Equilibrium, instability, growth and feedback in economics

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Key words

Feedback; systems; system dynamics; causation; emergence; microfoundations; equilibrium; business cycle; crises; trend extrapolation; path dependence; lock-in; economic growth; arms race; complexity.

In the “capitalist” economies that have developed since the industrial revolution, many of the most important features are due to feedback processes. These recurring features generate regularities that are indispensable in trying to explain how the economy works. In contrast, human behaviour is highly heterogeneous and unpredictable, making it a poor basis for generating reliable explanations. A focus on the regularities generated by feedback and other system properties provides a reliable basis for systematic study. This is an alternative strategy to the traditional one of *imposing* regularity on human behaviour by assuming strict rationality and optimization, which has become questionable in view of the findings of behavioural economics.

The observed regularities include (i) stability, in the sense that major degrees of excess demand and supply are unusual, which is especially characteristic of product markets; (ii) fluctuations, with periods of underused resources, which occur in particular markets such as real estate, as well as in the economy as a whole (the “business cycle”); (iii) periodic crises, often characterised as the occurrence of bubbles and crashes; (iv) technological lock-in, the adoption of technologies that may be inferior, and other multiple-equilibrium phenomena; (v) growth in *per capita* GDP of historically unprecedented magnitude, of approximately exponential functional form, in successful economies since the industrial revolution. It is important to recognise that although these features occur regularly, they are typically not predictable in their timing, magnitude, etc.

An important advantage of this approach is that it provides an explicitly *causal* analysis: the feedback systems are loops made up of causal links. This satisfies the recommendation of Hausman (1992), referring specifically to the price mechanism, “that supply and demand explanations are causal explanations and that it is helpful to recognize this fact explicitly”. It also accords with more recent work in economic methodology that emphasises the importance of a causal account that is similar to the actually-occurring process (e.g. Alexandrova and Northcott 2013; Grüne-Yanoff 2013; Rol 2013; Rodrik 2015). It departs from an older tradition that recommended the use of “as if” theories, which substitute an abstract theoretical concept for the real-life causal process (Friedman 1953).

Feedback systems are able to causally explain empirically-observed regularities, because they have their own intrinsic (endogenous) causal processes that tend to generate a characteristic pattern of behaviour. They are relatively insensitive to the vagaries of heterogeneous human behaviour, and to initial conditions (Forrester 1970; Lane 2007).

Feedback systems, with similar properties, occur in all domains, including engineering and biology as well as economics. In the economy, feedback systems are driven by their incentive structures and behavioural factors. Each has its specific conditions of existence (generative causes, or etiology), including the type of market and the institutional conditions. Their operation generates unintended consequences that are *structured*.

The purpose of this paper is to demonstrate the contribution that a focus on feedback systems can make to the understanding of the modern economy. This involves a description of the various types of feedback, the incentive structures that drive them and the behavioural aspects, as well as a description of the conditions under which they typically occur, for example, why does market stability sometimes break down? It is important to recognise the context, which is that multiple causal forces occur in the economy, so that the feedback systems do not operate in isolation. This corresponds to the *ceteris paribus* clauses that are routinely included when modelling a particular causal process.

The description of the various types of feedback in this article does not constitute a complete list. Only rather simple systems with few loops are included. No attempt is made at creating "a model of the whole economy".[1] Rather, small feedback models are described that correspond to specific features, because the resulting simplicity makes the key points stand out more clearly. There are also reasons why it would be challenging to combine them into an overarching model. These small models have different units of analysis – e.g. the whole population, the whole economy, the financial sector (with links to more general economic activity), the housing market and its financial links, a sector of the real economy, the labour market as applied to a single firm, an individual bank. They also have different timescales, ranging from short-term market exchange to long-term economic growth. Near the end of the article I also provide a brief outline of some other ways that emergence can occur in the economy ("complexity economics").

Balancing[2] feedback

Stability in the economy

A long tradition in economics has been that markets are stable. The demonstration by Adam Smith and others that fluctuations or shocks in demand or supply are accommodated by price movements may be regarded as one of the founding concepts of economic theory. The flexibility of prices means that markets adjust. Consequently, market clearing – no excess supply or demand – is widely seen as *the* fundamental property of market economies, both at the level of the individual market, and at the macro level where Dynamic Stochastic General Equilibrium models have become standard. This is one of the most important meanings of the term "equilibrium" (for a discussion of the diversity of usage of this term see Mosini 2007, especially the chapter by Chick).

An alternative way of approaching this is that optimising behaviour facilitates stable and predictable market behaviour, especially if rational expectations are also present. The two views are not necessarily incompatible. However, given the findings of behavioural economics (Thaler 2015), this may be less convincing than it once was. More plausible is the view of Vernon Smith (1989, 166), based on findings from the related field of experimental economics, that while short-term behaviour is often far from the rational ideal, "the incentive properties of markets" ensure that "subjects adapt their expectations and behavior', thereby reaching equilibrium through the interaction of buyer and seller. This view emphasizes "the role of time in driving the market to higher degrees of rationality" (Heukelom 2014, 134).

The way the price mechanism works is most clearly seen if something changes. If a product becomes more popular, e.g. as a result of a successful promotion campaign, a celebrity's endorsement, or news reports that it is beneficial in some way (e.g. it is a "super-food"), there will be more potential buyers, some of whom will be willing and able to pay an increased price. Competition between them will cause the price to rise.[3] This in turn makes it more desirable for sellers to supply this product, so that over time more suppliers will tend to enter this market. These two processes correspond to the upper right and lower left arrows in figure 1, respectively.

[1] Attempts to create system dynamics models of the economy have been attempted, e.g. Forrester's national model (Forrester 2013), the Threshold 21 dynamic simulation tool to support development decision making (Bassi and Perdercini 2007), and the PKI-SD model (Radzicki 2008).
[2] I use the terms "balancing" and "reinforcing" feedback throughout, instead of "negative" and "positive", respectively, because the latter pair are often misused. For example, reinforcing (positive) feedback may be wrongly termed negative because its consequences are harmful (e.g. in Acemoglu and Robinson 2012).
[3] The outcome of competition between potential buyers tends to favour richer consumers, who have more buying power (Joffe 2017a); however, this is not readily expressed using standard feedback analysis.

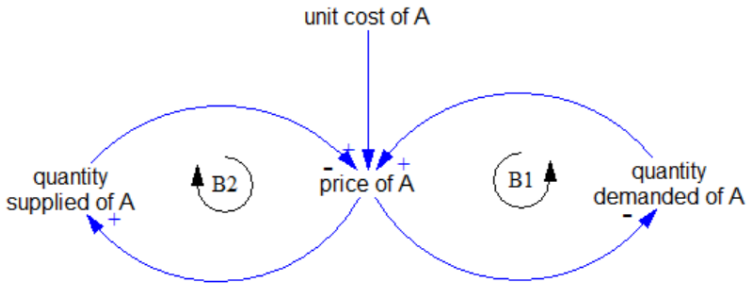


Figure 1.[4] The price mechanism

This is a demand shock. There can also be a supply shock: if there is a bumper crop due to favourable weather conditions, or if an abundant and easily accessible source of a mineral is discovered, the increased quantity will induce suppliers to compete amongst themselves to sell their produce, which will cause them to lower the price. In turn, the lower price will attract customers, raising the quantity demanded. These correspond to the upper left and lower right arrows in figure 1. The process is also likely to affect supply, because the lower price will tend to discourage traders from operating in that market, and indeed some of them may be driven out of that line of business.[5]

These various causal processes, depicted by arrows in figure 1, naturally form into a loop structure, with two balancing feedback loops, one each for demand and supply. The overall impact of this price mechanism is to bring about adjustment towards a position of equilibrium, in the sense that further trade is not advantageous to the participants. If it reaches equilibrium, this is stable: as long as the system is undisturbed, it remains unchanged. An exogenous shock is required to induce a change, either from the demand or the supply side as in the examples just given. The system has no other endogenous causal processes that lead it towards fluctuations, crises or growth, the causes of which lie elsewhere. This balancing feedback system explains why many markets tend to be rather stable; however, it does not necessarily bring about equilibrium at the macro level.[6]

In most markets, the profit, and therefore the viability, depends on the price being above the unit costs (arrow top centre in figure 1). The unit costs set a limit below which prices cannot go, at least for any appreciable time. The price is determined by supply and demand, but if the result is a price below unit costs, continued production is no longer profitable and is likely to cease. As a result, price competition drives prices down to a level just above unit costs, the difference being the markup (Lee 1998). Such markets could be described as *cost tethered*, because of the strong dependence of the price on unit costs. The model provides an excellent account of such sectors as goods and non-financial services in mature sectors, in which prices have had time to gravitate to a position just above unit costs. It is

[4] The diagrams in this article follow the convention that all arrows are causal. A plus sign indicates that an increase in the source variable causes the destination variable to increase above what it would otherwise have been (or a decrease in the source variable causes a decrease), other things being equal. A negative sign indicates the opposite. Loops are designated by B for balancing feedback, as here, or R for a reinforcing loop.

