"Sunspot Equilibrium" by Karl Shell and Bruce D. Smith, in *The New Palgrave Dictionary of Money & Finance* (J. Eatwell, M. Milgate, and P. Newman, Eds.), Vol. 3, Macmillan: N.Y., 1992.

new debt raises the p
This increase in risk
debt so that the init
contrast, the equity
rate they are paying on the old debt is lower than if they had issued all the debt simultaneously. This transfer of value from bondholders to shareholders can be eliminated if the initial debt specifies that all subsequent issues be subordinated. Fama and Miller (1972) referred to this type of subordination as a 'me-first' rule.

There have been a number of empirical studies investigating the effects of violations of me-first rules. Kim, McConnell and Greenwood (1977) consider a sample of firms that formed wholly owned finance subsidiaries. These subsidiaries issue debt and purchase the accounts receivable of the parent firm. Owners of the debt issued by the subsidiary essentially have a more senior claim on the accounts receivable than the bondholders of the parent corporation. Thus, forming a wholly owned subsidiary is effectively equivalent to issuing debt which has a higher claim than the existing bonds. The authors consider a sample of 24 firms that established captive finance subsidiaries between 1940 and 1971. They found strong evidence of a wealth transfer from the original company's bondholders to its shareholders.

Brauer (1983) has also investigated the effect of violations of me-first rules. His study considered the pricing of two bonds issued by Sunshine Mining Company in 1980. These bonds were identical except for the different timing of their payments and a difference in their me-first protective covenants. Adjusting for the difference in timing of payments, Brauer found that the bond with the more effective protection from subsequent issue was indeed more valuable than the bond without it.

An alternative explanation for subordination has recently been suggested by Winton (1990). His approach centres on a variant of the delegated monitoring story that has developed in the literature. Gale and Hellwig (1985) (building on Townsend 1979) showed that if a lender finds it costly to verify the level of income of a borrower, then in the optimal debt contract there is no verification provided the payment on the debt is actually paid, since this minimizes the total verification costs. Winton considers a similar framework but with multiple lenders. It is shown that if all lenders have the same claim, there is an inefficiency because verification costs are duplicated when the borrower fails to make the required debt payments. If the investors each hold debt with different levels of seniority, this duplication is eliminated. Accordingly, subordinated debt reduces the cost of monitoring and increases the value of the firm.

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See also BANKRUPTCY AND CAPITAL STRUCTURE; BOND COVENANTS; CORPORATE FINANCE; DEBT AND DEFAULT: CORPORATE VS. SOVEREIGN; INSOLVENCY AND BANKRUPTCY.

BIBLIOGRAPHY

Black, F. and Cox, J. 1976. Valuing corporate securities: some effects of bond indenture provisions. *Journal of Finance* 31(2): 351–67.
Brauer, G.A. 1983. Evidence of the market value of me-first rules.
Theory of Finance. New
...rk.
...ntive-compatible debt
...m. *Review of Economic Studies* 52: 647–63.
Johnson, R.W. 1955. Subordinated debentures: debt that serves as equity. *Journal of Finance* 10: 1–16.
Kim, E.H., McConnell, J.J. and Greenwood, P.R. 1977. Capital structure rearrangements and me-first rules in an efficient capital market. *Journal of Finance* 32: 789–810.
Merton, R.C. 1974. On the pricing of corporate debt: the risk structure of interest rates. *Journal of Finance* 29: 449–70.
Smith, C.W. and Warner, J.B. 1979. On financial contracting: an analysis of bond covenants. *Journal of Financial Economics* 7: 117–61.
Townsend, R.M. 1979. Optimal contracts and competitive markets with costly state verification. *Journal of Economic Theory* 22: 265–93.
Winton, A.J. 1990. Costly state verification and multiple investors: the role of subordination. Ch. 2 of Three Essays on Information, Contracting, and Financial Intermediation, Ph.D. Thesis, University of Pennsylvania, Philadelphia.

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subscription warrants. *See* WARRANTS.

sunspot equilibrium. The volatility of market outcomes (for instance, employment, the price level and exchange rates) and what – if anything – to do about it are important subjects in macroeconomics. Some observed randomness in market outcomes originates in shocks to economic fundamentals (preferences, endowments and technologies) that are transmitted through the economy. Uncertainty about economic fundamentals is called *intrinsic uncertainty*. The general-equilibrium model extended to incorporate uncertainty (see Arrow 1953, 1964) provides an explanation of how intrinsic uncertainty causes randomness in economic outcomes. However, this is not the only possible source of economic volatility. The remaining randomness, or *excess volatility*, can be thought of as *market uncertainty*, the randomness generated by the economic mechanism itself; see Shell (1987).

The sunspot-equilibrium concept was introduced by Cass and Shell; see Shell (1977, 1987) and Cass and Shell (1980, 1982, 1983, 1989). Sunspot models are full-blown rational-expectations, general-equilibrium models that allow for excess volatility. Hence they can be used to analyse macroeconomic and monetary economic fluctuations. Because sunspots models entail rational expectations, they are also useful for judging the robustness, stability and internal consistency of the rational-expectations hypothesis. Uncertainty that is not intrinsic to the economy is by definition *extrinsic uncertainty*. In this literature, the term *'sunspots'* is synonymous with 'extrinsic randomizing device'. If an allocation of resources depends on the outcome of such a device, then it is a sunspot allocation and we say that *sunspots matter*. If the sunspot allocation is an equilibrium for the economy, then it is a *sunspot-equilibrium* (SSE) allocation. Allocations that do not depend on extrinsic uncertainty are nonsunspot allocations. The corresponding equilibria are *nonsunspot equilibria* (NSEs).

