consequence of incomplete factor markets. In this model, self-fulfilling beliefs trigger permanent movements in economic activity.

The defining feature of the Farmer EBC2 model is the assumption that households are not on their labor supply curve. In this sense, this model follows Keynes' *General Theory*.⁵ But it goes beyond the *General Theory* by providing an explicit microfoundation that explains *why* households are not on their labor supply curve. The labor supply equation is missing because there are incomplete factor markets. By this I mean that there are no prices for the two independent inputs to a technology that describes how searching workers are matched with vacant jobs; instead, workers find jobs through random search.

My work replaces the assumption that the demand and supply of labor are equal with an explicit model of unemployment based on the search and matching framework of Mortensen (1970), Pissarides (1976) and Diamond (1982a,b, 1984). Following Howitt and McAfee (1987), I drop the Nash bargaining equation that is typically added to search models of this kind, and I assume instead that firms produce as much as is demanded. Demand

is determined by forward looking households who form a sequence of self-fulfilling beliefs about the value of their wealth. Beliefs are determined by an alternative independent equation that replaces the assumption that firms and workers bargain over the wage.

The EBC2 model, like its first generation cousin, relies on the idea that DSGE models may have multiple indeterminate equilibria to explain real world phenomena. Unlike the EBC1 model, the EBC2 model displays steady-state indeterminacy. *This is a significant departure from the earlier literature.* Whereas the EBC1 model adds an additional shock, self-fulfilling beliefs, to a classical model; the EBC2 model provides a microfoundation for the Keynesian idea that there may be many equilibrium unemployment rates. This work recasts the central ideas from *The General Theory* (1936) in the language of dynamic stochastic general equilibrium theory.⁶

6 Plotnikov’s Example: An EBC2 Model with Investment

In Farmer (2006, 2010a, 2012b) I embedded a search market into an asset pricing model where capital is fixed and cannot be reproduced. This model is distinct from the RBC model and does not explicitly include a theory of investment. I chose that framework because I wanted to model the connection between the value of the stock market and the value of unemployment, a connection that is strong and structurally stable in the post-war period

(Farmer, 2012c, 2013b).

In the model with non-reproducible capital, the value of a capital asset varies with expectations of future dividends. Although this leads to a model where there is an obvious analog of stock market valuation, it cannot easily be compared with the RBC model because it does not allow for investment. In his Ph.D. thesis, Plotnikov (2013) estimates an incomplete factor markets model with reproducible capital. Since stock market wealth does not enter his model, Plotnikov assumes instead that households form beliefs about their permanent income using adaptive expectations as in Friedman's (1957) work on the consumption function. I will use Plotnikov's second generation EBC2 model in this discussion because it explicitly models investment and can therefore be more easily compared with the RBC model.

The Plotnikov model has the following characteristics. Output is produced from labor and capital by a large number of competitive firms. Firms are owned by a representative household that allocates output between consumption and investment and next period's capital stock is determined by a standard capital accumulation equation. These assumptions lead to a model that has five equations in common with the RBC model and with first generation EBC1 models. It is closed by adding an explicit theory of the determination of beliefs.

In a paper written in 2002, (Farmer, 2002), I developed an EBC1 model where adaptive expectations determine beliefs. Because, in that model, there are many dynamic equilibrium paths, there are ways of forming adaptive

expectations that are also consistent with the assumption that expectations are rational; it is the form of the adaptive expectations equation that selects an equilibrium. Plotnikov (2013) uses that same idea. In his model, because there are multiple steady-state equilibria, adaptive expectations are fully rational.

The RBC model does not contain prices. But when the solution to the model is decentralized with competitive markets, the household's labor allocation decision, Equation (4), can be split into two parts as follows,

$$(13a) \quad \omega_t = C_t L_t^\gamma,$$

$$(13b) \quad \omega_t = (1 - a) \frac{Y_t}{L_t},$$

where ω_t is the real wage. Equation (13a) reflects the assumption that the representative household equates the slope of an indifference curve between leisure and consumption to the real wage. Equation (13b) is the first order condition for the choice of labor by a competitive firm.