[5] The textbook (Marshallian) approach to the price mechanism involves the implicit assumption that the regression coefficient for the situation where a supply shock affects demand is the inverse of that for when a demand shock affects supply. This has been called into question empirically by Beaudry et al (2018) for the labour market: they note that studies of minimum wage legislation tend to observe small wage elasticities of employment demand, yet studies of labour supply shocks tend to find elastic labour demand. Similarly, the textbook description of the price mechanism states that in competitive markets, prices are formed to equate marginal revenue (given by the demand curve) with marginal cost (given by the supply curve). However, it has long been known that the causal process used by businesspeople is quite different from this account (Hall and Hitch 1939; Lee 1998).

[6] The emphasis on actual causal processes, depicted in a causal loop diagram that is easy to understand, is not only methodologically superior to the conventional static diagram involving supply and demand curves. It has also been shown to produce better results in the context of teaching (Mashayekhi et al 2006; Wheat 2008).

less applicable to recently-introduced products, where prices can initially depart substantially from unit costs, as was amply demonstrated in the 1637 Dutch tulip mania and in the "dot-com" boom and crash around the year 2000. It also does not apply e.g. to real estate and financial markets, where unit costs do not play a dominant role (see below).

The incentive structure and behavioural factors that form the endogenous causal processes of the price mechanism depicted in figure 1 are straightforward: people tend to prefer more of something to less of it, and to pay as little as possible. The basic relationship of demand and supply probably applies to all types of market, and therefore has an ancient history, but it is also important to remember that other causal forces sometimes operate, e.g. the well-known phenomenon that higher prices sometimes indicate higher quality, or the wealth of the buyer, and therefore *increase* demand. Other examples are discussed later in this paper.

Critics of the stability idea

Stability implies a smooth path for the economy. However, at least since the industrial revolution, the capitalist system has been prone to fluctuations in output and in employment, often with serious recessions. One account of such business cycles, highly influential in macroeconomics in recent decades, is Real Business Cycle theory, which attributes the fluctuations to exogenous forces such as productivity shocks arising from technological change. This preserves the notion that markets always tend to converge towards a stable equilibrium, requiring no change or addition to the model depicted in figure 1. However, the Real Business Cycle model has not been empirically successful (Summers 1986; Romer 2008).

Contrary views have been expressed by many economists. Notably, Kindleberger (1978) argued that "manias, panics and crashes" are an inherent feature of markets. He described the recurrent nature of booms and busts, going back well before the industrial revolution to such events as the 1637 Dutch tulip mania and the 1720 South Sea Bubble. From being a relatively minor sub-branch of economics, this focus has become far more prominent, and there is now a burgeoning literature on bubbles, especially since the 2008 financial crisis (e.g. Cheng et al 2014; Galí and Gambetti 2015; Eckel and Füllbrunn 2015; Charles et al 2016).

The crisis also focused attention on Minsky's Financial Instability Hypothesis (Minsky 1986; 1992), which is described below. After being largely ignored for many years, Minsky's account has received considerable attention since 2008, and has been credited with providing a good framework for understanding the crisis (McCulley 2009; *The Economist* 2010). It is now widely agreed that the tendency to instability is an intrinsic part of the economic system, even if this view has not been well integrated with the abstract models of general equilibrium, or with standard theory more broadly.

Fluctuations

The balancing feedback system depicted in figure 1 does not always guarantee stability. Even if the causal processes of supply and demand operate as shown, the equilibrium position is not necessarily reached if there is substantial delay. In real estate markets, the demand for offices, housing, etc is high when the local economy is thriving, so that rents and prices tend to rise. This attracts developers, and many new projects are started; this tendency is greatly amplified by the providers of finance. The buildings typically take two to five years to complete, and the availability of this extra space then creates a glut, so that rents fall (Sterman 2000, 698-701). The system thus has a built-in tendency to overshoot, generating fluctuations. Clearly, the instability could be avoided if developers and financiers took account of the supply line of buildings on order and under construction – and they would also gain financially. However, market participants initiate new building in response to *current* profit levels, not to the profit that could be anticipated if the supply line were part of the calculation (Sterman 2000, 701-707). It is noteworthy that the real estate market is not cost tethered – rather, it is *free floating* in that unit costs do not play the dominant role in price setting.[7] The top-centre arrow in figure 1 is not present.

[7] Other important examples of free-floating markets, in which prices lack a major input from unit costs, are the financial sector, primary products – minerals and agricultural produce ("commodities"), and collectibles e.g. valuable works of art.

Such fluctuations are the hallmark of balancing feedback with delay. It is a plausible candidate for understanding the causal forces underlying business cycles more generally, as this pattern fits well with the periodic oscillations that are manifest in modern economies, going back at least as far as 1825. Some but not all of this business cycle fluctuation is attributable to the boom-and-bust cycle in real estate itself and its amplification by finance. It is likely that similar phenomena occurring also in other parts of the economy could be responsible, e.g. a "general glut" of aggregate supply in relation to aggregate demand (Kates 2003), debt accumulation not exclusively linked to real estate (Eckstein and Sinai 1990), changes in the distribution of aggregate income between profits and wages (Goodwin 1967), etc. This is a large topic, detailed discussion of which is beyond the scope of the present paper.

A related idea is concerned with financial crises, which are downturns that are more severe, and less common, than "normal" recessions in the course of the business cycle. Minsky's financial instability hypothesis deals with the long-term changes that predispose to crises, emphasising that the tendency to crisis is a property of the system: "The financial instability hypothesis is a model of a capitalist economy which does not rely upon exogenous shocks to generate business cycles of varying severity" (Minsky 1992) (this would not prevent such a shock being a precipitating factor that propels the system from one state to another). When a crisis occurs, the authorities respond by introducing controls, and market participants become more cautious because they remember the turmoil. As the decades pass, traders become less conscious of the dangers and start taking more risks, and the authorities loosen their control, partly as a response to lobbying. This may be rationalised using such phrases as "this time is different", "we economists have now solved the problem of instability", "the new economy", etc. Eventually the financial system crashes, and caution becomes fashionable again.

Minsky expresses the increase in risk-taking in terms of three types of finance: hedge finance in which borrowers can repay capital and interest (typical of governments, corporations and banks); speculative finance in which only the interest is repaid, with reliance on rolling over the debt at maturity; and Ponzi finance in which not even interest can be repaid from current earnings, relying as it does on asset prices continuing to rise. The increase in risk-taking takes the form of transition from one type of finance to a riskier type. As long as hedge finance dominates, the economy may well be stable. But "the greater the weight of speculative and Ponzi finance, the greater the likelihood that the economy is a deviation amplifying system" (Minsky 1992). This process of the gradual loss of caution following a crisis is balancing feedback with a long delay, creating its characteristic fluctuating pattern, which is then accentuated in the final stage by reinforcing feedback. The role of finance in converting fluctuations to crises is well demonstrated in Keen's "Minsky" model (see below).

A further important role of balancing feedback occurs in modern economies that have a welfare system and a comparatively large state. The effects of recessions, however caused, are cushioned by "automatic stabilisers". These consist of a welfare system that increases payments to those affected by a downturn, and the taxation system that goes with a sizeable state. When the economy slows, tax receipts diminish and welfare payments increase, leading to a budget deficit that allows the private sector to expand without damaging economic output (Godley 1996). Conversely, in good economic times, tax revenues increase and welfare payments decrease, so that the government's deficit is reduced. The impact of the business cycle is thereby damped. The relatively good recovery of the US economy from the 2008 crisis – especially when compared to the years following 1929 – has been attributed to this mechanism (Krugman 2009).

Reinforcing feedback

Feedback in the economy is not necessarily only of the balancing type. Some economic phenomena are due to reinforcing (positive) feedback. This insight is not new: it was emphasized by economists such as Young (1928), Myrdal (1957) and Kaldor (1966).

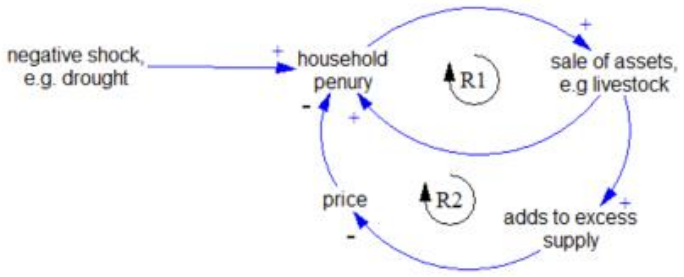
Reinforcing feedback systems have the property that as causal impulses are propagated around the feedback loop, each iteration generates a further increment of change. Even if the increment is small for each iteration, large effects can result from multiple iterations over a long time period. (This property of iterative systems is not confined to those displaying reinforcing feedback, and is seen for

example with compound interest, the multiplier, and Schelling's model of segregation (Schelling 1971)).

