ANIMAL SPIRITS

1. Animal Spirits and Economics

The term “Animal Spirits” is closely associated with John Maynard Keynes who used it in his 1936 book, *The General Theory of Employment Interest and Money* to capture the idea that aggregate economic activity might be driven in part by waves of optimism or pessimism: (although Robin Mathews 1984, points out that Keynes would have been aware of its use by David Hume 1739, Part iv, Section vii).

> "Most, probably, of our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as the result of animal spirits - a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities."
>
> (*The General Theory of Employment Interest and Money,* 161-162)

The idea that waves of spontaneous optimism might drive business cycles was not new to Keynes and can be traced at least as far back as Henry Thornton who attributed a central role in his theory of credit to “… that confidence which subsists among commercial men in respect to their mercantile affairs…” (Thornton 1802, p. 75).

2. The Advent of Rational Expectations

The early writers, including Keynes, did not develop fully worked out dynamic models in which expectations of agents’ are related to outcomes that are later realized. The development of complete artificial economies of this kind occurred first with the rational expectations revolution in the 1970’s in which the static macroeconomic disequilibrium model of Keynes’ General Theory was replaced by modern dynamic general equilibrium models rooted in Chapter 7 of Gerard Debreu’s *Theory of Value* (1959). This development began with the work of Robert E. Lucas Jr. and early examples of rational expectations models include Lucas and Leonard Rapping (1969), and Lucas (1972, 1973). Lucas’ 1972 and 1973 papers were attempts to understand the business cycle as a monetary phenomenon. Monetary models gave way to exclusively real models of the business cycle following the publication of influential papers by Fynn Kydland and Edward C. Prescott (1982) and John B. Long and Charles Plosser (1983) and modern macroeconomics theories, based on these early contributions, are referred to as dynamic stochastic general equilibrium (DSGE) models.

Early DSGE models were restricted to examples in which there exists a finite number of agents (often only one) choosing consumption, investment and employment sequences in an economy with complete markets. Infinite horizon models of this kind (IH models) have the same structure as the finite general equilibrium model studied by Kenneth Arrow and Gerard Debreu (1954) and Lionel McKenzie (1959) with the exception that the commodity space is infinite dimensional. Timothy Kehoe and David Levine (1985) showed that the competitive equilibria of IH exchange economies satisfy the first and second theorems of welfare economics and by applying their methods to production economies it follows that that consumption, investment and employment sequences can be treated 'as if' they were chosen by a social planner maximizing a concave objective function subject to a set of linear constraints. Social planning problems have a unique solution in which all fluctuations in investment must occur as a direct consequence of fluctuations in the fundamentals of the economy; typically taken to consist of preferences, endowments and technologies. It follows that, if expectations are rational, there is no room in these economies for animal spirits to exert an independent influence on economic activity.

3. The Infinite Horizon Model under Constant Returns to Scale

The modern use of DSGE models has followed two routes. One class of models, following the IH approach, assumes that all decisions are taken by a finite set of infinitely lived households each of which makes decisions for current and future family members. This class includes the real business cycle model (RBC), currently dominant in the profession, which has a history dating back to Frank Ramsey (1928), David Cass (1965) and Tjalling Koopmans (1965).

In simple representations of the IH model, one assumes that a single representative agent allocates output, Y_t between consumption, C_t and next period's capital stock, K_{t+1}. Output is produced from capital, K_t and labor L_t using a constant returns to scale technology that is subject to a productivity shock which is modeled as a random variable A_t. The representative agent ranks alternative probability distributions over consumption and labor supply using an additively separable utility function. This problem can be represented as follows:

(1.1) $$\max_{\{C_t, L_t, K_{t+1}\}} \sum_{t=1}^{\infty} \left(\frac{1}{1+\rho}\right)^{t-1} E_1\left[U\left(C_t, L_t\right)\right],$$

