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Crises and Sunspots

During a visit to the London School of Economics as the 2008 financial crisis was reaching its climax, Queen Elizabeth asked the question that no doubt was on the minds of many of her subjects: "Why did nobody see it coming?" The response, at least by the University of Chicago economist Robert Lucas, was blunt: Economics could not give useful service for the 2008 crisis because economic theory has established that it cannot predict such crises.[1] As John Kay writes, "Faced with such a response, a wise sovereign will seek counsel elsewhere."[2] And so might we all.

England's royal family is no stranger to financial crises, or to the evolution of economic thought that such crises have spawned. Our standard economic model, the neoclassical model, was forged in Victorian England during a time of industrial and economic revolutions—and the crises and the cruel social and economic disparities that came with them. This economic approach arose because the classical political economy of Adam Smith and David Ricardo failed in this new reality. The neoclassical model was championed by the Englishman William Stanley Jevons, who experienced the effects of these crises firsthand, and was prepared to bring new tools to the job. Jevons was the first modern economist, introducing mathematics into the analysis and initiating what became known as the marginalist revolution—a huge leap forward that reshaped our thinking about the values of investment and productivity.[3] Nonetheless, despite all the areas in which Jevons's approach improved our thinking, the economic model he originated still failed to predict or elucidate crises. We can make a start in under-

standing the limitations in the current standard economic approach to financial crises, and what to do about them, by looking at the path Jevons took in mid-nineteenth-century England.

This economic revolution was driven by a technical one. The railroad was the disruptive technology. It reached into every aspect of industry, commerce, and daily life, a complex network emanating from the center of the largest cities to the remotest countryside. Railroads led to, in Karl Marx's words, "the annihilation of space by time" and the "transformation of the product into a commodity." A product was no longer defined by where it was produced, but instead by the market to which the railroad transported it. The railroad cut through the natural terrain, with embankments, tunnels, and viaducts marking a course through the landscape that changed perceptions of nature. For passengers, the "railway journey" filled nineteenth-century novels as an event of adventure and social encounters.[4]

Railroads were also the source of repeated crises. Then as now, there was more capital chasing the dreams of the new technology than there were solid places to put it to work. And it was hard to find a deeper hole than the railroads. Many of the railroad schemes were imprudent, sometimes insane projects, the investments often disappearing without a trace. The term *railway* was to Victorian England what *atomic* or *aerodynamic* were to be after World War II, and *network* and *virtual* are today. When it came to investments, the romantic appeal of being a party to this technological revolution often dominated profit considerations. Baron Rothschild quipped that there are "three principal ways to lose your money: wine, women, and engineers. While the first two are more pleasant, the third is by far more certain." Capital invested in the railway seemed to be the preferred course to the third. Those with capital to burn were encouraged by the engineers whose profits came from building the railroads, and who could walk away unconcerned about the bloated costs that later confronted those actually running the rail. A mile of line in England and Wales cost five times that in the United States.[5] The run of investor profits during the manias of the cycle were lost in the slumps that unerringly followed. One down-cycle casualty was Jevons's father, who was an iron merchant.

In 1848, in the midst of this revolution and its cycle of crises, the great economist and intellectual John Stuart Mill published his *Principles of Political Economy*, a monument to the long and rich tradition of classical political economy of Adam Smith, Jean-Baptiste Say, Thomas Robert Malthus, and David Ricardo. With this publication, economics reached a highly respectable, congratulatory dead end, the station of those in a staid gentlemen's

club sitting in wing-back chairs, self-satisfied and awash in reflection. Economic theory then languished for the better part of the next two decades. Mill wrote that "happily, there is nothing in the laws of Value which remains for the present or any future writer to clear up; the theory of the subject is complete."[6]

But over those two decades, with a backdrop of labor unrest and a rising footprint of poverty, cracks began to emerge in the pillars of Mill's theory.[7] His economics failed to see the essential changes wrought by the Industrial Revolution. He put labor front and center. The more labor used to produce a good, the greater that good's value. This was reasonable when production was driven by labor.[8] But with the Industrial Revolution, capital could multiply the output of a laborer, and, furthermore, capital was not fixed. It could drive ever-increasing efficiency. At the same time, the supply of labor was brimming over the edges because many small landholders and agricultural workers moved to the cities as landholdings were consolidated through enclosures into more efficient large estates. The laborers were paid subsistence wages, while the economic benefit from the increased productivity was captured by those controlling the machinery, the capitalists.