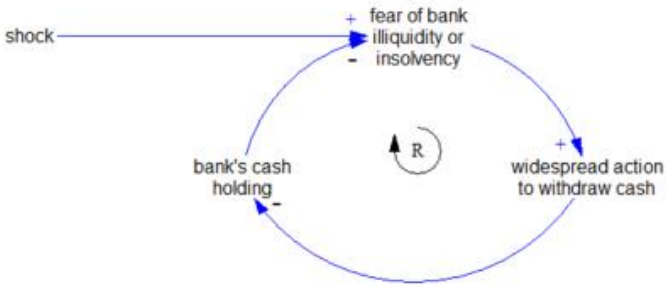
One example of reinforcing feedback is that high inflation leads to the expectation of continuing inflation, so that wage demands are higher, fuelling yet more inflation. This is a self-fulfilling prophecy, driven by trend extrapolation, the tendency to believe that an existing trend is bound to continue into the future. In this instance, it means a belief that the existing inflation rate will persist. Another example is that one of the key properties of money, social acceptance, is self-fulfilling: the more reliable is the acceptance of a currency, the stronger is the belief in its acceptability, and *vice versa*. The phenomenon of self-fulfilling prophecies is more general. It is a form of reinforcing feedback that results from the interaction between the economy and agents' perceptions and expectations. Other self-fulfilling prophecies are described in the next section.

Crises

Beyond the fluctuations of the business cycle, more severe forms of economic downturn can occur. Typically these originate in the financial sector, but this is not necessarily the case. For example a fire sale can occur in any sector, and the phenomenon is not confined to modern capitalist economies. Figure 2 panel (a) sketches out the reinforcing feedback involved in a fire sale affecting pastoralists in a low-income country, e.g. in the Sahel drought of 2012 (Callimachi 2012). A negative shock such as a drought leads to a decrease in household income, not just for the individual household but for many over a wide area. In order to eat, households are forced to sell their main assets, their livestock, reducing their assets (loop R1). In addition, because a large number of people are in this situation, the price falls. As a result, the proceeds from the sale of each animal is ever-decreasing, adding to the penury of the household (R2).



(a) a fire sale among low-income pastoralists



(b) a bank run

Figure 2. Fire sale and bank run

A similar phenomenon, the "poverty premium", occurs more routinely. Again, it is not confined to the modern economy. People on low incomes may be unable to afford certain items without borrowing. Often this is at a high rate of interest. They therefore end up paying more for a given product, thus reinforcing their poverty.

Returning to the modern economy, the financial sector appears to be especially prone to instability, bubbles and crashes. It shares this tendency with other free-floating markets; they are not dominated by unit costs, and therefore lack their tethering influence. Note that this is a *system property*, and does not depend on the characteristics of the participating individuals – indeed, participants in financial markets tend disproportionately to be highly educated in subjects such as economics, mathematics and physics, and are likely to be at least as rational as the general population.

An obvious example of instability in the financial sector is a bank run: the fear of bank illiquidity or insolvency leads to widespread action to withdraw cash. This depletes the bank's cash holding, further accentuating the fear of bank illiquidity or insolvency (figure 2, panel (b)). It is another instance of reinforcing feedback of the self-fulfilling prophecy type. The issue here is the quantity of cash.

It can also be a question of price. For example, if a government is short of finance and needs to borrow, as with Greece and other southern European countries during the recent Eurozone crisis, a high perceived risk of default leads to a higher interest rate, which increases the risk of default. A similar relationship was observable as the 2007-08 crisis developed, with a spiral of increasing risk and rising interest rates over time.

Similarly with a stock exchange: a fall in the price of a stock can lead to large-scale selling and a further fall. Since the introduction of computerised systems to control buying and selling, this can occur without any human intervention, just from the computers following the rules embodied in their algorithms – as in the flash crash of 6 May 2010 in which the Dow Jones lost 9 percent of its value within minutes, and then quickly rebounded to almost the same level. The reinforcing feedback is automated, based on the underlying dynamic which is trend extrapolation: the falling price of a stock is taken as signifying a trend that will continue.

Upward price movements that are not justified by fundamentals, bubbles, are also caused by trend extrapolation ("momentum trading"). A rise in asset prices, e.g. in financial markets or real estate, leads to the expectation that prices will continue to increase. Traders fear missing out on the gain, and are therefore willing to pay more (except when the rise is sudden and excessive) (Caginalp and Desantis 2011). Intensity of competition between agents only amplifies this behaviour. Unlike the situation depicted in figure 1, price rises are self-reinforcing, until the money runs out. This is readily demonstrable in experimental situations (Caginalp et al 2001), as well as occurring in the real world. This self-reinforcing system behaviour occurs predominantly in free-floating markets, because prices are based purely on perceptions, unlike in cost-tethered markets.[8] It is distinct from the fluctuating behaviour in real estate markets described above, but they are linked; typically the reinforcing feedback is initiated by an upturn in price during the course of fluctuations due to balancing feedback with delay, with trend extrapolation accentuating this initial movement.

Relatedly, a fall in asset prices deteriorates firms' balance sheets, reducing their net worth and thus their ability to borrow and to invest, leading to a further fall in asset prices. This can happen to an individual firm, or at the macro level (the financial accelerator). It is problematic even on the upside – as Rogoff (2015) has put it: "As credit booms, asset prices rise, raising their value as collateral, thereby helping to expand credit and raise asset prices even more." An unsustainable bubble is likely to result. This has been described as a "doom loop", in which mortgage debt interacts with land and house prices to produce ever-rising asset prices in real estate (figure 3) (Ryan-Collins 2016). This type of reinforcing feedback means that private sector debt has a destabilising effect in many situations.

[8] See for example the list of 70 historical "manias, panics and crashes" in Kindleberger (1978, 45-46), which are virtually confined to the financial sector, company shares, commodities (including gold) and real estate. This picture is confirmed by a further 20 examples since 1978 (Aliber and Kindleberger 2015, 18). The exceptions to this pattern are new products, as previously argued, from the Dutch tulip bulb craze of 1636 to the dot-com bubble. Note that emotions such as "irrational exuberance" (Shiller 2005) do not play a *causal* role in this process, which operates in the same manner irrespective of whether a house buyer is *worried* that she will be priced out of her desired home if she does not buy quickly, or *excited* by the prospect of capital gains.

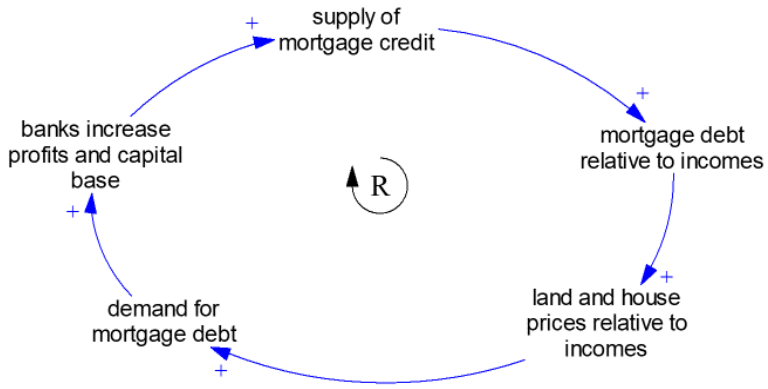


Figure 3. Ryan-Collins' "doom loop"

Reinforcing feedback can exacerbate an existing downturn. According to Friedman and Schwartz (1963, 673), in the Great Depression "The contraction … instilled an exaggerated fear of continued economic instability, of the danger of stagnation, of the possibility of recurrent unemployment." There was thus a feedback loop of economic depression and psychological depression among households and businesses, and vice-versa. Subsequent research has lent support to Friedman and Schwartz's hypothesis (Haldane 2015). This "dread risk" reduced investment and innovation by companies and the number of start-ups, a scarring effect that lasted a generation (Haldane 2015). As President Roosevelt expressed it in his inaugural speech of 1933: "the only thing we have to fear is fear itself".

A more complicated sequence of events, relating to financial crashes rather than inflating bubbles, is captured in Fisher's theory that attributes them to debt deflation (Fisher 1933) (figure 4). A downturn in the presence of a high debt level leads to a need for debtors to cover debt repayments, and therefore to distress selling at severely reduced prices. The repayment of debts causes the money supply to shrink, leading to deflation. The deflation raises the real burden of debt, because debts are in nominal terms (R1). More bankruptcies and a fall in profit result, followed by lower levels of output, trade and employment. This leads to pessimism and loss of confidence. Those who have money then hoard it, further reducing business activity (R2). And despite a falling interest rate in money terms, the real interest rate rises, greatly reducing investment (R3).