(1.2) $$Y_t = A_t K_t^{a} L_t^{b},$$

(1.3) $$K_{t+1} = K_t\left(1-\delta\right) + Y_t - C_t, \quad K_1 = \bar{K}_1.$$

Here, $\rho > 0$ is the agent's discount rate and $0 \le \delta < 1$ represents depreciation. The parameters a and b represent the elasticities of capital and labor in production and the assumption of constant returns to scale implies that

(1.4) $$a + b = 1.$$

$E_1[\bullet]$ is the expectations operator and the interpretation of this problem is that the agent chooses sequences $\left\{C_t\left(A^t\right), L_t\left(A^t\right) K_{t+1}\left(A^t\right)\right\}_{t=1}^{\infty}$ where $A^t = \{A_1, A_2 ... A_t\}$ is the history of shocks from date 1 to date t. A_t is a random variable, generated by an autocorrelated stochastic process.

In standard IH models one assumes that $U(x, y)$ is increasing in x, decreasing in y, strictly concave and twice continuously differentiable, and under these assumptions, the programming problem defined in Equation (1.1) is concave and has a unique solution. Under the commonly assumed functional form,

$$U(C,L) = \log(C) - \frac{L^{1+\gamma}}{1+\gamma},$$

this solution is characterized by the first order conditions:

(1.5) $$C_t L_t^{\gamma} = b\frac{Y_t}{L_t},$$

(1.6) $$\frac{1}{C_t} = E_t\left\{\frac{1}{(1+\rho)C_{t+1}}\left(1-\delta + a\frac{Y_{t+1}}{K_{t+1}}\right)\right\},$$

(1.7) $$\lim_{T\to\infty}\left(\frac{1}{1+\rho}\right)^T E_1\left[\frac{K_{T+1}}{C_T}\right] = 0.$$

For the real business cycle program it is critical to assume that the production function is linearly homogenous and preferences are strictly concave since these assumptions imply that the problem of the representative agent has a unique solution. More generally, if there are multiple agents, one can write down the problem of a social planner who maximizes a social welfare function, defined as a weighted sum of individual utilities.

4. The OLG Model and How it Differs

In contrast to the IH model, in overlapping generations economies (OLG) one assumes that the set of agents is infinite and that each agent lives for a finite number of periods; this model was developed first in English by Paul Samuelson (1958) although Maurice Allais (1948), written in French, predates Samuelson's contribution.

In OLG models, unlike the IH model with concave preferences and technologies, there may exist equilibria that are dynamically inefficient. In equilibria of this kind the economy has "too much capital" and a benevolent social planner could improve social welfare for all generations by consuming part of the capital stock (thereby raising consumption for the current generation) and diverting future output from investment to consumption, (thereby raising consumption for all future generations).

After the publication of Samuelson's (1958) article, a considerable literature developed discussing the source of dynamic inefficiency. The question was finally settled with the publication of Shell's (1971) paper, "Notes on the Economics of Infinity". Shell argued that both IH and OLG models are special cases of Debreu's (1959) formulation of general equilibrium. In both cases the commodity space is infinite dimensional. In the IH model the number of agents is finite; in the OLG model it is infinite. This apparently innocuous difference is the key to understanding why there may be inefficient equilibria in the OLG model since, in an inefficient equilibrium, no single agent can make a welfare improving trade. In contrast, dynamic inefficiency in an IH economy would imply the existence of an agent with infinite wealth at equilibrium prices.

Both IH and OLG models have been used as vehicles to develop the idea that animal spirits may independently influence economic activity. Since the IH model with concave preferences and technologies leads to equilibria that are efficient it was the OLG model that was first exploited to develop the modern version of the "animal spirits hypothesis". However, since the period of the two-period OLG model is typically interpreted as 25 or 30 years, and since the average period of a business cycle is six to eight years, it was easy to dismiss the early work, based on the OLG structure, on the grounds that the equilibria that it led to were theoretical curiosities that are not relevant in the real world. This criticism was addressed by a second generation of animal spirits economies, in which the OLG model was replaced by an IH framework that relaxed the assumption that the technology is subject to constant returns-to-scale.