If we add the real wage as a variable, the RBC model explains the six variables K_t , L_t , C_t , Y_t , S_t and ω_t as functions of the innovation to TFP, with six equations; Equations (1)–(3), (5) and Equations (13a) and (13b). The EBC2 model has five equations in common with the EBC1 model; these are equations (1a–5a),

$$(1a) \quad Y_t = A_t S_t K_{t-1}^a L_t^{1-a},$$

$$(2a) \quad K_t = K_{t-1}(1 - \delta) + Y_t - C_t,$$

$$(3a) \quad \frac{1}{C_t} = E_t \left\{ \frac{1}{1 + \rho} \frac{1}{C_{t+1}} \left(1 - \delta + \frac{aY_{t+1}}{K_t} \right) \right\},$$

$$(4a) \quad \omega_t = (1 - a) \frac{Y_t}{L_t},$$

$$(5a) \quad S_t = S_{t-1}^\lambda \exp(e_t).$$

The model also retains the boundary conditions, given by,

$$(6a) \quad K_0 = \bar{K}_0,$$

$$(7a) \quad S_0 = \bar{S}_0,$$

$$(8a) \quad \lim_{T \rightarrow \infty} E_t \left\{ \left(\frac{1}{1 + \rho} \right)^T \frac{K_T}{C_T} \right\} = 0.$$

But this gives only five equations to determine the six unknowns, K_t , L_t , C_t , Y_t , S_t and ω_t . The Plotnikov EBC2 model is missing Equation (13a). Instead of assuming that the labor market is competitive, employment is determined in a search equilibrium. Households do not vary labor supply in response to changes in wages and interest rates as in the RBC and EBC1 models; instead, each household sends a fixed fraction of its members to look for a job in every period and variation in employment arises as a consequence of endogenous changes in the efficiency with which workers are matched with jobs.

7 Unemployment and Search Externalities

The EBC1 and EBC2 model both exploit the idea that there is an externality in the production function; but they do it in fundamentally different ways. In EBC1 models, the externality leads to multiple dynamic equilibria; in the EBC2 model, it leads to multiple steady state equilibria. This section explains how that works by utilizing the concept of incomplete factor markets.

To model the frictional costs of recruiting, assume that a representative firm with L_t workers, can allocate them to the activity of recruiting or production. If we let V_t be the number of recruiters and X_t the number of production worker, V_t and X_t are related to L_t by the equation.

$$(14) \quad L_t = X_t + V_t.$$

Now assume that every recruiter can hire q_t workers,

$$(15) \quad L_t = q_t V_t,$$

where q_t is taken as given by the representative firm but is determined in aggregate by the degree of congestion in the labor market. Using the definition of X_t , we can express the output of the representative firm as,

$$(16) \quad Y_t = S_t K_t^a X_t^{1-a}.$$

Substituting (14) and (15) into (16) leads to the expression,

$$(17) \quad Y_t = A_t S_t K_t^a L_t^{1-a},$$

where

$$(18) \quad A_t = \left(1 - \frac{1}{q_t}\right)^{1-a}.$$

In words, the externality, A_t , is a function of the number of workers, q_t , than can be hired by a representative worker assigned to the task of recruiting. The term q_t is taken as given by each firm, but it is determined in aggregate by the number of other firms who are trying to attract workers. The connection with aggregate recruiting activity is found by specifying a matching technology that relates aggregate hires to the aggregate number of recruiters, \bar{V}_t . The important idea here, is that the assumption that workers and firms take prices and wages as given does not lead to enough equations to determine q_t .

Farmer (2012b) adds a Cobb-Douglas matching function to this model to determine the number of workers that are hired when firms, in aggregate, allocate \bar{V}_t workers to recruiting and when a measure 1 of workers looks for a job. By making the simplifying assumption that all workers are fired and rehired every period,⁷ he shows that $q_t = 1/\bar{L}_t$ and hence the externality A_t

is given by the expression,

$$(19) \quad A_t = (1 - \bar{L}_t)^{1-a}.$$

As in the EBC1 model of Benhabib and Farmer (1994), the term A_t represents a labor market externality. In the EBC2 model, this is represented by Equation (19), where \bar{L}_t is average employment by all other firms.