The 'sunspot' terminology is a bit of a spoof on the work of Jevons (1884) and his followers, who related the business cycle to the cycle of actual sunspots. To the extent that actual sunspots do affect economic fundamentals this is intrinsic uncertainty, but the overall effects of actual sunspots on economic fundamentals are probably not major. Then, if actual sunspot activity does have substantial impacts on the economy, it must be that it serves a role beyond its effects on fundamentals. Cass–Shell sunspots are highly stylized; by definition, they represent purely extrinsic uncertainty, and in sunspot-equilibrium models any randomness in economic outcomes is by definition an instance of excess volatility. In actual applications, things are not so simple. The stock market, for example, is clearly affected by intrinsic uncertainty, but some might suggest that there is also 'excess volatility' in the market, or that randomness in stock prices cannot be 'fully explained' by fundamentals. SSE models are meant to be suggestive: they approximate economies in which intrinsic uncertainty affects outcomes much more than it does fundamentals. Indeed, Manuelli and Peck (forthcoming) show that SSEs can be interpreted as the limit of traditional rational-expectations equilibria as the effects of intrinsic uncertainty on economic fundamentals vanish. This shows how variables that have only minor effects on fundamentals can have major effects on economic outcomes.

The SSE concept is an extension of the rational-expectations equilibrium (REE) concept. In moving from the usual REE model to the SSE model, commodities contingent on extrinsic states of nature are introduced. The effects on the equilibrium set of expanding the commodity space in this way is dramatic in many (but not all) models: sunspots matter and – in terms of the number of SSEs relative to the number of NSEs – they often matter very much. Furthermore, REEs are not always stable in the face of the introduction of sunspots: the equilibrium set is altered by sunspots and depends on the sunspot mechanism itself. While findings of this general nature were familiar to game theorists, who had experience with stochastic solutions to nonstochastic games, the sunspots results did come as a surprise to many general-equilibrium theorists.

The initial reaction of the macroeconomics community to formal sunspots theories was not generally positive, despite the established oral tradition of attributing business-cycle fluctuations to expectational factors. Theories of 'credit cycles' date back at least to the Currency and Banking Schools (White 1984). These theories played a prominent role in politics and policy-making in both England and the US in the second quarter of the 19th century (Schlesinger 1953; White 1984; Hammond 1957). A typical representation of such a theory would be that 'waves of optimism' sweep the economy, causing speculative investment fuelled by expanding bank (or trade) credit. Such speculation could temporarily raise prices, possibly in a self-fulfilling manner. Eventually such optimism must be reversed, however, and its reversal would cause contractions in credit and (again potentially self-fulfilling) price-level declines. Moreover, these price level fluctuations might be reflected in real activity.

This kind of reasoning permeates a variety of macroeconomic discussions. Keynes (1936, ch. 12) identifies 'animal spirits' as an important factor influencing investment levels, and hence business cycles. In addition, expectational theories of the cycle have had more subtle influences on discussions concerning government regulation of banks and financial markets. For example, it has often been argued that the unrestricted operation of financial markets allows for 'excessive fluctuations' in the price level and the inside money stock, and possibly for indeterminacies as well. Such arguments motivated the passage of Peel's Bank Act of 1844 (see Smith 1988, for a discussion) or the proposals of Simons (1948) and Friedman (1960) for 100 percent reserve banking, and have clear roots in historical discussions of the credit cycle. Finally, many theories of banking panics (including possibly that of Diamond and Dybvig 1983) attribute financial crises to sunspot-like phenomena.

The remainder of the survey is in six sections. We begin with finite, convex economies in which information is symmetric. For sunspots to matter in these economies, there must be market 'imperfections'. We follow with asymmetric-information, nonconvex, and overlapping-generations (and other infinite) economies. In these economies, sunspots can matter even if markets are perfect. In the section on coordination, we review the literature on implementing SSEs, that is, on how randomizing devices are 'selected' by economic actors. We conclude with an analysis of stabilization policies for economies subject to potential volatility due to extrinsic shocks.

FINITE, CONVEX ECONOMIES. For this section, preferences and technologies are convex, the number of consumers and the number of standard (i.e. certainty) commodities is finite, and individuals share the same probability beliefs about the extrinsic states of nature. Shared beliefs, or symmetric information, can be argued to be the case of strong rational-expectations; see Shell (1987). The number of extrinsic states of nature – and hence the number of contingent commodities – can be finite or infinite.

In a finite, strictly convex sunspots economy, a sunspot allocation cannot be Pareto optimal: because of the strict convexity of preferences (and the fact that sunspots do not affect preferences) there is always some feasible nonsunspot allocation which is better (see Cass and Shell 1983, section IV, and the extensions by Balasko 1983 and Chiappori and Guesnerie 1991). If there are no externalities in the associated certainty economy – and hence no externalities in the sunspots economy – and if all possible contingent-claims markets in the sunspots economy exist and are perfect, then from the first welfare theorem, it follows that every competitive equilibrium allocation is an NSE allocation. The competitive equilibria in the certainty and sunspots economies are essentially equivalent: sunspots do not matter in this particular (Arrow–Debreu perfect-markets) environment.