5. Animal Spirits, Sunspots and Incomplete Participation

In DSGE models the term *animal spirits* (Azariadis 1981, Howitt and McAfee 1992, Farmer and Guo 1994) is used interchangeably with *sunspots* (Cass and Shell 1983), *self-fulfilling prophecies* (Azariadis 1981, Farmer 1993) and most recently *irrational exuberance* by Alan Greenspan (1996) at an after dinner speech.

Jevons used the term sunspots to refer to the literal possibility that astronomical events could influence the trade cycle through the intermediating effect of the weather on agriculture. In their 1983 article, Cass and Shell meant something different. They constructed a two period general equilibrium model with complete markets in which some agents are unable to enter into insurance contracts. They referred to this restriction as *incomplete participation* to distinguish it from a potentially more serious market breakdown in which some kinds of insurance contracts cannot be entered into *by anyone*. Cass and Shell distinguished between *intrinsic uncertainty*, that can influence fundamentals of the economy and *extrinsic uncertainty* in which the fundamentals are unchanged across alternative extrinsic events. They showed that the inability for a subset of agents to enter into insurance contracts is a sufficient departure from standard general equilibrium assumptions to permit the existence of equilibria in which allocations differ across states of the world in which all uncertainty is extrinsic: When this occurs they said that *sunspots matter*.

In an economy with a complete set of insurance markets and risk-averse agents, all of whom can participate in these markets, sunspots cannot matter. Since agents are risk averse they would prefer the mean of a random allocation to the allocation itself. But if all uncertainty is extrinsic then the mean allocation is feasible hence a sunspot allocation cannot be an equilibrium of a complete markets economy with complete participation. Sunspot equilibria are Pareto inefficient, but for a different reason from the dynamic inefficiency associated with over-accumulation of capital in deterministic OLG models. Sunspot inefficiency arises from the addition of unnecessary randomness to an economy in which agents prefer to avoid fluctuations in their consumption allocations.

6. Animal Spirits in an OLG Model

The first application of sunspots to a DSGE model is due to Azariadis (1981). He constructed a two period overlapping generations model with no intrinsic uncertainty. This model possesses a unique steady state in which money has value. Under typical assumptions about preferences, the linearized dynamics of equilibrium price sequences in the neighborhood of the steady state, obey a functional equation of the form

$$p_t = \alpha E_t\left[p_{t+1}\right] + c, \quad |\alpha| < 1. \tag{1.8}$$

Azariadis looked for equilibria that follow a two-state Markov process: that is, equilibria of the form:

$$\begin{bmatrix} p_t\left(s_t = 1\right) \\ p_t\left(s_t = 2\right) \end{bmatrix} = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} \alpha p_{t+1}^1\left(s_t = 1\right) \\ \alpha p_{t+1}^1\left(s_t = 2\right) \end{bmatrix} + \begin{bmatrix} c \\ c \end{bmatrix} \tag{1.9}$$

where $s_t \in \{1,2\}$ is the state at date *t* and π_{ij} is the probability that $s_t = i$ conditional on $s_{t-1} = j$. For the linearized model, the fact that $|\alpha| < 1$ implies that the only equilibrium in this class is one for which

$$p\left(s_t = i\right) = \frac{c}{1-\alpha}, \quad i = 1, 2, \tag{1.10}$$

that is, the price is constant and independent of the non-fundamental uncertainty. But in the non-linear model the equation that defines equilibrium price sequences takes the form

$$p_t\left(s_t\right) = E_t\left[g\left(p_{t+1}\left(s_{t+1}\right) \mid s_t\right)\right], \tag{1.11}$$

where the function $g(\bullet)$ depends on assumptions about the form of the utility function. The equation defining a two-state Markov equilibrium takes the more general form

$$\begin{bmatrix} p_t\left(s_t = 1\right) \\ p_t\left(s_t = 2\right) \end{bmatrix} = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} g\left(p_{t+1}^1\left(s_t = 1\right)\right) \\ g\left(p_{t+1}^1\left(s_t = 2\right)\right) \end{bmatrix}. \tag{1.12}$$