8 Closing the EBC2 Model with Adaptive Expectations

The models developed in Farmer (2006, 2012b,c), and Farmer (2013a) are closed by assuming that households form self-fulfilling beliefs about the value of their wealth. In Plotnikov (2013), there is no analog of stock market wealth, but households must still form expectations of their human wealth. To capture this concept, Plotnikov adapts Friedman's concept of permanent income. As in Friedman (1957), those expectations are formed adaptively. And as in Farmer (2002), because the model has an indeterminate set of equilibria, adaptive expectations are also rational.

If we evaluate Equations (1a)–(5a) at a steady state, we are able to pin down a value for \bar{S} which equals 1, and values of the ratios, \bar{C}/\bar{K} , \bar{Y}/\bar{K} and

\bar{C}/\bar{Y} , which are given by the expressions

$$(20) \quad \frac{\bar{C}}{\bar{K}} = \frac{\rho + \delta(1 - a)}{a},$$

$$(21) \quad \frac{\bar{Y}}{\bar{K}} = \frac{\rho + \delta}{a},$$

and

$$(22) \quad \frac{\bar{C}}{\bar{Y}} = \frac{\rho + \delta(1 - a)}{\rho + \delta}.$$

But the steady-state real wage, $\bar{\omega}$ and steady employment, \bar{L} cannot be found from these equations. Instead, the model is closed by assuming, as in Friedman's work on the consumption function, that consumption, C_t is proportional to permanent income, Y_t^P ,

$$(23) \quad C_t = \phi Y_t^P.$$

Here, permanent income is defined to be the value of income that would be earned by the representative household in the absence of shocks.

Because permanent income and current income are the same in a non-stochastic steady state, the coefficient ϕ is constrained by Equation (22) to be,

$$(24) \quad \phi \equiv \frac{\rho + \delta(1 - a)}{\rho + \delta}.$$

Under the adaptive expectations hypothesis, permanent income depends on current income and on the view of permanent income that households formed one period in the past. That assumption leads to Equation (25),

$$(25) \quad Y_t^P = (Y_{t-1}^P)^\theta Y_t^{1-\theta} \exp(e_t^b).$$

The parameter θ measures the speed with which revisions to current income are incorporated into permanent income and e_t^b is a belief shock that represents the optimism or pessimism of households. This shock has distribution $D(\cdot)$ with mean 0 and variance σ_b^2 ,

$$(26) \quad e_t^b \sim D(0, \sigma_b^2).$$

Finally, since Y_t^P is a state variable, the model must be closed with the initial condition

$$(27) \quad Y_0^P = \bar{Y}^P.$$

The complete EBC2 model consists of the dynamic equations (1a)–(4a), (23) and (25), the initial conditions (6a), (7a) and (27) and the transversality condition, (8a).

For any set of initial conditions, equations (1a)–(4a), (23) and (25) define a unique dynamic equilibrium. But setting the shocks to zero and solving for the steady state yields one less equation than unknown. This indeterminacy

of the steady state arises because although Equations (23) and (25) define a unique path for any set of initial conditions, they do not add information to help pin down the steady state. The steady-state value of (25) defines \bar{Y}^P to be equal to \bar{Y} , the steady-state value of (23) replicates the information from (22) and the complete set of equations defines a system that is path dependent. In the absence of shocks, the economy would converge to a steady-state value of employment that depends on the initial belief about permanent income, Y_0^P .

What have we gained by adapting a DSGE model in this way? *The important feature that distinguishes EBC2 models from other DSGE models is that data generated by the model display hysteresis: a small perturbation of the initial conditions leads to a similar perturbation of the eventual steady state. As Blanchard and Summers (1986, 1987) have argued convincingly, and as I have argued elsewhere, (Farmer, 2012a,c, 2013a), this is exactly the behavior we see in the data.*⁸

9 Conclusion

This paper has discussed the use of endogenous business cycle models that display indeterminate equilibria as a positive explanation of real world phenomena. This idea originated at the University of Pennsylvania during the early 1980s with the work of Cass and Shell (1983), Azariadis (1981) and Farmer and Woodford (1984) and it evolved into the EBC agenda; a re-

search program that explains business cycles as endogenous responses to self-fulfilling shocks to beliefs.

I have identified two generations of EBC models. First generation EBC1 models display indeterminate dynamic equilibria in which many equilibrium paths converge to the same steady state. Second generation EBC2 models display steady-state indeterminate equilibria in which there are many steady-state equilibrium unemployment rates.

