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Ponzi games. Charles Ponzi (188?–1949) was the archetypical confidence man, a swindler who in the space of eight months raised nearly 15 million dollars from 40,000 investors by promising 'double your money' in 90 days. While Ponzi claimed to be taking advantage of arbitrage opportunities in international postal coupons, he was in reality operating a financial chain letter, using funds from new investors to pay off earlier investors. Federal agents arrested Ponzi in August 1920, and he served three and a half years in prison. The final bankruptcy report, issued in 1931, showed Ponzi's firm to be insolvent to the tune of over two and a half million dollars (see Grodsky 1990; Time Magazine 31 January 1949; Newsweek 1 April 1957; and Train 1985. No two accounts fully agree on the details of Ponzi's activities).

To Kindleberger and other writers on financial scams, the essential feature of Ponzi's activities was 'misrepresentation or the violation of an implicit or explicit trust' (1978: 79–80). In economic theory, however, the label 'Ponzi' survives largely stripped of its connotation of fraud. Minsky (1975) was perhaps the first to appropriate the label in print, defining 'Ponzi finance' as a 'situation in which cash payments on debt are met by increasing the amount of debt outstanding' (Minsky 1982: 67). In Minsky's case, both borrowers and lenders expect, *ex ante*, that debts will be repaid out of the proceeds of real assets.

The neoclassical general equilibrium literature has focused on a second, more fundamental feature of Ponzi's scheme: the fact that debts were backed not by real assets but by future debts. The term 'Ponzi game' therefore describes a situation in which a borrower rolls over debt *perpetually*, covering all interest and/or principal repayments with additional borrowing. Such an arrangement has the property that the initial flow of resources from lenders to the borrower is not ultimately offset by a flow of equal present value in the opposite direction. Thus O'Connell and Zeldes (1988: 434) define a 'rational Ponzi game' as 'a sequence of loan market transactions with positive present value to the borrower'.

While a debtor's getting something for nothing might seem inconsistent with investor rationality, it is not hard to find examples of Ponzi games in models with rational, fully informed agents. Diamond's (1965) overlapping generations model, for example, has steady state equilibria in which the real interest rate is below the growth rate of the labour force and government debt per capita is positive. In these steady states, the total stock of government debt increases at the rate of population growth, which exceeds the interest rate. New debt therefore finances all of the interest payments on existing debt, plus some additional transfers to the young. Government debt in this context represents a Ponzi game.

Ruling out irrationality or asymmetric information, the critical requirement for the feasibility of rational Ponzi games is a perpetual flow of new lenders into the system. Without this feature, Ponzi games can be ruled out quite generally under certainty; with this feature, both Ponzi games and a variety of other related phenomena, including asset price bubbles and dynamic inefficiency, are possible.

To see the importance of the number of lenders, consider a world of certainty in which an agent's net indebtedness at the end of period t, D_t, satisfies the recursion $D_t = (1 + r_t)D_{t-1} + Z_t$, where Z_t is the net cash flow received from lenders in period t. If all debt is to be fully repaid by some period T, the present value of future payments from period 1 to period T must be at least as great as the debt outstanding at time 0, that is, $D_0 \leqslant PV(-Z_s,\ 1 \leqslant s \leqslant T)$. Alternatively, using the recursion and assuming for convenience that the interest rate is constant, we must have $(1+r)^{-T}D_T \leqslant 0$. The analogous infinite horizon condition is $D_0 \leqslant PV(-Z_s,\ s \geqslant 1)$, or $\lim_{T\to\infty}(1+r)^{-T}D_T \leqslant 0$, which we will call the standard terminal constraint (if the limit does not exist, the analysis goes ahead with lim sup). A Ponzi game is a scheme in which this repayment condition is violated, that is, in which the agent's discounted future indebtedness is strictly positive. A government that borrows an amount Z_0 in period 0 and rolls it over forever is running a rational Ponzi game, since in this case, $\lim_{T\to\infty}(1+r)^{-T}D_T = Z_0 > 0$.

When the number of potential lenders is finite, Ponzi games can be ruled out by appealing to rationality. Clearly no rational lender will be willing to hold a debt that is never repaid, since to do so would involve sacrificing current consumption without any offsetting gain. The borrower therefore faces a constraint of the form $\lim_{T\to\infty}(1+r)^{-T}D_T(j) \leqslant 0$, *vis-à-vis* any lender j, where $D(j)$

is the borrower's debt to that lender (this constraint holds regardless of the horizon of the lender, although clearly an even stronger constraint, $D_T(j) \leq 0$, holds *vis-à-vis* any lender whose horizon is $T < \infty$). Summing up over a finite set of lenders, we get the standard terminal constraint, which rules out Ponzi games (see O'Connell and Zeldes 1988, Proposition 2).