If the sunspots model is modified to account for restrictions on market participation (some of which are inescapable in dynamic economies), then the SSE concept is a proper extension of the standard notion of competitive equilibrium. The certainty equilibria reappear in the sunspots model as the NSEs, but because of restricted participation there are also new equilibria, the SSEs. Some of the SSEs are randomizations over NSEs, but others are not (Cass and Shell 1983: 212–27). Balasko, Cass and Shell (1991) modify the Cass–Shell restricted-participation model to allow for continuous changes in market participation. When relatively few consumers are restricted, sunspots do not matter. If the endowment is in the neighbourhood of a Pareto-optimal allocation, then sunspots do not matter. But if there are multiple certainty equilibria and if relatively many consumers face restrictions on market participation, then there are SSEs (see also Préchac 1990 and Villanacci 1988).

Another source of SSEs is incompleteness of financial markets – the polar case of restricted participation in which some financial markets are closed to all consumers. In this case, there is at least a continuum of SSEs if endowments are not Pareto optimal (see Cass 1989). Recent work on sunspots and incomplete financial markets, for example Cass (forthcoming), Pietra (forthcoming) and Suda, Tallon and Villanacci (forthcoming), establishes that the set of SSEs is at least equal in dimension to the number of missing financial markets. Since this result also obtains in economies with intrinsic uncertainty and incomplete markets (see Balasko and Cass 1989 and Geanakoplos and Mas-Colell 1989), it reinforces the idea that an SSE can be thought of as the limit of REEs as the effects of intrinsic uncertainty on the fundamentals become small.

The three models discussed thus far began with the same ertainty economy, but different sunspots models were formed by varying properties of the securities markets. It is, of course, not necessary that the underlying certainty economy be an Arrow–Debreu economy. For Peck and Shell (1991), the underlying certainty economy is a market game. Even with complete financial markets and unrestricted participation, such imperfectly competitive economies can have uncertainty about market prices. As in the competitive-equilibrium incomplete-markets literature, SSEs exist in market games if and only if endowments are not Pareto optimal. Indeed, as the market-game economy becomes large through replication of consumers, then the limiting result is a competitive, incomplete-markets or complete-market SSE or NSE. Any spectrum of open and closed markets, financial and real, is consistent with limit equilibria in the market game. Certainty (i.e. pure-strategy) equilibria in the market game are also NSEs in the corresponding sunspot-contingent-securities game.

Detailed market structure matters more in imperfectly competitive economies than in perfectly competitive ones. Peck and Shell (1989) construct two different securities games from the same market game. In one, there is a full spectrum of Arrow (financial) securities. In the other, there is a full spectrum of (real) contingent commodities. A sunspot Nash equilibrium allocation in the Arrow-securities game that is not a mere lottery over Nash equilibrium (NE) allocations from the market game is *never* an NE allocation for the contingent-commodities game. The two games differ because the market power of individual traders depends on the way markets are organized.

ASYMMETRIC INFORMATION. Much existing sunspot theory is based on symmetric-information randomizing devices. This is not necessary. Indeed, asymmetric information enriches the role of extrinsic uncertainty in economic models, making it possible to relate sunspot-equilibrium theory to game theory (see Peck and Shell 1991; see also Maskin and Tirole 1987 and Aumann, Peck and Shell, forthcoming). If asymmetric information is introduced in market games, then there are NSEs in the securities game that are not equivalent to any certainty equilibrium from the underlying market game. More generally, we have that a correlated equilibrium to a market game is always either an NSE or an SSE to the corresponding securities game, but not conversely. Since SSE permits transfer of income across states of nature, while the self-enforcing nature of correlated equilibrium does not, there are SSEs which are not correlated equilibria. The market game with symmetric information was shown to yield recognizable competitive results as the economy is made large through replication. With asymmetric information, things are different. As the economy is made large through replication, some proper correlated equilibria persist. Each individual has a negligible influence on prices, but he does *not* take prices as given.

NONCONVEX ECONOMIES. Extrinsic uncertainty plays a role in nonconvex economies which is absent in convex economies. In nonconvex economies, the introduction of sunspots (or other randomizing devices) can lead to unambiguous welfare improvements, while in strictly convex economies SSEs are never Pareto optimal.

Possibly because of the importance of 'indivisible' goods in macroeconomic theory much of the analysis of SSEs in nonconvex economies is based on this case. In many macro applications (e.g. Hansen 1985 or Rogerson 1988), the indivisible good is labour. In the real world, labour time is, of course, divisible. What is assumed in this literature is that labour is only productive in standard work-week units; this is obviously only a first-order approximation to a more complicated nonconvex situation.

Indivisible labour is randomly allocated to jobs in the Azariadis (1975)–Bailey (1974) implicit labour-contract model and in the employment lotteries of Rogerson (1988) and Hansen (1985). These lotteries are similar to those that can arise in the presence of asymmetric information, as discussed by Prescott and Townsend (1984a, 1984b) (see also Townsend 1987). The early papers on SSEs in nonconvex economies are Guesnerie and Laffont (1991) and Cass and Polemarchakis (1990).