One of the most important ideas to come from Keynes' *General Theory* was that high unemployment can persist as an equilibrium phenomenon. Second generation EBC2 models provide a microfoundation to this idea, and just as EBC1 models were part of the DSGE agenda that provided a microfoundation for the economics of Pigou (1929), EBC2 models provide a microfoundation for the economics of Keynes (1936). The idea that involuntary unemployment can persist as an equilibrium phenomenon is one that will gain more credence, the longer the current recession persists.

Notes

¹Benhabib and Farmer (1999) survey EBC1 models and discuss the issues related to dynamic indeterminacy and the mechanisms that generate it and Farmer (1999) explains how indeterminacy can arise in general equilibrium models and provides an accessible introduction to the topic. Since the Benhabib-Farmer survey in 1999, many important papers have been published in the field. Due to space restrictions, this paper is unable to provide a comprehensive introduction to that literature.

²Related papers that I would include in the second generation EBC2 literature include Angeletos and La'O (2011), Benhabib, Wang, and Wen (2012), Brown (2010), Farmer and Plotnikov (2012), Gelain and Guerrazzi (2010), Guerrazzi (2011, 2012), Heathcote and Perri (2012), Kashiwagi (2010), Kocherlakota (2011, 2012), Michailat and Saez (2013, 2014), Miao, Wang, and Xu (2012), Plotnikov (2013), and Schmitt-Grohé and Uribe (2011, 2012).

³Kocherlakota (2012) uses the term, *incomplete labor markets*, to refer to the concept that I call *incomplete factor markets* Farmer (2006, page 12).

⁴Lucas (1987) showed that, in an RBC model, the welfare costs of business cycles are less than one tenth of one percent of steady state consumption. In DSGE models with added frictions, the welfare costs of business cycle fluctuations are also small (Galí, Gertler, and Salido, 2007).

⁵Keynes drops what he calls 'Postulate II of classical economics'. By Postulate II, he means that: "The utility of the wage when a given volume of labour is employed is equal to the marginal disutility of that amount of employment", (Keynes, 1936, page 5).

⁶Alternative approaches include Phelps (1994) work on structural slumps and Blanchard and Summers (1986, 1987) who use the insider-outsider model of Lindbeck and Snower (1986) to generate models of persistent unemployment. Frydman and Goldberg (2011), argue the case for non-stationarity of the fundamentals.

⁷In most models of unemployment, see the survey by Rogerson, Shimer, and Wright (2005), the number of unemployed workers appears as a state variable. Farmer (2010a, 2012b) assumes instead that labor is fired and rehired every period. I maintain that assumption here since it allows me to write a second generation, EBC2 model that is close to first generation, EBC1 models and to the canonical RBC model. Farmer (2013a) develops a model that relaxes this assumption and shows that nothing of substance hinges on the simplification.

⁸Blanchard and Summers (1986, 1987) argue that unemployment is highly persistent and that persistence should be modeled by a dynamical system that displays hysteresis.

Hysteresis means that a small perturbation of the initial conditions leads to a similar perturbation of the eventual steady state. In a system that displays hysteresis, the equilibrium is path dependent.

References

- ANGELETOS, G.-M., AND LA'O (2011): "Sentiments," *Econometrica*, 81(2), 739–779.
- AZARIADIS, C. (1981): "Self-fulfilling Prophecies," *Journal of Economic Theory*, 25(3), 380–396.
- BEAUDRY, P., AND F. PORTIER (2006): "Stock Prices, News, and Economic Fluctuations," *American Economic Review*, 96, 1293–1307.
- BENHABIB, J., AND R. E. A. FARMER (1994): "Indeterminacy and Increasing Returns," *Journal of Economic Theory*, 63, 19–46.
- (1999): "Indeterminacy and Sunspots in Macroeconomics," in *Handbook of Macroeconomics*, ed. by J. B. Taylor, and M. Woodford. North-Holland.
- BENHABIB, J., P. WANG, AND Y. WEN (2012): "Sentiments and Agregate Demand Fluctuations," *NBER working paper 18413*.
- BLANCHARD, O. J., AND L. H. SUMMERS (1986): "Hysterisis and the European Unemployment Problem," in *NBER Macroeconomics Annual*, ed.