In this case, Azariadis showed that as long as consumption and leisure are not gross substitutes, it is possible to find positive numbers p_1, p_2 such that $p_1 \neq p_2$ and positive probabilities $\pi_{11}, \pi_{12}, \pi_{21}$ and π_{22} such that

$$\begin{bmatrix} p_1 \\ p_2 \end{bmatrix} = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} g\left(p_1\right) \\ g\left(p_2\right) \end{bmatrix}. \tag{1.13}$$

In other words, prices (and implicitly employment, consumption and gdp) in this economy fluctuate between two different levels based purely on the occurrence of self-fulfilling expectations or, in Keynes' terminology, 'animal spirits'. As with the Cass-Shell example of sunspots, however, the Azariadis example could easily be dismissed as a model of a real economy since it required the assumption that consumption and leisure are gross complements; an assumption that was widely believed to be implausible and inconsistent with other evidence. The challenge was to develop a quantitative model of the business cycle in which aggregate fluctuations are driven by animal spirits, expectations are rational, and the model can capture the observed volatilities of output, consumption, gdp and hours.

7. Animal Spirits and Indeterminacy

The example of sunspots provided in the Cass-Shell (1982) paper relied on constructing an economy in which there are multiple equilibria. They showed that, when some agents are unable to participate in the insurance markets that occur before they are born, randomizations across deterministic allocations can also be sustained as equilibria. In the presence of complete participation in insurance markets these randomized equilibria would be ruled out since they are associated with unnecessary uncertainty that risk-averse agents would prefer to avoid.

In addition to the fact that an OLG equilibrium can be dynamically inefficient, there is a second key way in which OLG and IH models differ. In the IH model the set of equilibria is generically finite whereas OLG economies can contain a continuum of equilibria. (Roughly speaking, 'generically finite' means that for almost all IH economies there is a finite number of equilibria and 'almost all' means that this statement is true for an open dense set of parameters in a parameterized family of economies.) The fact that there is a finite number of equilibria implies that each equilibrium of the IH model is locally unique, that is, there is no other equilibrium that is arbitrarily close to it.

A locally unique equilibrium is also called determinate. Determinacy of equilibrium is an important property since, if one is interested in comparative statics, it is important that small changes in exogenous variables lead to predictable small changes in endogenous variables. If the equilibrium is one of a continuous set of equilibria (as would happen if the equilibrium was indeterminate) then the model does not make a clear prediction as to how prices and quantities would be expected to change in response to a change in policy or in some other fundamental of the economy.

Under some assumptions about preferences, (a sufficient condition is that the endowment of the agents' is sufficiently tilted towards youth) the one-good two-period OLG model, possesses two steady states. Each of these steady states is a stationary equilibrium with a constant real rate of interest; in one stationary equilibrium money has positive value and in the other it does not. David Gale (1973) refers to economies that possess a monetary steady state as "Samuelson" to distinguish them from those that do not (he calls these "Classical"). In a Samuelson economy the two steady states are respectively "generationally autarkic" (money has no value) and the "golden rule" (the real rate of interest equals the population growth rate). In Samuelson economies there exists a continuum of non-stationary equilibria and, when consumptions in adjacent periods are gross substitutes, each of these non-stationary equilibria converges to the autarkic steady state.

The non-stationary equilibria in the OLG model provide a rich source of equilibria over which to randomize, however, they all converge to an autarkic equilibrium in which money has no value. This property makes it difficult to construct stationary stochastic equilibria around the autarkic steady state since there are no non-stationary paths that approach the steady state from below. To get around this difficulty, Farmer and Woodford (1984) showed that by adding government spending to the OLG model, one can construct randomizations over a set of non-stationary equilibria that converge to a stationary state in which money has value. The addition of positive inflation-financed government expenditure shifts the set of stationary equilibria and the indeterminate non-monetary equilibrium of the OLG model becomes a second monetary equilibrium. By adding a zero mean random variable to the model, Farmer and Woodford were able to construct a new set of *stationary* sunspot equilibria. Locally, these equilibria obey a difference equation of the form of Equation (1.8), but the parameter α is greater than 1 in absolute value. It follows that one can construct equilibria in this model of the form:

$$p_{t+1} = \frac{1}{\alpha} p_t - \frac{c}{\alpha} + u_{t+1}, \tag{1.14}$$

where u_{t+1} is *any* random variable with zero conditional mean. Further, the unconditional probability distribution of the price level can be shown to converge to an invariant probability measure that depends on the distribution of the sequence of sunspot shocks, $\{u_t\}$. This is an important property of a rational expectations equilibrium since, arguably, stationarity is necessary for agents to learn about the world in which they live and to find ways of making unbiased forecasts of the moments of future prices.