Shell and Wright (forthcoming) analyse SSEs in a competitive economy with indivisible goods. (Their model is similar to that developed by Hylland and Zeckhauser 1979). They establish that employment lottery equilibria can be decentralized as SSEs. Unlike the situation in the finite, convex case, in the indivisible-goods model (1) SSE allocations can be Pareto optimal and can even welfare dominate certainty equilibrium allocations and (2) certainty equilibrium allocations do not necessarily reappear as NSE allocations when extrinsic randomization is introduced.

There is a sense in which nonconvex economies 'choose' their own randomizing devices. SSE probabilities are typically not unique in economies with indivisible goods, and the SSEs in these economies are less robust than SSEs in finite, convex economies. Not all SSEs in nonconvex economies are stable to coalition formation, since some SSEs are not in the core. Nor are all SSEs stable to the introduction of more general casinos, that is, to refinements in the probability law. Restrictions on the available randomizing device can have profound effects on the allocation of resources. These issues are now getting further attention from Garratt, Goenka, Shell and Wright. The same group is taking the lead of Garratt (1991) in analysing the relationship between (Prescott–Townsend) lottery equilibrium and (Cass–Shell) sunspot equilibrium.

OVERLAPPING-GENERATIONS ECONOMIES. The original SSE research was influenced by Lucas's (1972) monetary theory of the business cycle. Lucas examines a stationary overlapping-generations economy in which monetary and demographic shocks occur simultaneously, and are not separately observed. As a result, individuals face a signal-extraction problem: shocks that would be neutral under full observability can have real effects under partial observability. Lucas also focuses exclusively on a specific class of equilibria – a quantity-theoretic class – in which the current-period price level is, *ceteris paribus*, proportional to the current-period money supply. This however, raises several questions. One is, is incomplete observability necessary for otherwise extrinsic uncertainty to matter? And, will equilibria naturally (necessarily) display quantity-theoretic properties?

Given Lucas's focus on the overlapping-generations model, it was natural for others to pose these questions in the same framework. Shell (1977) gives a negative answer to each of the above questions: extrinsic uncertainty can matter even when realizations of all random variables are fully observed, and the price level can fluctuate independently of fluctuations in the money supply (or other fundamentals). Azariadis (1981) extends these findings. Focusing on a stationary overlapping-generations model with a constant money supply (*à la* Gale 1973), he shows that there may exist SSEs in which the price level follows a stationary, two-state Markov process. Such SSEs work in the following way. A high current-period price level signals that next period's price level will be either lower than, or the same as, the current-period price level. Thus the expected return on money holdings will be (relatively) high. This is consistent with a high current-period price level (low real balances) if saving is decreasing in the rate of return. This requires relatively strong income effects: Azariadis shows that if these are strong enough, the constructed sunspot-contingent allocation will also be an REE allocation.

This mechanism is, of course, the same as that at work when Gale's model gives rise to equilibria displaying two-period cycles under perfect foresight. Such an observation suggests a relationship between the existence of Azariadis's SSEs and equilibrium 2-cycles; the existence of just such a relationship is demonstrated by Azariadis and Guesnerie (1986) and Grandmont (1986) under relatively mild regularity conditions.

These SSEs do not exhaust the set of possible SSEs in overlapping-generations economies. Guesnerie (1986) and Grandmont (1986) show that there are stationary SSEs that evolve in n-state Markov chains. Along different lines, Peck (1988) demonstrates that (possibly nonstationary) SSEs will arise in Gale's model under the condition that there is a continuum of perfect foresight equilibria, a condition which always obtains for properly chosen tax/transfer policies. Thus strong income effects are not required for SSEs to be observed. A similar mechanism to that used by Peck to construct SSEs is employed by Farmer and Woodford (1984) in the case of an economy monetizing a deficit. Further elaboration of conditions sufficient to allow SSEs in overlapping-generations models is provided by Spear (1984), Chiappori and Guesnerie (1991) and Guesnerie and Woodford (forthcoming).

Shell (1971) isolates two features that distinguish the OG model from the classical Arrow–Debreu model: (1) the 'double-infinity' of consumers and dated commodities, and (2) the natural restrictions imposed on market participation. The assumption of restricted participation does not affect perfect-foresight equilibrium, but it is, as we saw, a source of SSEs. Cass and Shell (1989) show that the 'double infinity' is also a separate source of SSEs. They also show how sunspot randomization can serve as an *imperfect* substitute for fiat money in attenuating the tendency of an economy to oversave.

In the developments discussed thus far, attention is restricted (as with Lucas) to economies with a single asset (and without credit). The credit-cycle discussion above emphasizes the importance of inside money and credit extension in generating expectations-driven cycles. This intuition is formalized by Smith (1988, 1989), who provides examples of economies that produce credit cycles. This observation motivates some of our discussion in a later section.

We note that many of the results that obtain in overlapping-generations economies also apply to economies with infinitely-lived agents who face cash-in-advance constraints. This idea is developed in detail by Woodford (1986), whose model can also accommodate multiple assets. Spear (1991) also constructs SSEs in such economies with externalities.