- by S. Fischer, vol. 1, pp. 15–90. National Bureau of Economic Research, Boston, MA.
- (1987): “Hysteresis in Unemployment,” *European Economic Review*, 31, 288–295.
- BROWN, A. (2010): “Essays in Macroeconomics and International Trade,” Ph.D. thesis, UCLA.
- CASS, D., AND K. SHELL (1983): “Do Sunspots Matter?,” *Journal of Political Economy*, 91, 193–227.
- CHRISTIANO, L., M. EICHENBAUM, AND C. EVANS (2005): “Nominal Rigidities and the Dynamics Effects of a Shock to Monetary Policy,” *Journal of Political Economy*, 113, 1–45.
- DIAMOND, P. A. (1982a): “Aggregate Demand Management in Search Equilibrium,” *Journal of Political Economy*, 90, 881–94.
- (1982b): “Wage determination and efficiency in search equilibrium,” *Review of Economic Studies*, 49, 217–227.
- (1984): “Money in Search Equilibrium,” *Econometrica*, 52, 1–20.
- FARMER, R. E. A. (1999): *The Macroeconomics of Self-Fulfilling Prophecies*. MIT Press, Cambridge, MA, second edn.
- (2002): “Why Does the Data Reject the Lucas Critique?,” *Annales d’Economie et de Statistiques*, 67/68, 111–129.

- (2006): “Old Keynesian Economics,” *UCLA mimeo.*, Paper presented at a conference in honor of Axel Leijonhufvud, held at UCLA on August 30th 2006.
- (2008a): “Aggregate Demand and Supply,” *International Journal of Economic Theory*, 4(1), 77–94.
- (2008b): “Old Keynesian Economics,” in *Macroeconomics in the Small and the Large*, ed. by R. E. A. Farmer, chap. 2, pp. 23–43. Edward Elgar, Cheltenham, UK.
- (2010a): *Expectations, Employment and Prices*. Oxford University Press, New York.
- (2010b): *How the Economy Works: Confidence, Crashes and Self-fulfilling Prophecies*. Oxford University Press, New York.
- (2010c): “How to Reduce Unemployment: A New Policy Proposal,” *Journal of Monetary Economics: Carnegie Rochester Conference Issue*, 57(5), 557–572.
- (2012a): “Animal Spirits, Persistent Unemployment and the Belief Function,” in *Rethinking Expectations: The Way Forward for Macroeconomics*, ed. by R. Frydman, and E. S. Phelps, chap. 5, pp. 251–276. Princeton University Press, Princeton, NJ.
- (2012b): “Confidence, Crashes and Animal Spirits,” *Economic Journal*, 122(559).

- (2012c): “The Stock Market Crash of 2008 Caused the Great Recession: Theory and Evidence,” *Journal of Economic Dynamics and Control*, 36, 697–707.
- (2013a): “Animal Spirits, Financial Crises and Persistent Unemployment,” *Economic Journal*, 123(568), 317–340.
- (2013b): “The Stock Market Crash Really Did Cause the Great Recession,” *NBER Working Paper 19391 and CEPR Discussion Paper 9630*.
- FARMER, R. E. A., AND J. T. GUO (1994): “Real Business Cycles and the Animal Spirits Hypothesis,” *Journal of Economic Theory*, 63, 42–73.
- FARMER, R. E. A., AND D. PLOTNIKOV (2012): “Does Fiscal Policy Matter? Blinder and Solow Revisited,” *Macroeconomic Dynamics*, 16(Supplement 1), 149–166.
- FARMER, R. E. A., AND M. WOODFORD (1984): “Self-fulfilling Prophecies and the Business Cycle,” *Caress Working Paper 84-12*.
- (1997): “Self-fulfilling Prophecies and the Business Cycle,” *Macroeconomic Dynamics*, 1(4), 740–769.
- FRIEDMAN, M. (1957): *A Theory of the Consumption Function*. Princeton University Press, Princeton, N.J.