As pointed out by Tirole (1985a), however, one cannot pass the summation operator through the limit operator when the summation is over an infinite set of terms. The standard terminal constraint therefore need not hold when the number of potential lenders is unbounded. With an infinity of lenders, the borrower may be able to pay off each generation of lenders by borrowing from the next generation.

A number of observations are immediately implied by the necessity of an infinity of agents. First, since populations are finite at any point in time, Ponzi games can only take place over the indefinite future, and require the perpetual birth of new agents into the economy. Death, in contrast, is unimportant for feasibility (for examples in which Ponzi games may be feasible even though the horizons of lenders are infinite, see O'Connell and Zeldes 1988, and Weil 1989). Second, what matters is that these agents act independently, so that the number of lenders is not only numerically, but also behaviourally infinite (see Koopmans 1957). Thus Ponzi games can be ruled out, for example, if intergenerational altruism reduces the infinite set of agents over time to a single finite set of infinitely-lived dynasties (*à la* Barro 1974), or if the decisions of successive generations are subordinated to those of an infinitely-lived central planner.

Third, there is a close link between rational Ponzi games and other phenomena that rely on an infinity of agents, such as valued fiat money, asset price bubbles and dynamic inefficiency. When a borrower runs a rational Ponzi game, the stock of debt grows at the rate of interest, r; the same is true, as shown by Tirole (1985b), for fiat money or other asset price bubbles (where an asset price bubble is defined as the difference between the price of the asset and the discounted value of the stream of associated payments). In order for these claims to be willingly held, desired aggregate saving must grow at least as rapidly. If income per capita is constant in a steady state, desired saving must grow asymptotically at the rate of population growth, n. In this case, since introduction of a bubbly asset or a rational Ponzi game crowds out real capital and raises the interest rate, it follows that these phenomena can only exist if the economy would be dynamically inefficient ($r < n$) in their absence.

O'Connell and Zeldes (1988, Proposition 3: 442) explore the relationships between Ponzi games and bubbles further. They show, for example, that rational Ponzi games are feasible in any economy in which there are equilibria with valued fiat money; moreover, any monetary equilibrium in such an economy can be replicated by an equilibrium with rational Ponzi games.

In the international debt context, Niehans (1985) and Bulow and Rogoff (1989) have emphasized that sovereign Third World debtors have an incentive, in the absence of sanctions other than exclusion from future borrowing, to default on any debt that does not constitute a rational Ponzi game. This suggests that lenders assessing the risks of international lending should be concerned only with the intentions and lending abilities of other lenders, current and future, rather than with assessing the borrower's creditworthiness (O'Connell and Zeldes 1988).

Most of the literature on Ponzi games and asset price bubbles has used versions of the neoclassical growth model of Diamond (1965) without technological change (e.g., Tirole 1985b). If technological knowledge can grow along with other factors, however, equilibrium income growth may exceed n. In this case, rational Ponzi games will be feasible for a wider range of initial r. The relationship of asset bubbles to dynamic efficiency in endogenous growth models has yet to be explored.

The preceding analysis is based on models with certainty. Under uncertainty the definition of a Ponzi game is unchanged, subject to an appropriate generalization of the present value calculation. An example of a Ponzi game would be a situation in which interest and principal were rolled over not only perpetually, but also in all states of the world. The analysis of the feasibility of Ponzi games becomes more complicated, however. Even when the Ponzi game debt is itself riskless, feasibility no longer depends on the relationship between the riskless interest rate and the (average) growth rate (Abel et al. 1989; Bohn 1991). Recent work suggests that Ponzi games are feasible only when the economy is dynamically (Pareto) inefficient in the absence of Ponzi games (Blanchard and Weil 1990).

STEPHEN A. O'CONNELL AND STEPHEN P. ZELDES

See also ASSET PRICE BUBBLES; BUBBLES; CRASHES; DEBT AND DEFAULT: CORPORATE VS. SOVEREIGN; OVERLAPPING-GENERATIONS MODEL AND MONETARY ECONOMICS RATIONAL BUBBLES; SPECULATION.

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