COORDINATION. SSEs appear to require a substantial degree of coordination among individuals. In particular, it seems that individuals must somehow agree on a relevant randomizing device, and on how it affects economic outcomes. But how is this agreement to be achieved? In the face of many possible randomizing mechanisms, coordination on one of them might seem improbable in a decentralized economy.

The issue of how this coordination might occur is taken up by several authors. One possibility is that individuals need to learn about their economic environment, and that various learning mechanisms they might employ converge to REEs that are also SSEs. This possibility is developed formally by Woodford (1990) and others. Another possibility, explored by Spear (1989), is that no extrinsic random variables are required as sunspot variables; rather, endogenous variables themselves function as sunspot variables. In Spear's example, there are two locations, and the price level in one location functions as the 'sunspot variable' in the other location. Thus individuals need not agree on an extrinsic randomizing scheme. Jackson and Peck (1991) construct a model in which individuals receive privately observed, non-fundamental signals (interpreted by them as signals about 'market psychology'). In this world the 'charting' of past prices contains information about future signals, and this charting can even provide economic actors with their extrinsic signals. The result is that there are some SSEs in which private signals affect observed prices. (We should note that this result is obtained in the context of trading via auction rather than competitively, but it holds even with a large number of traders.) All of these represent interesting approaches to how the coordination required for SSEs could be achieved in actual economies.

'STABILIZING' SUNSPOT FLUCTUATIONS. The possibility of SSEs raises questions as to whether there are policies that eliminate (some of) these equilibria. Or, alternatively, if these equilibria are not to be eliminated, are there policies that can neutralize the undesirable effects of extrinsic uncertainty?

Shell (1977) considers a policy that would not eliminate SSEs but would counteract their effects. This has the money supply expand or contract according to the current sunspot realization. He shows by example that such a policy can be optimal and will typically be active in every period. This sharply contrasts with the policy prescription in Lucas (1972), who calls for constant money-growth.

Grandmont (1986, see also 1985) designs government policies that eliminate SSEs. His policies set money-growth and tax/transfer levels according to 'feedback rules' that render the current price level a predetermined variable; this precludes the possibility of SSEs. A policy proposal that is commonly made is to have the government target a constant (or nearly constant) inflation rate, possibly zero, which is constitutionally mandated. Such a proposal has much in common with Grandmont's, in that it makes the current price level a predetermined variable, although not one set via a feedback rule. Smith (1991b) examines this policy in an overlapping-generations economy in which money coexists (because of reserve requirements) with assets that dominate it in rate of return. If the government maintains a target price-level path by standing ready to exchange money for interest-bearing assets on demand, this precludes SSEs, as in Grandmont. However, Smith shows that this policy can be very inefficient. Other policies that support a given target price-level path – like tax/transfer schemes – may be less inefficient, but permit sunspot indeterminacies to affect the money supply and real allocations.

The idea that the 'operating procedure' for the monetary authority may influence the scope for SSEs is also pursued by Woodford (1988). He considers a cash-in-advance economy operating under rules that either fix a constant money growth rate or a constant (positive) nominal interest rate. An interest-rate rule is supported by having the government stand ready to exchange interest-bearing bonds for currency on demand. Woodford then obtains the following result, which is quite striking in view of other results on the indeterminacy of the price level under an interest-rate rule. There is a unique equilibrium under an interest-rate rule, while money-supply rules that support the same steady-state (positive) nominal interest rate may allow SSEs to exist. The special feature of Woodford's economy that permits this result is that, under an interest-rate rule, all possible price-level histories but one result in the government accumulating claims on the private sector at a rapid enough rate to violate the transversality condition that arises from individual optimization. This kind of reasoning, of course, relies heavily on the presence of a transversality condition: in Smith's (1991b) economy, this interest-rate rule is consistent with a variety of equilibria.

Another class of policy proposals that deserves comment seeks to prevent private agents from issuing 'close substitutes' for money. Such proposals are based on the notion that a failure to do so will permit equilibria in which the price level and the inside money stock fluctuate 'excessively', and are possibly indeterminate (recall our discussion of the credit cycle). Obviously a consideration of this issue requires a model with both money and active credit markets. Smith (1988), following in many respects Sargent and Wallace (1982), constructs such a model in which SSEs can exist in the absence of government intervention. He then considers a 100 percent reserve requirement on lenders, and provides conditions under which this precludes certain kinds of SSEs. This obviously rationalizes the idea that legal restrictions which 'separate' money from credit markets may tend to reduce indeterminacies or the scope for excessive fluctuations. However, Smith also shows by example that these legal restrictions may result in greater welfare losses than the SSEs they are intended to preclude. Furthermore, Smith (1989) shows that there are other legal restrictions which are often advocated to separate money from credit markets and that can actually expand the scope for SSEs.

The idea that legal restrictions could be used to prevent 'excessive price-level fluctuations', but that these would have their own welfare costs, appears in Friedman (1960). In particular Friedman recognizes that, if legal restrictions cause individuals to face different interest rates, this is inefficient. As a remedy, Friedman advocates high reserve requirements in order to separate money from credit markets, but also that interest be paid on reserves at market rates. Friedman's proposal along these lines is analysed by Smith (1991a), who shows that paying interest on reserves at market rates can allow SSEs to exist, even if these are not possible when reserves earn no interest. This result is suggestive of a tension in the choice of economic institutions between the determinacy and the efficiency of equilibrium, a tension that is further suggested by the results of Woodford (1988) and Smith (1991b) discussed above, and in a static context by Goenka (1989, 1991). The idea of designing economic mechanisms in which *one* of the desiderata is *relative* stability in the face of sunspots is deserving of further research attention.