- FRYDMAN, R., AND M. D. GOLDBERG (2011): *Beyond Mechanical Markets*. Princeton University Press.
- GALÍ, J., M. GERTLER, AND D. L. SALIDO (2007): “Markups, Gaps and the Welfare Costs of Business Cycle Fluctuations,” *The Review of Economics and Statistics*, 89(1), 44–59.
- GELAIN, P., AND M. GUERRAZZI (2010): “A DSGE Model from the Old Keynesian Economics: An Empirical Investigation,” *University of St. Andrews; Centre for Dynamic Macroeconomic Analysis Working Paper Series*, CDMA10/14.
- GUERRAZZI, M. (2011): “Search and Stochastic Dynamics in the Old Keynesian Economics: A Rationale for the Shimer Puzzle,” *Metroeconomica*, 62(4), 561–586.
- (2012): “The ‘Farmerian’ Approach to Ending Finance-Induced Recession: Notes on Stability and Dynamics,” *Economic Notes by Banca Monte dei Paschi di Siena SpA*, 41(1/2), 81–99.
- HALL, R. E. (1997): “Macroeconomic Fluctuations and the Allocation of Time,” *Journal of Labor Economics*, 15(1), S223–S250.
- HEATHCOTE, J., AND F. PERRI (2012): “Wealth and Volatility,” *Federal Reserve Bank of Minneapolis, mimeo*.
- HOWITT, P., AND R. P. MCAFEE (1987): “Costly Search and Recruiting,” *International Economic Review*, 28(1), 89–107.

- KASHIWAGI, M. (2010): “Search Theory and the Housing Market,” Ph.D. thesis, UCLA.
- KEYNES, J. M. (1936): *The General Theory of Employment, Interest and Money*. MacMillan and Co., London and Basingstoke, 1973 edition published for the Royal Economic Society, Cambridge.
- KING, R. G., C. I. PLOSSER, AND S. T. REBELO (1988): “Production, Growth, and Business Cycles: I. The Basic Neoclassical Model,” *Journal of Monetary Economics*, 21(March/May), 195–232.
- KOCHERLAKOTA, N. (2011): “Bubbles and Unemployment,” *Federal Reserve Bank of Minneapolis, mimeo*.
- (2012): “Incomplete Labor Markets,” *Federal Reserve Bank of Minneapolis, mimeo*.
- KYDLAND, F. E., AND E. C. PRESCOTT (1982): “Time to Build and Aggregate Fluctuations,” *Econometrica*, 50, 1345–1370.
- LINDBECK, A., AND D. J. SNOWER (1986): “Wage Setting, Unemployment and Insider-Outsider Relations,” *American Economic Review*, 76(2), 235–239.
- LONG, J. B., AND C. I. PLOSSER (1983): “Real Business Cycles,” *Journal of Political Economy*, 91(1), 39–69.

- LUCAS JR., R. E. (1972): “Expectations and the Neutrality of Money,” *Journal of Economic Theory*, 4, 103–124.
- (1987): *Models of Business Cycles*. Basil Blackwell, Oxford, UK.
- MIAO, J., P. WANG, AND Z. XU (2012): “Stock Market Bubbles and Unemployment,” *Boston University mimeo*.
- MICHAILLAT, P., AND E. SAEZ (2013): “A Model of Aggregate Demand and Unemployment,” *NBER Working Paper 18826*.
- (2014): “An Economical Business Cycle Model,” *NBER Working Paper 119777*.
- MORTENSEN, D. T. (1970): “Job Search, the Duration of Unemployment, and the Phillips Curve,” *American Economic Review*, 60(5), 847–62.
- PHELPS, E. S. (1994): *Structural Slumps*. Harvard University Press, Cambridge, Mass.
- PIGOU, A. C. (1929): *Industrial Fluctuations*. McMillan.
- PISSARIDES, C. A. (1976): “Job Search and Participation,” *Economica*, 43, 333–349.
- PLOTNIKOV, D. (2013): “Three Essays on Macroeconomics with Incomplete Factor Markets,” Ph.D. thesis, UCLA.

ROGERSON, R., R. SHIMER, AND R. WRIGHT (2005): “Search-Theoretic Models of the Labor Market: A Survey,” *Journal of Economic Literature*, 43, 959–988.

SCHMITT-GROHÉ, S., AND M. URIBE (2011): “Pegs and Pain,” *NBER Working Papers 16847*.

——— (2012): “Pegs, Downward Wage Rigidity and Unemployment,” *NBER Working Paper 18223*.

SMETS, F., AND R. WOUTERS (2007): “Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach,” *American Economic Review*, 97(3), 586–606.