8. Real Business Cycles and the Animal Spirits Hypothesis

The examples of stationary sunspot rational expectations equilibria, originally constructed in the OLG model, did not have much impact on mainstream macroeconomics. Although the first rational expectations models were constructed as monetary examples within the two-period OLG structure (for example, Lucas' seminal 1972 paper), the profession soon moved on to real models based on IH economies. The IH structure is more amenable to confrontation with data since the period of the model can easily be mapped into the period of data collection. Further, the examples of Azariadis and Farmer-Woodford were constructed in models that relied on assumptions widely believed to be unrealistic: these included the assumption of gross complements and two-period lives, (in the case of the Azariadis model) and the assumption that sunspots exist close to a dynamically inefficient steady state, in the Farmer-Woodford model, (this assumption can be shown to generate counterintuitive responses of inflation to expansionary fiscal policy).

To confront these criticisms, Howitt and McAfee (1992), Benhabib and Farmer (1994) and Farmer and Guo (1994) constructed examples of animal spirits equilibria within the IH paradigm by dropping the assumption that the technology is subject to constant returns-to-scale. At the time that this work was published, a number of authors (Caballero and Lyons 1990, is a prominent example) had estimated the degree of increasing returns-to scale in U.S. manufacturing industries and found it to be large.

In their 1994 paper, Benhabib and Farmer took a relatively standard IH model and they added externalities and increasing-returns to scale. Farmer and Guo (1994) constructed a discrete time version of the Benhabib-Farmer model and showed that it can be used to generate business cycle fluctuations driven by animal spirits. They argued that the animal spirits driven model is *more* successful than the real business cycle model at capturing the observed dynamics of output, employment, investment and consumption because it can replicate the hump-shaped response of output and investment to shocks that is observed in U.S. data.

The Benhabib-Farmer-Guo (BFG) model has the same form as the IH model described in Equations (1.1) -(1.7) but it distinguishes between the *private* technology and the *social* technology. BFG assume that the economy contains a large number of identical firms, each of which produces output using the production function

(1.15) $$Y_t = A_t K_t^a L_t^b .$$

In BFG, the term A_t is not exogenous. Instead, it represents an input externality of the form

(1.16) $$A_t = \bar{K}_t^{\alpha - a} \bar{L}_t^{\beta - b} ,$$

where $\bar{K}_t$ and $\bar{L}_t$ represent the economy-wide average use of capital and labor. Replacing (1.16) in (1.15) and imposing the assumption that the economy is in a symmetric equilibrium in which $\bar{K}_t = K_t$ and $\bar{L}_t = L_t$ leads to the *social technology*

(1.17) $$Y_t = K_t^{\alpha} L_t^{\beta} .$$

BFG assumed that

(1.18) $$\alpha + \beta > 1, \qquad a + b = 1 ,$$

which implies that there are increasing returns to scale in the social technology but constant returns to scale at the level of the individual firm. Since increasing returns enter the economy as an external effect, each firm maximizes a concave profit function and the equilibrium of the competitive economy is well defined. BFG showed that equilibria in their IH economy with increasing returns is characterized by the following system of equations.