SURVEYS. For references on sunspots, see the reviews by Shell (1987) (which is very short on long-run dynamics), Chiappori and Guesnerie (1991) (which focuses on issues in long-run dynamics and has a large bibliography), Guesnerie and Woodford (forthcoming) (which mixes sunspots with complex dynamics and learning), and Geanakoplos and Polemarchakis (1991) (on overlapping generations).

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See also CONFIDENCE; MARKET AND ENVIRONMENTAL UNCERTAINTY; NEW MONETARY ECONOMICS; OVERLAPPING-GENERATIONS MODEL AND MONETARY ECONOMICS; RATIONAL EXPECTATIONS EQUILIBRIUM; VOLATILITY.

BIBLIOGRAPHY

Arrow, K.J. 1953. Le rôle des valeurs boursières pour la répartition la meilleure des risques. *Econométrie* 11: 41–7, Colloques Internationaux du Centre National de la Recherche Scientifique.

Arrow, K.J. 1964. The role of securities in the optimal allocation of risk-bearing. *Review of Economic Studies* 31: 91–6.

Aumann, R., Peck, J. and Shell, K. Asymmetric information and sunspot equilibria: a family of simple examples. In *Models of Incomplete Information and Bounded Rationality*, forthcoming, ed. H.W. Kuhn, New York: Springer-Verlag.

Azariadis, C. 1975. Implicit contracts and underemployment equilibria. *Journal of Political Economy* 83: 1183–202.

Azariadis, C. 1981. Self-fulfilling prophecies. *Journal of Economic Theory* 25: 380–96.

Azariadis, C. and Guesnerie, R. 1986. Sunspots and cycles. *Review of Economic Studies* 58: 725–37.

Bailey, M. 1974. Wages and unemployment under uncertain demand. *Review of Economic Studies* 41: 37–50.

Balasko, Y. 1983. Extrinsic uncertainty revisited. *Journal of Economic Theory* 31: 203–10.

Balasko, Y. 1990. Equivariant general equilibrium theory. *Journal of Economic Theory* 52: 18–44.

Balasko, Y. and Cass, D. 1989. The structure of financial equilibrium with exogenous yields: the case of incomplete markets. *Econometrica* 57: 135–62.

Balasko, Y., Cass, D. and Shell, K. 1991. Market participation and sunspot equilibria. CAE Working paper no. 88-11, Cornell University.

Cass, D. 1989. Sunspots and incomplete financial markets: the leading example. In *The economics of imperfect competition and employment: Joan Robinson and beyond*, ed. G. Feiwel, London: Macmillan.

Cass, D. Sunspots and incomplete markets: the general case. *Economic Theory*, forthcoming.

Cass, D. and Polemarchakis, H. 1990. Convexity and sunspots: a remark. *Journal of Economic Theory* 52: 433–9.

Cass, D. and Shell, K. 1980. In defense of a basic approach. In *Models of Monetary Economies*, ed. J. Kareken and N. Wallace, Federal Reserve Bank of Minneapolis: Minneapolis.

Cass, D. and Shell, K. 1982. Les tâches solaires ont-elles de l'importance? *Cahiers du Séminaire d'Econométrie* 24: 93–127.

Cass, D. and Shell, K. 1983. Do sunspots matter? *Journal of Political Economy* 91: 193–227.

Cass, D. and Shell, K. 1989. Sunspot equilibrium in an overlapping-generations economy with an idealized contingent-commodities market. In *Economic Complexity: Chaos, Sunspots, Bubbles, and Nonlinearity*, ed. W. Barnett, J. Geweke and K. Shell, New York: Cambridge University Press.

Chiappori, P.A. and Guesnerie, R. 1989. On stationary sunspot equilibria of order k. In *Economic Complexity: Chaos, Sunspots, Bubbles, and Nonlinearity*, ed. W. Barnett, J. Geweke and K. Shell, New York: Cambridge University Press.

Chiappori, P.A. and Guesnerie, R. 1991. Sunspot equilibria in sequential markets models. In *Handbook of Mathematical Economics*, Vol 4, ed. W. Hildenbrand and H. Sonnenschein, New York: Elsevier.

Diamond, D. and Dybvig, P. 1983. Bank runs, deposit insurance, and liquidity. *Journal of Political Economy* 91: 401–19.

Farmer, R.A. and Woodford, M. 1984. Self fulfilling prophecies and the business cycle. CARESS working paper, 84-12, University of Pennsylvania.

Friedman, M. 1960. *A Program for Monetary Stability*. New York: Fordham University Press.

Gale, D. 1973. Pure exchange equilibrium of dynamic economic models. *Journal of Economic Theory* 6: 12–36.

Garratt, R.J. 1991. On decentralizing lottery allocations in a market with simple non-convexity. In *Essays on Money, Taxation, and Uncertainty*, ch. 3, Ph.D. dissertation, Cornell University.