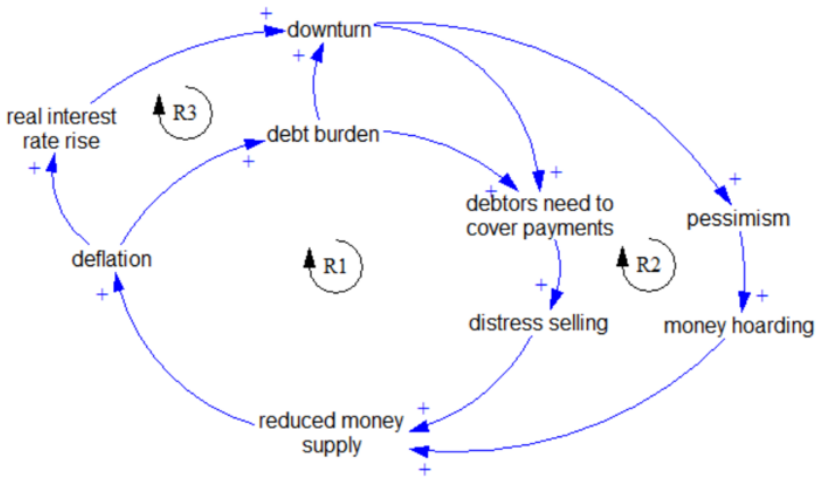


Figure 4. Fisher's debt deflation theory

These accounts do not exhaust the role of particular reinforcing feedback loops in financial crises. For example, in Tett's narrative of the 2008 crash (Tett 2010), she recounts six separate occasions in which reinforcing feedback played a role.

In addition, contagion between different parts of the economy is a system property. For example in the modern context, governments usually guarantee large banks against failure, so that banking crises often become associated with fiscal crises as well (Bordo and Meissner 2016). The flows in the financial sector do not remain confined to that sector, but spill over into the government sector. Similarly, financial flows can propagate within the financial sector – especially as it lacks a modular structure – causing localised risk to become systemic (Haldane and May 2011). Detailed discussion of these issues is beyond the scope of the present paper.

Complementarity: increasing returns and path dependence

Another type of reinforcing feedback occurs as a result of complementarity. A simple example is that a person may have a natural aptitude for a particular activity, e.g. playing the guitar. She is then more likely to spend time on this activity, as a result of which her expertise improves. Her increased skill in turn reinforces her attraction to the guitar, and so on through multiple iterations. The result is that people tend to specialise in specific niches that suit them, and conversely to exclude themselves from activities at which they could be proficient, but lack the initial attraction that draws them in. This is a situation of multiple equilibria.

An important instance is path dependence and technological lock-in, the consequence of increasing returns (Arthur 1994; Sterman 2000, 349-364 and 387-406). A classic example is the QWERTY keyboard, which did not necessarily have the optimal design when it was introduced, but which became the standard. This was because a relatively small initial advantage, which could have been for minor and/or random reasons, led to its increasing use, which in turn encouraged manufacturers to opt for that design (figure 5, panel (a), R1). In addition, training courses were then set up that prepared its students for what was becoming the industry standard, creating a cohort of workers with skills and a vested interest in its continuing success (R2). The reinforcing feedback here results from the complementarity of keyboard producers and users/trainers/etc.

The importance of complementary facilities can be seen also in reverse. When the motor car was first invented, its use was initially limited by the lack of fuel stations and suitable roads. A similar situation currently applies to electric vehicles, the expansion of which is limited by the lack of charging facilities.

This phenomenon is particularly important nowadays, in relation to software and internet apps, where it is generally referred to as "network effects". It results from the dependence of the attractiveness of an app on the prevalence of its use: once a word-processing program is widely used, it becomes more attractive because that facilitates sharing with colleagues, as well as efficiency in learning. A social media app is attractive because a large number of people are already signed up to it.

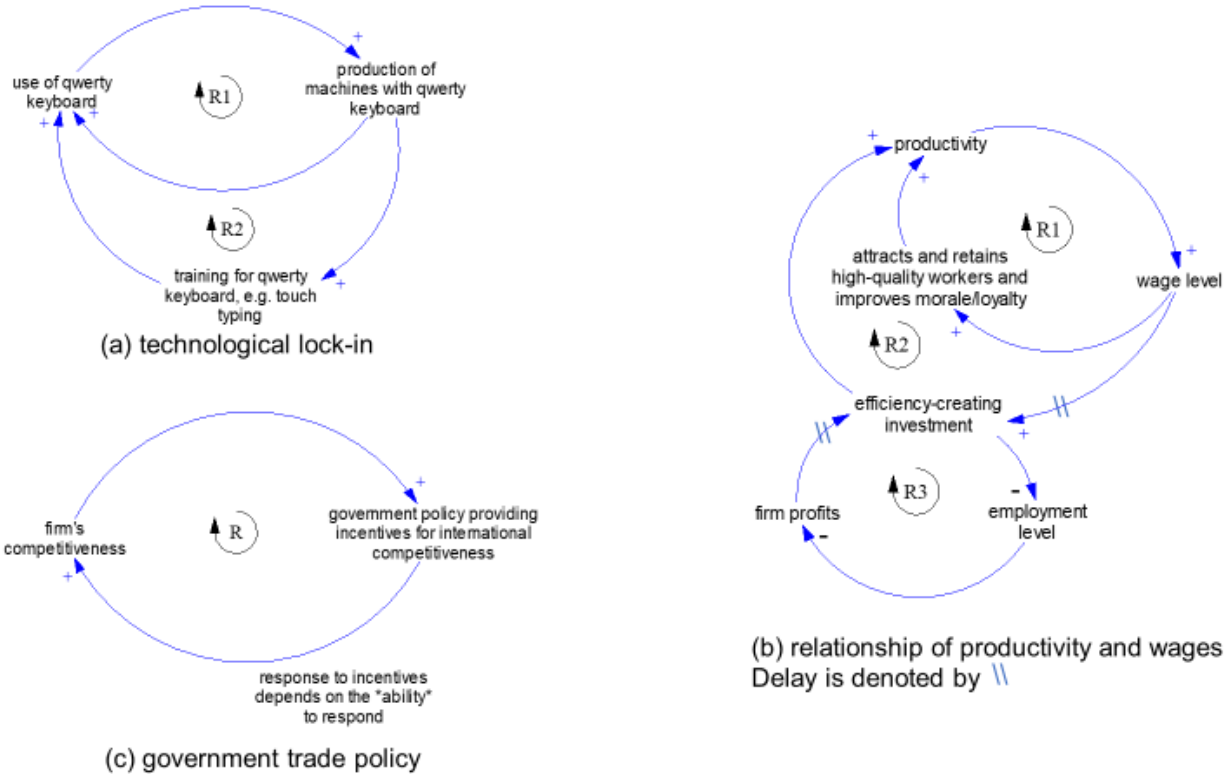


Figure 5. Increasing returns and path dependence

A different example of the same process is seen in the relationship of productivity and wages, due to the complementarity between employers and workers. A higher wage level attracts higher-quality workers. It also improves their morale and loyalty to the firm, as well as creating an incentive to perform well due to the fear of being dismissed and having to take a lower paid job. This contributes to higher productivity (Manning 2003). And the resulting profitability facilitates the higher wages, making one reinforcing feedback loop (figure 5, panel (b), R1). On a longer timescale, high wages provide an incentive to invest so as to reduce the wage bill. If successful, this investment improves productivity and profitability, reinforcing the ability of the firm to afford high wages. This completes a second reinforcing loop (R2). In addition, such investment may result in a lower number of workers required to generate the same output, thereby increasing profits, which in turn increases the affordability of further investment – a third loop (R3). As with all such systems, it can also be read in reverse terms: low wages, unproductive employees, worker alienation, high staff turnover, low productivity and low investment. Similarly, over-stressful working conditions can lead to difficulties in retaining and recruiting staff, leading to a smaller workforce available to carry out the work, leaving the remaining workers with an ever-heavier workload and a further increase in stress.

A third reinforcing-feedback cycle of the same family occurs in the policies of different governments in relation to foreign trade, and specifically, international competitiveness. East Asian governments such as Japan, Taiwan and South Korea have famously induced their domestic firms to become able to compete successfully at a global level, using incentives, regulations and direct channelling of capital (Studwell 2013). The firms responded, and contributed to high and sustained levels of economic growth on this basis (figure 5, panel (c)). On the other hand, the prevailing practice in mid-twentieth century Latin America was import-substitution industrialization (ISI), reflecting a lesser capacity of their firms to respond to the challenge of international competitiveness – or a lack of governments' confidence in their ability to do this (Franko 2007). The complementarity here is between governments and firms.

