Positive feedbacks

Economics, Macroeconomics

Positive Feedbacks in the Economy A new economic theory elucidates mechanisms whereby small chance events early in the history of an industry or technology can tilt the competitive balance by W. Brian Arthur onventional economic theory is built on the assumption of diminishing renrrns. Economic actions engender a negative feedback that leads to a predictable equilibrium for prices and market shares. Such feedback tends to stabilize the economy because any major changes will be offset by the very reactions they generate. The high oil prices of the 1970's encouraged energy conservation and increased oil exploration, precipitat- ing a predictable drop in prices by the early 1980's. According to conventional theory the equilibrium marks the 'best" outcome possible under the cir- natives will be the " best" one. Furthermore, once random economic events select a particular path the choice may become locked-in regardless of the advantages of the alternatives. If one product or nationin a competitive marke@lace gets ahead by " chance," it tends to stay ahead and even increase its lead. hedictable, shared markets are no longer guaranteed. During the past few years I and other economic theorists at Stanford University, the Santa Fe Insurute in New Mexico and elsewhere have been developing a view of the economy based Such a market is initially unstable. Both systems were introduced at about the same time and so began with roughly equal market shares; those shares fluctuated early on because of external circumstance, " luclC' and corporate maneuvering. Increasing returns on early gains eventually tilted the competition toward VHS: it accumulated enough of an advantage to take vhrually the entire VCR market. Yet it would have been impossible at the outset of the competition to say which system would win,

which of the two possible equilibria would be se- Such an agreeable picture often on positive feedback. Increasing-returns economics has roots that go back 70 years or more, but its application to the economy as a whole is does violence to reality. In many parts largely new. The theory has strong lected. Furthermore, if the claim that Beta was technically superior is true, then the market's choice did not represent the best economic outcome. Conventional economic theory of- stabilizing forces parallels with modern nonlinear physics (instead of the pre-ZOth-century physical models that underlie conventional economics), it requires new and challenging mathematical techniques between two technologies or products performing the same function. An example is the competition between water and coal to generate electricity. As cumstances: the most efficient use and allocation of resources. of the economy, appear not to operate. Instead positive feedback magnifies the effects of small economic shifts; the economic models that describe such effects differ vastly from the conventional ones. Diminishing returns imply a single equilibrium point for the economy, but positive feedback-increasing returns-makes for many possible equilibrium points. There is no guarantee that the particular economic outcome selected from among the many alterW. BRIANARTHUR is Morrison hofes- sor of Population Studies and Economics at Stanford University. He obtained his Ph. D. from the University of California, Berkeley, in 1973 and holds graduate degtees in operations research, economics and mathematics. Until recently Arthur was on leave at the Santa Fe Institute, a research insdrute dedicated to the srudy of complex systems. There he directed a team of economists, physicists, biologists and others investigating behavior of the economy as an evolving, complex

system. and it appears lTth" history of the videocassette I recorder furnishes a simple exI ample of positive feedbaik. the vcR market started out with two competing formats selling at about the same price: VIIS and Beta. Ehch format could realize increasing rerurns as its market share increased: large numbers of VHS recorders would encourage video outlets to stock more prerecorded tapes in VHS format, thereby enhancing the value of owning a WIS recorder and leading more people to buy one. (The same would, of course, be true for Beta-format players.) Ir this way, a small gain in market share would improve the competitive position of one system and help it further increase its lead. 92 Scrrmrrc AMERTcAN to be the appropri- ate theory for understanding modern high-technology economies. February 1990 fers a different view of competition hydroelectric plants take more of the market, engineers must exploit more costly dam sites, thereby increasing the chance that a coal-fired plant will be cheaper. As coal plants take more of the market, they bid up the price of coal (or trigger the imposition of costly pollution controls) and so tip the balance toward hydropower. The two technologies end up sharing the market in a predictable proportion that best e>'qploits the potentials of each, in contrast to what happened to the two video-recorder systems. The evolution of the VCR market would not have surprised the great Victorian economist Alfred Marshall, one of the founders of today's conventional economics. In his 1890 Pr'nciples of Economics, he noted that if firms' production costs fall as their market shares increase, a firm that simply by good fortune gained a high proportion of the market early on would be able to best its rivals; 'uhatever firm first gets a good start" would corner the market. Marshall did not follow up this observatior

however, and theoretical economics has until recently largely ignored it. Marshall did not believe that increasing returns applied everywhere; agriculture and mining-the mainstays of the economies of his timewere subject to diminishing returns caused by limited amounts of fertile land or high-quality ore deposits. Manufacturing, on the other hand, eqioyed increasing returns because large plants allowed improved organization Modern economists do not see economies of scale as a reliable source of increasing returns. Sometimes large plants have proved more economical; often they have not. would update Marshall's insight by observing that the parts of the economy that are resource-based (agficull ture, bulk-goods production, mining) are still for the most part subject to diminishing returns. Here conventional economics rightly holds sway. The parts of the economy that are knowledge-based, on the other hand, are largely subject to increasing retums. Products such as computers, pharmaceuticals, missiles, aircraft, automobiles, software, telecommunications equipment or fiber optics are complicated to design and to manufacture. They require large initial investments in research, development and tooling, but once sales begin, incremental production is relatively cheap. A new airframe or aircraft engine, for example, typically costs between $2 and $3 billion to design, develop, certify and put into production. Each copy thereafter costs perhaps $50 to $100 million. As more units are built, unit costs continue to fall and profits increase. Increased production brings additional benefits: producing more units means gaining more experience in the uct so as to be able to exchange information with those using it already. manufacturing process and achieving greater understanding of how to produce additional units even

more mechanisms that did not involve technology. Orthodox economists avoided increasing returns for deeper reasons. cheaply. Moreover, er