(1.19) $$Y_t = A_t K_t^{\alpha} L_t^{\beta} ,$$

(1.20) $$K_{t+1} = K_t \left(1 - \delta\right) + Y - C_t .$$

(1.21) $$C_t L_t^{\gamma} = b \frac{Y_t}{L_t} ,$$

(1.22) $$\frac{1}{C_t} = E_t \left\{ \frac{1}{\left(1+\rho\right) C_{t+1}} \left(1 - \delta + a \frac{Y_{t+1}}{K_{t+1}} \right) \right\} ,$$

(1.23) $$\lim_{T \to \infty} \left(\frac{1}{1+\rho} \right)^T E_1 \left[\frac{K_{T+1}}{C_T} \right] = 0 .$$

When $a = \alpha$ and $b = \beta$, this model collapses to the real business cycle version of the IH economy. But if $\alpha > a$, $\beta > b$ and $\alpha + \beta$ is greater than 1 and "large enough" Benhabib and Farmer showed that the dynamics of the IH model change character and the model contains a continuum of indeterminate equilibria, just like the OLG model. Farmer and Guo calibrated the model to US data and by choosing parameters that appeared consistent with contemporary estimates of returns-to-scale, they showed that the model exhibits business cycles driven by self-fulfilling waves of optimism and pessimism.

To provide a degree of discipline to the calibration exercise, real business cycle economists estimate the volatility of real productivity shocks by constructing an estimate of total factor productivity. This is an accurate measure of TFP under the maintained assumptions of competitive markets and constant returns-to-scale. Farmer-Guo provided discipline to their calibration exercise by constructing the measure of TFP that would be estimated from data generated by an animal spirits economy by an econometrician who assumed incorrectly that the technology was driven by technology shocks and imposed the incorrect identifying assumption of constant returns-to-scale. They showed that this measure has very similar properties to that of the TFP estimates from U.S. data.

9. Animal Spirits, Business Cycles and Welfare

Much recent business cycle research assumes that business cycles are driven by technology shocks but we do not have a very good explanation of what these shocks represent. The BFG model represents a plausible alternative to the real business cycle model. It recaptures an idea that is at least as old as Henry Thornton (1802), and recasts it in modern language.

Why should we care if shocks arise in the productivity of the technology or in the minds of entrepreneurs? The answer is connected to the efficiency question. If business cycles arise as the consequence of the optimal allocation of resources in the face of unavoidable fluctuations in the technology, then there is not much that government can or should do about them. But if they arise as the consequence of avoidable fluctuations in the animal spirits of investors then the fluctuations that result are avoidable and the allocations are Pareto suboptimal. Animal spirit driven business cycles provide a reason for countercyclical stabilization policy and the cause of cycles is therefore an important question.

In 1996, Takashi Kamihigashi showed that the RBC economy (driven by TFP shocks) and the Benhabib-Farmer model (driven by animal spirits) are observationally equivalent when estimated on aggregate data and that, using aggregate evidence alone, constant returns-to-scale is an identifying assumption. The empirical literature since the publication of *JET* volume 63 in 1994 suggests that early estimates of the degree of returns-to-scale were over stated and more recent estimates (e.g. Basu and Fernald 1997) are more modest. This has led to renewed developments by theorists who have constructed modifications of the basic animal spirits model that are able to bring down the required degree of returns-to-scale to well within the tolerance of the best econometric estimates. Innovations to this literature include the construction of multi-sector models, (Benhabib and Farmer 1996, Weder 1998, Benhabib Nishimura and Meng

2000, Harrison 2001) externalities in preferences, (Farmer and Bennett 2000, Hintermaier 2003), capital-labor substitution (Grandmont, Pintus and De Vilder 1998) stabilization policy (Schmitt-Grohé and Uribe 1997, Guo and Lansing 1998, Lloyd Braga 2003), alternative explanations of the Great Depression (Harrison and Weder, forthcoming) and variable capacity utilization Yi Wen (1998) and Benhabib and Wen (2004). Benhabib and Farmer (1999) provide a survey of this literature and references to additional related papers.

Recent examples of animal spirits driven models are able to explain a wide range of phenomena and, when supplemented by the assumption of variable capacity utilization, the animal-spirits explanation of business cycles outperforms the RBC model in most dimensions. Since the two models have very different policy conclusions; research that addresses the question: Are business cycles driven by Animal Spirits? is likely to remain a lively and important focus of research for some time to come.

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