Competition: arms races and economic growth

For most of human history, economic growth was zero, and the vast majority of people lived at the level of bare subsistence. Some economic historians analyse this as a “Malthusian” economy (Clark 2007; see also Richardson 1999): any temporary rise in prosperity leads to population growth and therefore to pressure on resources; this results in living standards falling back to the original level, a balancing feedback loop (figure 6).[9]

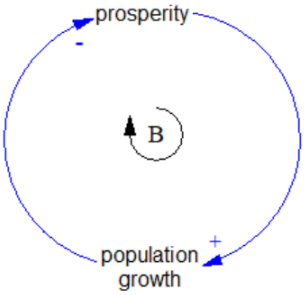


Figure 6. The Malthusian loop

Economic growth in the modern sense dates only from the industrial revolution, two and a half centuries ago (see below). But there were important instances of growth before that, albeit small in magnitude by modern standards, and generally lasting less than a century – sometimes followed by decline in absolute terms. Examples include China in the Song dynasty (11th and 12th centuries), early medieval northern Italy, the Netherlands in the Golden Age of the 17th century, and Britain in the period before the industrial revolution.

In the very early phase of transition to an industrial economy in Britain, Smith (1776) argued that the main feature leading to increased prosperity was the division of labour: specialisation allowed greater skill in production (figure 7, R1) and less wasted time in passing from one task to another (R2). It also facilitated the introduction of better production methods (R3). As a result of each of these, unit costs fell – and so did prices, increasing the potential number of buyers. In addition, he pointed out that the extent of the division of labour depends on the extent of the market, as a higher production volume allows differentiation to take place within the workforce – a reinforcing feedback loop that depends on economies of scale. Economic historians call this “Smithian growth” (Kelly 1997).

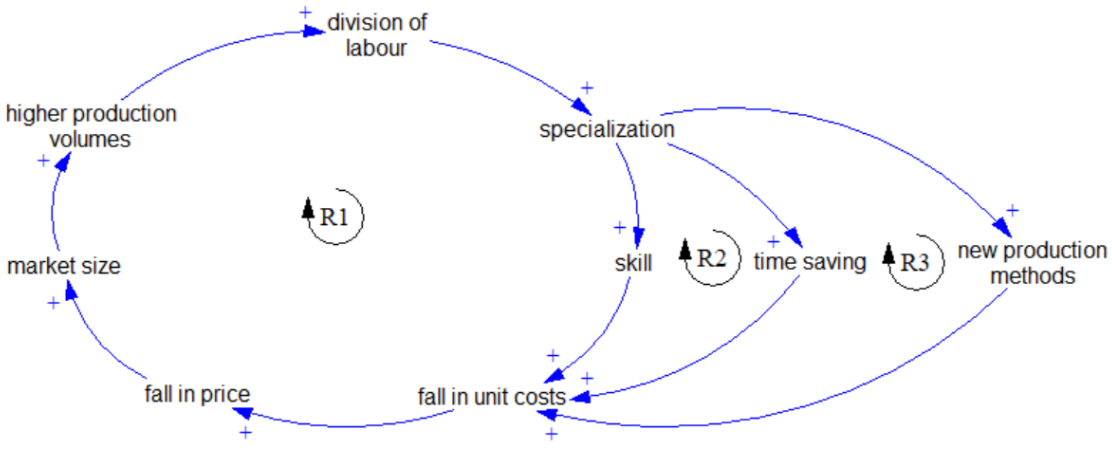


Figure 7. Smithian growth

[9] This situation refers to preindustrial times. Since the industrial revolution, countries have undergone demographic transitions, after which prosperity tends to reduce the rate of population growth.

In the pre-industrial era, other reinforcing loops were present, including important links between the economy and institutions. Smith emphasised that his economic theory only applied under suitable institutional arrangements. It is also clear that a degree of prosperity facilitated the development of "good" institutions, which in turn provided a foundation for reliable commercial activity – an example of reciprocal causation that remains an issue today in less-developed economies (Casson et al 2010).

Smith's account of the role of specialisation and trade in economic development has been highly influential, indeed it can be regarded as a foundation stone of economic thinking. However, it does not explain the type of growth that started to occur shortly after his classic account was published. In late eighteenth-century Britain, a new type of economic system began to emerge that combined radical organisational innovation, especially the factory system, with accelerated technical change. Once this became established, and developed its legal underpinnings, it was associated with a completely new phenomenon in economic history: a positive growth rate of substantial magnitude, continuing apparently indefinitely, which transformed the economy both quantitatively and qualitatively (Kaldor 1961; Joffe 2011). Schumpeter (1934; 1942) introduced the brilliant metaphor creative destruction for this new type of economy, but was not able to explain how it happened (Joffe 2013a).

Growth in such a system is the result of competition between firms of a new hierarchical type, which in system terms is an *arms race*: a reinforcing feedback system constituted by entities that compete with one another. This generates continuing growth because the survival and strength of such firms depends on its degree of competitiveness relative to others. If this falls too far below that of its competitors, it fails to make a profit, and ultimately ceases to exist.

The hierarchical structure of the new type of firm opened up the possibility of radically transforming its methods of production, its products, the location of its plants, etc. Its *ability to compete* was thereby greatly boosted. All inputs could now be purchased, allowing indefinite expansion of the successful firms, and consequently the possibility of taking over market share from less successful competitors. Firm size was now no longer limited by the labour of the owner and close associates, as had been the case with e.g. a pre-industrial blacksmith. Size and success were now able to expand to the limit of managerial capacity (Penrose 1959). This led to the emergence of a broad and highly right-skewed distribution of firm size (Axtell 2001).

The new "capitalist" firm also enormously facilitated innovation: the possibility of profit provided a clear *direction* for the talents of inventors, entrepreneurs and innovators to follow. The rewards of success in this endeavour are great, providing a powerful *incentive* for them to find ways to achieve it, and for those with relevant talents to *become* inventors, entrepreneurs and innovators. In these three ways the capitalist firm created the conditions that developed, motivated and channelled the types of invention, entrepreneurship and innovation that power the system. This explains the link between inventiveness and growth/prosperity, which is a modern phenomenon (Joffe 2015).

The historical attributes of this type of economy indicate that it is best regarded as a distinct type of system. This new economic structure, based on the new hierarchical type of firm, was successfully imported into other countries in Europe and lands of European settlement including the United States, and subsequently into Japan and then other East Asian economies, despite the enormous cultural differences between these societies. It transformed production, and led to economic growth of approximately exponential functional form. The implication is that all these features are attributable to the intrinsic causal properties of the system.[10]

[10] This explains why modern economic growth has only occurred since the advent of firms able to purchase all their inputs. It was an institutional change that started with the factory system, leading to legal changes that facilitated the expansion of the new type of firm into all areas of the economy (Joffe 2011). It also explains catch-up growth, e.g. in East Asia, which is a puzzle for the conventional view that modern economic growth is due to inventiveness, seen as external to the economic system. In addition, it can account for the relative *lack* of success in some economies with a capitalist structure, such as Latin America during the twentieth century, because the dynamism of the national economy depends on the degree of competitiveness of its constituent firms.

The incentive structure ensures that (surviving) firms are successful in competing, by reducing unit costs and/or by introducing new or better-quality products. The former case is depicted in figure 8 (for simplicity just two firms are shown – this should not be taken to imply duopoly). Firms invest to try and stay ahead: price reduction by one firm, or the threat thereof, encourages the other to invest to reduce its unit costs and hence its price. The other firm responds in kind.[11] This process can occur even without economies of scale or scope.

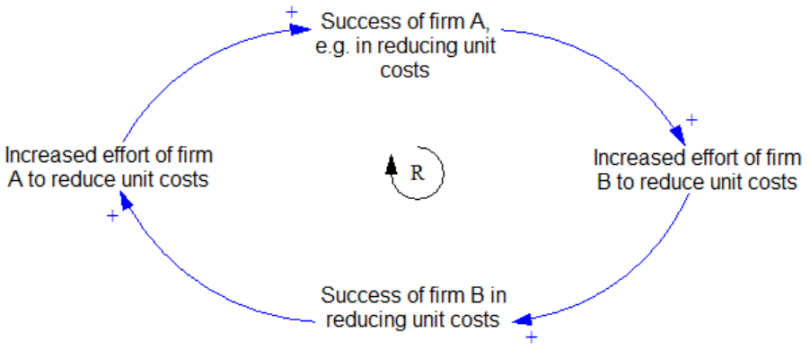


Figure 8. Cost competition

A firm with relatively low unit costs is in a strong position relative to its competitors, because it can charge a relatively low price while maintaining its profit margin and thereby increase its market share, and/or it can maintain a price similar to its competitors and increase its profit. This is cost competition, which occurs over a long timescale. It is distinct from price competition, which occurs in addition as a secondary consequence, so that prices fall approximately parallel to the fall in unit costs (Joffe 2011). The result has been a secular decline in real prices (measured in labour hours) (Cox and Alm 1997). The same basic process of inter-firm competition applies to product innovation as well as to process innovation.

Like all arms races, competition constantly erodes the advantage of each participant compared to others, but at the aggregate level there is a fall in unit costs for all the competing firms that survive.[12] There is no limit to the resulting fall in unit costs, as can be seen in such industries as recorded music and films, for which the marginal cost has now fallen to essentially zero.