Geanakoplos, J.D. and Mas-Colell, A. 1989. Real indeterminacy with financial assets. *Journal of Economic Theory* 47: 22–38.

Geanakoplos, J.D. and Polemarchakis, H.M. 1991. Overlapping generations. In *Handbook of Mathematical Economics*, Vol 4, ed. W. Hildenbrand and H. Sonnenschein, New York: Elsevier.

Goenka, A. 1989. Government rules, public goods, and extrinsic uncertainty. CAE working paper no. 89-20, Cornell University.

Goenka, A. 1991. On the stability of rationing schemes. LSE discussion paper no. TE/91/222, London School of Economics.

Goenka, A. and Shell, K. 1990. Indivisibilities in production, and sunspot equilibrium. Notes prepared for the 1990 Meeting of the Society for Economic Dynamics and Control in Minneapolis. Mimeo, Cornell University.

Grandmont, J.-M. 1985. On endogenous, competitive business cycles. *Econometrica* 53: 995–1046.

Grandmont, J.-M. 1986. Stabilizing competitive business cycles. *Journal of Economic Theory* 40: 57–76.

Guesnerie, R. 1986. Stationary sunspot equilibria in an *n*-commodity world. *Journal of Economic Theory* 40: 103–27.

Guesnerie, R. and Laffont, J.-J. 1991. Notes on sunspot equilibria in finite economies. In *Essays in Honor of E. Malinvaud*, ed. P. Champsaur, Cambridge, Mass.: MIT Press.

Guesnerie, R. and Woodford, M. Endogenous fluctuations. In *Advances in Economic Theory*, forthcoming, ed. J.-J. Laffont, New York: Cambridge University Press.

Hansen, G. 1985. Indivisible labor and the business cycle. *Journal of Monetary Economics* 16: 309–28.

Hammond, B. 1957. *Banks and Politics in America from the Revolution to the Civil War*. Princeton: Princeton University Press.

Hylland, A. and Zeckhauser, R. 1979. The efficient allocation of individuals to positions. *Journal of Political Economy* 87: 293–314.

Jackson, M. and Peck, J. 1991. Speculation and price fluctuations with private, extrinsic signals. *Journal of Economic Theory* 55: 274–95.

Jevons, W.S. 1884. *Investigations in Currency and Finance*. London: Macmillan.

Keynes, J.M. 1936. *The General Theory of Employment, Interest and Money*. Reprinted in *The Collected Writings of John Maynard Keynes*, vol. 7, London: Macmillan, 1973.

Lucas, R.E., Jr. 1972. Expectations and the neutrality of money. *Journal of Economic Theory* 4: 103–24.

Manuelli, R. and Peck, J. 1990. Exchange rate volatility in an equilibrium asset pricing model. *International Economic Review* 31: 559–74.

Manuelli, R. and Peck, J. Forthcoming. Sunspot-like effects of random endowments. *Journal of Economic Dynamics and Control*.

Marimon, R., Spear, S.E. and Sunder, S. Forthcoming. Expectationally-driven market volatility: an experimental study. *Journal of Economic Theory*.

Maskin, E. and Tirole, J. 1987. Correlated equilibria and sunspots. *Journal of Economic Theory* 43: 364–73.

Peck, J. 1988. On the existence of sunspot equilibria in an overlapping generations model. *Journal of Economic Theory* 44: 19–42.

Peck, J. and Shell, K. 1989. On the nonequivalence of the Arrow-securities game and the contingent-commodities game. In *Economic Complexity: Chaos, Sunspots, Bubbles, and Nonlinearity*, ed. W. Barnett, J. Geweke and K. Shell, New York: Cambridge University Press.

Peck, J. and Shell, K. 1991. Market uncertainty: correlated and sunspot equilibrium in imperfectly competitive economies. *Review of Economic Studies* 58: 1011–29.

Pietra, T. The structure of the set of sunspot equilibria in economies with incomplete financial markets. *Economic Theory*,