The reinforcing-feedback nature of this system explains the magnitude of modern economic growth since the industrial revolution. McCloskey (2010) examined the various economic theories that have attempted to account for modern growth. She found that even taken together, at best they could only explain a few percent of the actual change, which has been of the order of an 18-fold increase in living standards.

In addition, the standard theories of economic growth do not explain *what changed* around the time of the industrial revolution in England, or the other empirical spatiotemporal features of modern growth, implicitly assuming that the growth tendency is natural or universal (Joffe 2017b). Instead, modern growth theory simply incorporates knowledge into its models, with the justification that being non-rival, its spillovers produce increasing returns that overcome the normal diminishing returns as present in

[11] A similar model has been constructed in the system dynamics software package Vensim (Joffe 2012). Simulations showed that the price charged by both firms steadily declined, apparently indefinitely, but only if they were both able to alter their unit costs. The findings were robust to other changes in the firms (efficiency of investment) or in the market (price elasticity of demand). The model did not include economies of scale or scope.

[12] Arms races also occur elsewhere in the economy, e.g. workers who work longer hours than they would wish, to try and achieve a better *relative* position over other workers – especially important in relation to positional goods, e.g. access to good schools (Frank 2011). Again, relative positions are constantly eroded as the success of one participant is matched by that of others, but the aggregate effect is that more hours are worked than would occur without this relative/positional aspect.

earlier models (e.g. Romer 1986). (One problem here is that there is no evidence for the hypothesis of diminishing returns (Nell and Thirlwall 2018).) New growth theory models also involve permanently different growth rates for each country, therefore predicting an ever-diverging world distribution, in contrast with the evidence since World War II (Sachs and Warner 1997; Parente 2001). And they are irrelevant to catch-up growth (Acemoglu 2009).

In addition to this basic system structure, it is well recognised that additional reinforcing feedback loops occur in the corporate world in an established capitalist economy. In the system dynamics literature, accounts are given in Sterman (2000) on corporate growth (pp. 364-85), market power (pp. 374-75), and price setting (pp. 813-24).

Another example is frequently observed in the modern industrial economy: when a firm is able to produce at low unit costs, and therefore low price, it is likely to be able to sell higher quantities. As the production volume increases, there is a tendency for unit costs to be reduced further, a phenomenon known as the experience curve (Henderson 1973; Hax and Majluf 1982), a type of learning curve (Radzicki and Sterman 1994). In each successive iteration, the effect is proportionally the same, but becomes progressively smaller in absolute terms.

Complexity

In recent decades, various theoretical approaches have been proposed that can be grouped under the heading of “complexity economics” (Anderson et al 1988; Waldrop 1992; Arthur et al 1997; Blume and Durlauf 2006; Beinhocker 2007; Orrell 2012). They have included attempts not only to explain the operation of the economy, or parts of it, but also to encompass the way that economies change over time as evolutionary and/or self-organising systems.

Complexity economics has sometimes been portrayed as superior to conventional economics, or even as a replacement for it: “the neoclassical era in economics has ended and has been replaced by … the complexity era” (Holt et al 2010). Arthur drew up a list contrasting “old economics” and “new economics” as long ago as 1979, with 21 separate items of difference (see Arthur 2015, 189-191).

Complexity can also be seen in a less overarching way, as providing a framework to analyse some important specific economic phenomena. Some key examples are outlined here, but detailed discussion is beyond the scope of the present article.

Power laws occur frequently in economic data. This was first noted by Pareto in 1896 in relation to the upper part of the income distribution, but has since been observed in other situations, including the distributions of wealth and of firm size, as well as non-economic examples such as the size of towns and cities. One way that this can arise is from “preferential attachment”, in which those who already have a great deal have a high probability of getting even more (Newman 2005; Gabaix 2009).

Mandelbrot (1963; Mandelbrot and Hudson 2008) has shown that certain markets are far more volatile than standard theories can explain. One aspect is that trend extrapolation amplifies minor fluctuations that are misinterpreted as the beginning of a trend, fuelling volatility. This is driven by endogenous system causation, through the impact of trades on prices. It is not due to exogenous shocks, which accords with the evidence on the unimportance of news for stock price movements (Fair 2002; Joulin et al 2008). Mandelbrot’s work is based on the application of fractals analysis methods to price series in commodities and in the financial sector – sectors that are free-floating, in the sense used above.

A connection between feedback systems and the complexity perspective is shown by Keen’s “Minsky” model (Keen 2013). The baseline model generates regular cycles that mimic the business cycle, corresponding to balancing feedback with delay. When the financial sector is introduced, i.e. the ability of firms to borrow in order to invest, the model becomes highly sensitive to initial conditions: if they are not sufficiently close to equilibrium, chaotic behaviour ensues.

Complexity and instability have also been studied using dynamic models of the type traditionally used for ecological food webs and for the networks in which infectious diseases spread (Haldane and May

2011). They show that excessive homogeneity in the financial sector leads to instability: if banks each follow the same strategy, while they may achieve diversification of risk for each bank, there is lower diversity across the system. Secondly, they demonstrate how a modular structure could help to prevent contagion.

Complexity economics is characterised not only by its theoretical contributions, but also by its practical methods, notably agent-based modelling. A pioneering example was the Santa Fe artificial stock market model (Arthur et al 1996; Ehrentreich 2008), which generated realistic dynamics that included bubbles – although their magnitude was only 2 percent, far lower than what is observed empirically. Agent-based models typically include feedback loops, but a drawback of this approach is that their specification is often highly complex so that the complete set of loops is virtually impossible to identify, and less transparent than with system dynamics modelling. It has been criticised as being easy to manipulate so as to produce any desired result (Colander 2003).

On the other hand, an advantage of agent-based modelling is that heterogeneity is centre stage. This is especially important in situations where it plays a major role, whereas system dynamics tends to be concerned with average or typical behaviour. Other advantages of agent-based models include agents with the ability to learn, and with heterogeneous utility functions. The two methods share much in common, e.g. that observed economic phenomena such as crises and growth arise from endogenous causation rather than external shocks. They can therefore be regarded as complementary.

Conclusion

Many important phenomena that occur in the modern economy are feedback systems. Although the concept of feedback is well known to economists, it has not been well integrated with standard theory. This is especially true in relation to some of the phenomena that traditional theory struggles to explain, notably crises, and the specific type of growth that characterises successful modern economies.

This article has focused only on simple systems, to illuminate each particular type of phenomenon. In practice, more complicated systems occur in the economy, with multiple feedback loops, etc, raising issues of loop dominance, tipping points, etc, that are beyond the present scope. In addition, the focus here has been entirely on causal loop diagrams, excluding flows and stocks, which play an important role in system dynamics. As market transactions are two-way flows that depend on stocks (e.g. of wealth, of resources, etc), integration of this viewpoint with feedback has potential as a way of providing a comprehensive analysis of the economy.

A significant advantage of the feedback perspective is that it provides a unified analysis; once one accepts that the market mechanism is a feedback system of one particular type, it is a small step to recognising that other types can occur. This contrasts with some proponents of a complexity viewpoint, who see a dichotomy between standard theory and complexity economics.

A key feature of the systems approach is that it emphasises *endogenous causation*: crises and growth are part of the way the system operates. They depend on the incentives that are embodied in the feedback structure, and the behavioural response of economic agents to these incentives. This means that one does not have to resort to the concept of exogenous shocks to explain these phenomena, which are clearly an inherent feature of the modern economy. Another implication, perhaps less obvious, is that a higher intensity of competition accentuates *any* dynamic, including reinforcing feedback as manifest in bubbles or arms races.

A focus on feedback also provides a realistic framework for analysing the role of behaviour in the economy. This departs from the traditional view in standard economic theory that behavioural aspects such as preferences (along with technology) are external, non-economic drivers of an optimal and therefore automatic economic outcome. Here, the position is that behaviour is an integral part of the mode of operation of the systems that play a central role in the processes that make up the economy. An implication is that a full description of these systems needs to be based on evidence concerning

the relevant actual behaviour, along with accounts of the incentive structure of the system, as well as evidence on how the system comes to exist and persist (Joffe 2019).

Analysis of the phenomena covered in this paper, and the feedback processes underlying them, also demonstrates how macro properties can arise out of their component causes. It is an alternative paradigm to the widespread concept of microfoundations, which assumes that phenomena at the macro level result from the simple aggregation of individual-level behaviour. It also assumes the traditional form of strict rationality and optimisation, which has become difficult to sustain in light of the findings of behavioural economics.

Systems analysis needs to explain not only how a system operates, but also how it comes to exist and persist – its conditions of existence, or generative causes. In the economy, these typically involve institutions. For example, the various feedback loops described for the financial sector depend on its institutional arrangements, which can change over time.

Feedback systems are one way that emergence occurs. The behaviour of the system has distinct characteristics that are not present in the component causes, individually or in summation. This results from the *interaction* between the agents. Feedback systems consist of bottom-up causation, i.e. the component causes combine to produce the system property. They do not feature top-down causation, unless the operation of the system contributes to the probability of its flourishing. In such a case, the success of the system plays a positive role in its own generative causes. Such two-way causation would itself be a form of feedback.[13] This may sometimes apply in the economy, for example it is plausible that the successful growth record of the post-industrial revolution economy has reinforced its institutions, especially the modern hierarchical firm. This would provide an answer to the important question, “why do such firms exist at all?” – given that the market mechanism is suppressed within the firm, and that markets are supposed to be the most efficient form of economic organisation (Coase 1937).

Feedback concepts should be at the heart of economic theory. A strength of this approach is that the traditional emphasis on stability, which does appear to be an important property in mature markets for goods and non-financial services, is preserved. This is done in a way that emphasises the causal nature of economic forces, as recommended by Hausman (1992), rather than on concepts of static equilibrium that ignore causation. Furthermore, it is readily extendable to important economic phenomena other than the market mechanism, including instability, crises and growth.

[13] This situation is characteristic of homeostatic processes in biology, such as temperature regulation in humans, which increase “inclusive fitness”, i.e. the probability of surviving and passing on one’s genes (Joffe 2013b).

References

Acemoglu D. 2009. *Introduction to modern economic growth*. Princeton, NJ: Princeton University Press.

Acemoglu D, Robinson JA. 2012. *Why nations fail: the origins of power, prosperity and poverty*. London: Profile Books Ltd.

Alexandrova A, Northcott R. 2013. It's just a feeling: why economic models do not explain. *Journal of Economic Methodology* 20(3): 262-67.

Aliber RZ, Kindleberger CP. 2015. *Manias, panics, and crashes: a history of financial crises, 7th edition*. Basingstoke: Palgrave Macmillan.

Anderson PW, Arrow KJ, Pines D. 1988. *The economy as an evolving complex system. Santa Fe Institute studies in the sciences of complexity*. Redwood City, CA: Addison-Wesley Publishing Company Inc.

Arthur WB. 1994. *Increasing Returns and Path Dependence in the Economy*. Ann Arbor, Michigan: University of Michigan Press.

Arthur WB. 2015. *Complexity and the economy*. Oxford: Oxford University Press.

Arthur WB, Holland JH, LeBaron B, Palmer R, Tayler, P. 1996. *Asset Pricing Under Endogenous Expectations in an Artificial Stock Market*. SFI Working Paper 1996-12-093, Santa Fe Institute.

Arthur WB, Durlauf SN, Lane DA. 1997. *The economy as an evolving complex system II. Santa Fe Institute studies in the sciences of complexity*. Reading, MA: Perseus Books.

Axtell RL. 2001. Zipf distribution of US firm sizes. *Science* 293(5536): 1818.

Bassi A, Pedercini M. 2007. Threshold 21 (T21) framework. https://ledsgp.org/wp-content/uploads/2015/10/T21-presentation.pdf [accessed 12 February 2020].

Beinhocker ED. 2007. *The origin of wealth: evolution, complexity, and the radical remaking of economics*. London: Random House.

Beaudry P, Green DA, Sand BM. 2018. In search of labor demand. *American Economic Review* 108(9): 2714–57.

Blume LE, Durlauf SN. 2006. *The economy as an evolving complex system III. Santa Fe Institute studies in the sciences of complexity*. Oxford: Oxford University Press.

Bordo MD, Meissner CM. 2016. *Fiscal and financial crises*. NBER Working Paper No. 22059. http://www.nber.org/papers/w22059 [accessed 12 February 2020].

Caginalp G, Porter D, Smith V. 2001. Financial bubbles: excess cash, momentum, and incomplete information. *The Journal of Psychology and Financial Markets* 2: 80-99.

Caginalp G, Desantis M. 2011. Stock price dynamics: nonlinear trend, volume, volatility, resistance and money supply. *Quantitative Finance* 11: 849-61.

Callimachi R. 2012. Sale of Niger nomad's last camel is sign of hunger. *The San Diego Union-Tribune* http://www.sandiegouniontribune.com/sdut-sale-of-niger-nomads-last-camel-is-sign-of-hunger-2012aug18-story.html [accessed 12 February 2020].

Casson MC, Della Giusta M, Kambhampati US. 2010. Formal and informal institutions and development. *World Development* 38: 137-41.

Charles KK, Hurst E, Notowidigdo MJ. 2016. The masking of the decline in manufacturing employment by the housing bubble. *Journal of Economic Perspectives* 30: 179-200.

Cheng I-H, Raina S, Xiong W. 2014. Wall Street and the housing bubble. *American Economic Review* 104: 2797-829.

Chick V. 2007. Equilibrium in economics: some concepts and controversies. In Mosini (ed.) *op cit*.

Clark G. 2007. *A farewell to alms: a brief economic history of the world*. Princeton NJ: Princeton University Press.

Coase RH. 1937. The nature of the firm. *Economica*. Reprinted in Coase RH. *The Firm, the Market and the Law*. 1988. Chicago, IL: University of Chicago Press.

Colander D. 2003. Post Walrasian macro policy and the economics of muddling through. *International Journal of Political Economy* 33: 17-35.

Cox WM, Alm R. 1997. *Time well spent: the declining* real *cost of living in America*. Dallas: Federal Reserve Bank of Dallas. http://www.dallasfed.org/assets/documents/fed/annual/1999/ar97.pdf [accessed 12 February 2020].

Eckel CC, Füllbrunn SC. 2015. Thar SHE blows? Gender, competition, and bubbles in experimental asset markets. *American Economic Review* 105: 906-20.

Eckstein O, Sinai, A. 1990. The mechanisms of the business cycle in the postwar period. In Gordon RJ (ed.) *The American business cycle: continuity and change*. University of Chicago Press, Chicago.

The Economist. 2010**.** The Fed discovers Hyman Minsky. http://www.economist.com/blogs/freeexchange/2010/01/the_fed_discovers_hyman_minsky [accessed 12 February 2020].

Ehrentreich N. 2008. *Agent-based modeling: the Santa Fe Institute Artificial Stock Market Model revisited*. Berlin & Heidelberg: Springer-Verlag.

Fair RC. 2002. Events that shook the market. *The Journal of Business* 75: 713-31.

Fisher I. 1933. The debt deflation theory of great depressions. *Econometrica* 1: 337-57.

Forrester JW. 1970. Counterintuitive behavior of social systems. In: *Collected papers of Jay W Forrester: collection*, 211–44. Cambridge, MA: Wright-Allen Press.

Forrester JW. 2013 [originally published 2003]. Economic theory for the new millennium. *System Dynamics Review* 29(1): 26-41.

Frank RH. 2011. *The Darwin economy*. Princeton NJ: Princeton University Press.

Franko PM. 2007. *The puzzle of Latin American economic development (3rd edition)*. Lanham MD: Rowman & Littlefield.

Friedman M. 1953. The methodology of positive economics, reprinted in D.M. Hausman (ed.) 1994. *The philosophy of economics: an anthology*, 2nd edition. Cambridge: Cambridge University Press.

Friedman M, Schwartz AJ. 1963. *A monetary history of the United States, 1867-1960*. Princeton, NJ: Princeton University Press.

Gabaix X. 2009. Power laws in economics and finance. *Annual Review of Economics* 1: 255-93.

Galí J, Gambetti L. 2015. The effects of monetary policy on stock market bubbles: some evidence. *American Economic Journal: Macroeconomics* 7: 233-57.

Godley W. 1996. *Money, finance and the national income determination. An integrated approach*. Levy Economic Institute Working Paper 167. http://www.levyinstitute.org/pubs/wp167.pdf [accessed 12 February 2020].

Goodwin RM. 1967. A Growth Cycle, in Feinstein CH (ed.) *Socialism, Capitalism and Economic Growth*. Cambridge: Cambridge University Press.

Grüne-Yanoff T. 2013. Genuineness resolved: a reply to Reiss' purported paradox. *Journal of Economic Methodology* 20: 255-61.

Haldane AG. 2015. *Stuck*. Speech given by the Chief Economist of the Bank of England. Milton Keynes: Open University. https://www.bankofengland.co.uk/speech/2015/stuck [accessed 12 February 2020].

Haldane AG, May RM. 2011. Systemic risk in banking ecosystems. *Nature* 469: 351-55.

Hall R, Hitch C. 1939. Price theory and business behaviour. *Oxford Economic Papers* 2(1): 12-45.

Hausman DM. 1992. Essays on philosophy and economic methodology, especially chapter 11, Supply and demand explanations and their *ceteris paribus* clauses. Cambridge: Cambridge University Press.

Hax AC, Majluf NS. 1982. Competitive cost dynamics: the experience curve. *Interfaces* 12(5): 50-61.

Henderson BD. 1973. The experience curve – reviewed (part II). Available at https://www.bcg.com/en-gb/publications/1973/corporate-finance-strategy-portfolio-management-experience-curve-reviewed-part-ii-the-history.aspx [accessed 12 February 2020].