forthcoming.
Préchac, A. 1990. Etudes sur des extensions du modèle d'équilibre général. Thesis, University of Paris I.
Prescott, E.C. and Townsend, R.M. 1984a. Pareto optima and competitive equilibria with adverse selection and moral hazard. *Econometrica* 52: 21–46.
Prescott, E.C. and Townsend, R.M. 1984b. General competitive analysis in an economy with private information. *International Economic Review* 25: 1–20.
Rogerson, R. 1988. Indivisible labor, lotteries and equilibrium. *Journal of Monetary Economics* 21: 3–16.
Sargent, T.J. and Wallace, N. 1982. The real-bills doctrine versus the quantity theory: a reconsideration. *Journal of Political Economy* 90: 1212–36.
Schlesinger, A.M., Jr. 1953. *The Age of Jackson*. Little, Brown and Company, Boston.
Schwartz, A.J. 1987. Banking school, currency school, free banking school. In *The New Palgrave: A Dictionary of Economics*, ed. J. Eatwell, M. Milgate and P. Newman, London: Macmillan; New York: Stockton.
Shell, K. 1971. Notes on the economics of infinity. *Journal of Political Economy* 29: 1002–11.
Shell, K. 1977. Monnaie et allocation intertemporelle, Communication to the Roy-Malinvaud Séminaire d'Econométrie. Mimeo, Paris. (Title and abstract in French, text in English.)
Shell, K. 1987. Sunspot equilibrium. In *The New Palgrave: A Dictionary of Economics*, ed. J. Eatwell, M. Milgate and P. Newman, London: Macmillan; reprinted in *The New Palgrave: General Equilibrium*, ed. J. Eatwell, M. Milgate and P. Newman, London: Macmillan, 1989.
Shell, K. and Wright, R. Indivisibilities: lotteries and sunspot equilibria. *Economic Theory*, forthcoming.
Simons, H.C. 1948. *Economic Policy for a Free Society*. Chicago: University of Chicago Press.
Smith, B.D. 1988. Legal restrictions, 'sunspots', and Peel's bank act: the real bills doctrine versus the quantity theory reconsidered. *Journal of Political Economy* 96: 3–19.
Smith, B.D. 1989. Legal restrictions, 'sunspots', and cycles. *Journal of Economic Theory* 47: 369–92.
Smith, B.D. 1991a. Interest on reserves and sunspot equilibria: Friedman's proposal reconsidered. *Review of Economic Studies* 58: 93–105.
Smith, B.D. 1991b. Efficiency and determinacy of equilibrium under inflation targeting. CAE working paper no. 90-20, Cornell University.
Spear, S.E. 1984. Sufficient conditions for the existence of sunspot equilibria. *Journal of Economic Theory* 34: 360–70.
Spear, S.E. 1985. Rational expectations in the overlapping generations model. *Journal of Economic Theory* 35: 251–75.
Spear, S.E. 1989. Are sunspots necessary? *Journal of Political Economy* 97: 965–73.
Spear, S.E. 1991. Growth, externalities, and sunspots. *Journal of Economic Theory* 54: 215–23.
Spear, S.E., Srivastava, S. and Woodford, M. 1990. Indeterminacy of stationary equilibrium in stochastic overlapping generations models. *Journal of Economic Theory* 50: 265–84.
Suda, S., Tallon, J.M. and Villanacci, A. Real indeterminacy of equilibria in a sunspot economy with inside money. *Economic Theory*, forthcoming.
Townsend, R.M. 1987. Arrow–Debreu programs as microfoundations for macroeconomics. In *Advances in Economic Theory: Fifth World Congress*, ed. T. Bewley, Cambridge: Cambridge University Press.
Villanacci, A. 1988. A note on regular economies in sunspot models. Preliminary paper, University of Pennsylvania.
White, L.H. 1984. *Free Banking in Britain: Theory, Experience, and Debate, 1800–1845*. Cambridge: Cambridge University Press.
Woodford, M. 1986. Stationary sunspot equilibria in a finance constrained economy. *Journal of Economic Theory* 40: 128–37.
Woodford, M. 1988. Money policy and price level indeterminacy in a cash-in-advance economy. Manuscript, University of Chicago.
Woodford, M. 1990. Learning to believe in sunspots. *Econometrica* 58: 277–307.

Super Bowl stock market predictor. Among the most perplexing and accurate predictors of stock market performance is the Super Bowl Stock Market Predictor (SB SMP). Proponents of the SB SMP contend that the value of equities, as measured by any of the popular stock market indices, will be higher at the end of the year than at the beginning if the American professional football championship game (the Super Bowl) is won by a member of the old National Football League (NFL). If the Super Bowl, which is played in January, is won by a member of the old American Football League (AFL), the stock market will finish the year lower than it began. Teams reassigned from the NFL to the American Football Conference in the 1970 league merger do not lose their original NFL classification.

The SB SMP has correctly forecast the change of major United States' equity market indices in 21 of the 24 years since the Super Bowl was first played in 1967, an accuracy rate of 87.5 percent. Even after adjusting for the commonality of National Football League team victories and stock market advances, this phenomenon is significant at the 0.01 level.

The SB SMP has been the subject of rigorous research and light-hearted reporting. Over the game's 24-year history, Kennedy and Krueger (1991) document an average Standard and Poor's 500 increase of about 15 percent during those years in which the Super Bowl is won by the NFL representative. Comparatively, the S&P 500 has declined by almost 11 percent on average when an AFL representative was victorious. Significant differences were also found to exist during the first day and week following the Super Bowl.

Kennedy and Krueger (1991) compared a buy-and-hold strategy and use of the SB SMP, wherein funds were invested in the S&P 500 following NFL victories and a money market fund following AFL victories. Tax-exempt investors earned over two and one-half times as much using the SB SMP. After adjusting for estimated taxes on capital gains and dividends, use of the SB SMP resulted in a terminal portfolio value two-thirds greater than a buy-and-hold strategy. Interestingly, in two of the three years that the SB SMP has been wrong, the AFL representative won, predicting a stock market decline, and directing investment in a money market fund. Returns on the money market fund in these years exceeded the return on the S&P 500. The buy-and-hold strategy outperformed the SB SMP in the other year.

Researchers have been unable to identify the source of this seemingly fortuitous relationship, but have discovered that (1) the phenomenon is international (the average change in the Financial Times Index during NFL years was 20 percent and AFL years was −7 percent); (2) no relationship exists between the Super Bowl outcome and prior stock