Heukelom F. 2014. *Behavioral economics: a history*. Cambridge: Cambridge University Press.

Holt RPF, Rosser JB, Colander D. 2010. *The complexity era in economics*. Middlebury College Economics Discussion Paper No. 10-01. http://sandcat.middlebury.edu/econ/repec/mdl/ancoec/1001.pdf [accessed 12 February 2020].

Joffe M. 2011. The root cause of economic growth under capitalism. *Cambridge Journal of Economics* 35: 873-96.

Joffe M. 2012. Competition between firms – system dynamics and other approaches. Presented at the 30th International Conference of the System Dynamics Society, St Gallen, Switzerland. https://proceedings.systemdynamics.org/2012/proceed/papers/P1283.pdf [accessed 15 February 2020].

Joffe M. 2013a. What causes creative destruction? In: A. Pyka, E.S. Andersen (Eds.), *Long term economic development, economic complexity and evolution*. Berlin Heidelberg: Springer-Verlag.

Joffe M. 2013b. The concept of causation in biology. *Erkenntnis* 78: 179-97.

Joffe M. 2015. The world created by capitalist firms. RWIO Center for Organization Studies, 10th Research Workshop on Institutions and Organizations. http://cors.usp.br/rwio/10rwio/14.pdf [accessed 12 February 2020].

Joffe M. 2017a. The neglect of buying power in traditional economic theory, and its practical implications. *Advances in Economics and Business* 5(8): 435-39.

Joffe M. 2017b. Evidence and the micro-foundations of economic growth. *Economics and Business Review* 3(17), no. 3: 52-79.

Joffe M. 2019. Mechanism in behavioural economics. *Journal of Economic Methodology* 26(3): 228-42.

Joulin A, Lefevre A, Grunberg D, Bouchaud J-P. 2008. Stock price jumps: news and volume play a minor role. https://arxiv.org/pdf/0803.1769.pdf [accessed 12 February 2020].

Kaldor N. 1961. Capital accumulation and economic growth. In Lutz FA and Hague DC (eds.) *The Theory of Capital*. St. Martins Press.

Kaldor N. 1966. *Causes of the Slow Rate of Economic Growth of the United Kingdom*. Cambridge: Cambridge University Press.

Kates S (ed.). 2003. *Two Hundred Years of Say's Law: Essays on Economic Theory's Most Controversial Principle*, Cheltenham: Edward Elgar.

Keen S. 2013. A monetary Minsky model of the Great Moderation and the Great Recession. *Journal of Economic Behavior & Organization* 86: 221-35.

Kelly M. 1997. The dynamics of Smithian growth. *Quarterly Journal of Economics* 112: 939-64.

Kindleberger C. 1978. *Manias, Panics and Crashes*. New York: Basic Books.

Krugman P. 2009. Deficits saved the world. *New York Times*, 15 July 2009. http://krugman.blogs.nytimes.com/2009/07/15/deficits-saved-the-world/ [accessed 12 February 2020].

Lane DC. 2007. The power of the bond between cause and effect. *System Dynamics Review* 23: 95-118.

Lee F. 1998. *Post Keynesian price theory*. Cambridge: Cambridge: University Press.

Mandelbrot B. 1963. The variation of certain speculative prices. *The Journal of Business* 36: 394-419.

Mandelbrot B, Hudson RL. 2008. *The (mis)behavior of markets: a fractal view of risk, ruin, and reward*. New York: Basic Books.

Manning A. 2003. *Monopsony in motion: imperfect competition in labor markets*. Princeton, NJ: Princeton University Press.

Mashayekhi A, Vakili K, Foroughi H. 2006. Supply Demand World (SDW): an interactive learning environment for teaching microeconomics. https://www.semanticscholar.org/paper/Supply-Demand-World-(-SDW-)-%3A-An-Interactive-for-Mashayekhi/ab9bce92c17ba62f2d3db55f5961f2ee3adcc6bb [accessed 15 February 2020].

McCloskey DN. 2010. *Bourgeois Dignity*. Chicago, IL: University of Chicago Press.

McCulley P. 2009. The shadow banking system and Hyman Minsky's economic journey. CFA Institute. https://www.cfainstitute.org/-/media/documents/book/rf-publication/2009/rf-v2009-n5-15.ashx [accessed 15 February 2020].

Minsky HP. 1986. *Stabilizing an unstable economy*. New Haven, CT: Yale University Press.

Minsky HP. 1992. *The financial instability hypothesis*. The Jerome Levy Economics Institute of Bard College, Working Paper No. 74. http://www.levy.org/pubs/wp74.pdf [accessed 12 February 2020].

Mosini V. 2007. *Equilibrium in economics: scope and limits*. London: Routledge.

Myrdal G. 1957. *Economic theory and underdeveloped regions*. London: University Paperbacks, Methuen.

Nell KS, Thirlwall AP. 2018. Explaining differences in the productivity of investment across countries in the context of 'New Growth Theory'. *International Review of Applied Economics* 32: 163–194. https://doi.org/10.1080/02692171.2017.1333089 [accessed 12 February 2020].

Newman MEJ. 2005. Power laws, Pareto distributions and Zipf's law. *Contemporary Physics* 46: 323-51.

Orrell D. 2012. *Economyths*. London: Icon Books Ltd.

Parente S. 2001. The failure of endogenous growth. *Knowledge, Technology, and Policy* 13(4): 49-58.

Penrose ET. 1959. *The Theory of the Growth of the Firm*. Oxford: Blackwell.

Radzicki MJ. 2008. Institutional economics, post-Keynesian economics, and system dynamics: three strands of a heterodox braid. In: Harvey JT and Garnett RF (eds.) *Future directions for heterodox economics*. Ann Arbor, MI: The University of Michigan Press.

Radzicki MJ, Sterman JD. 1994. Evolutionary Economics and System Dynamics. In England RW (ed.) *Evolutionary Concepts in Contemporary Economics*. Ann Arbor, MI: University of Michigan Press.

Richardson GP. 1999. *Feedback thought in social science and systems theory*. Pegasus Communications.

Rodrik D. 2015. *Economics rules: why economics works, when it fails, and how to tell the difference*. Oxford: Oxford University Press.

Rogoff K. 2015. *Debt supercycle, not secular stagnation*. VOX, CEPR. http://voxeu.org/article/debt-supercycle-not-secular-stagnation [accessed 12 February 2020].

Rol M. 2013. Reply to Julian Reiss. *Journal of Economic Methodology* 20(3): 244-49.

Romer CD. 2008. Business cycles. In Henderson, David R. (ed.) *Concise encyclopedia of economics (2nd edition)*. Indianapolis, IN: Library of Economics and Liberty. http://www.econlib.org/library/Enc/BusinessCycles.html [accessed 12 February 2020].

Romer PM. 1986. Increasing returns and long run growth. *Journal of Political Economy* 94(5): 1002-37.

Ryan-Collins J. 2016. UK housing: fixing the 'doom loop' between land value, inadequate supply and insecure financing. http://blog.politics.ox.ac.uk/11946-2/ [accessed 12 February 2020].

Sachs JD, Warner AM. 1997. Fundamental sources of long-run growth. *American Economic Review* 87(2): 184-88.

Schelling TC. 1971. Dynamic models of segregation. *Journal of Mathematical Sociology* 1: 143-86.

Schumpeter JA. 1934 [1911 in German]. *The theory of economic development*. New Brunswick, NJ: Transaction Publishers.

Schumpeter JA. 1942. *Capitalism, Socialism and Democracy*. London: Routledge.

Shiller RJ. 2005. *Irrational exuberance, 2nd edition*. Princeton, NJ: Princeton University Press.

Smith A. 1970 [1776]. *The Wealth of Nations*. Harmondsworth: Penguin Books.

Smith V. 1989. Theory, experiment and economics. *The Journal of Economic Perspectives* 3(1): 151-69.

Sterman JD. 2000. *Business dynamics: systems thinking and modeling for a complex world*. Boston: Irwin McGraw-Hill.

Studwell J. 2013. *How Asia works: success and failure in the world's most dynamic region*. London: Profile Books.

Summers LH. 1986. Some skeptical observations on Real Business Cycle theory. *Federal Reserve Bank of Minneapolis Quarterly Review* 10: 23-27.

Tett G. 2010. *Fool's gold: how unrestrained greed corrupted a dream, shattered global markets and unleashed a catastrophe*. London: Abacus.

Thaler RH. 2015. *Misbehaving: the making of behavioural economics*. New York: WW Norton & Company.

Waldrop MM. 1992. *Complexity: the emerging science at the edge of order and chaos*. New York: Simon and Schuster.

Wheat ID. 2008. The feedback method of teaching macroeconomics: is it effective? *System Dynamics Review* 23(4): 391-413.

Young A. 1928. Increasing returns and economic progress. *The Economic Journal* 38: 527-42.