For those whose success or luck of birth pushed them into the newly emerging business class, life was filled with promise and stability. Men would become gentlemen with country houses, providing an Oxbridge education for their sons. For the working class, life held something less. Henry Colman, a minister visiting the United Kingdom from America, reacted to the factory life he observed in the cities: "I have seen enough already in Edinburgh to chill one's blood, make one's hair stand on end. Manchester is said to be as bad, and Liverpool still worse. Wretched, defrauded, oppressed, crushed human nature lying in bleeding fragments all over the face of society. Every day that I live I thank heaven that I am not a poor man with the family in England."[9] The clergyman Richard Parkinson wrote with irony that he once ventured to designate Manchester as the most aristocratic town in England because "there is no town in the world where the distance between the rich and the poor is so great, or the barrier between them so difficult to be crossed."[10]

The Birth of Modern Economics

Industrial age economics moved away from Mill in two directions. The one traveled by Marx, based on historical analysis and with a focus on the human consequences of the dominance of capital, fomented revolution that would

engulf the world. The other, based on mathematics, emulated the mechanics of the natural sciences while ignoring the human aspect completely, forming the foundation for today's standard economic model, that of neoclassical economics. This was the way pushed forward by William Stanley Jevons.

To say that the development of the neoclassical approach ignored the human aspect is to say that it was a product of its times. Arithmetic, writes the historian Eric Hobsbawm, was the fundamental tool of the Industrial Revolution. The value of an enterprise was determined by the operations of addition and subtraction: the difference between buying price and selling price; between revenue and cost; between investment and return. Such arithmetic worked its way into the discourse and analysis of politics and morals. The simple calculations of arithmetic could express the human condition. The English philosopher Jeremy Bentham proposed that pleasure and pain could be expressed as quantities, and pleasure minus pain was the measure of happiness. Add the happiness across all men, deduct the unhappiness, and the government that produces the greatest net happiness for the greatest number has de facto applied the best policy. It is an accounting of humanity, producing its ledger of debit and credit balances.[11]

This formed the starting point of Jevons's *Theory of Political Economy*: a quantitative analysis of the feelings of pleasure and pain. Of the seven Benthamite circumstances associated with pleasure and pain, Jevons selected intensity and duration as the most fundamental dimensions of feeling. Clearly, "every feeling must last some time, and . . . while it lasts, it may be more or less acute and intense." The quantity of feeling, then, is just the product of its intensity and duration: "The whole quantity would be found by multiplying the number of units of intensity into the number of units of duration. Pleasure and pain, then, are magnitudes possessing two dimensions, just as an area or superficies possesses the two dimensions of length and breadth."[12]

Jevons was a polymath who started in the pure sciences and mathematics. He studied for two years at University College in London, winning a gold medal in chemistry and top honors in experimental philosophy. He left before graduating to take a post as an assayer in Sydney, Australia, for the new mint, stopping on the way to study in Paris, receiving a diploma from the French mint. While in Australia he expanded his interests beyond chemistry and mathematics, exploring the local flora, geology, and weather patterns. In fact, for a time he was the only recorder of weather in Sydney. He also wrote a manuscript for a book on music theory.[13]

His interest moved from meteorology and music into economics as he became engaged in the economic travails of the New South Wales railway, which no doubt echoed his family's financial travails. He found an immediate affinity for the subject, which he wrote "seems mostly to suit my exact method of thought." He wrote in 1856 that, as his interests moved to this new area, he felt he was "an awful deserter" of "subjects for which I believe I am equally well or even better suited" and he doubted that "I shall ever be able to call myself a scientific man." In fact, Jevons did remain engaged in mathematics and logic, and in 1874 would publish *The Principles of Science*, which, among other things, laid out the relationship between inductive and deductive logic, and treated the use of cryptography, including the factorization problem that is currently used in public key cryptography.[14] But his formal studies moved from pure science to political economy. In 1859, after five years in Australia, he returned to University College to study political economy, where he won a Ricardo scholarship and a gold medal for his master of arts.

He poured himself into his new focus of study, and by the following year had already discovered the idea of marginal utility. He wrote to his brother that "in the last few months I have fortunately struck out what I have no doubt is the true theory of economy. . . . One of the most important axioms is that as the quantity of any commodity, for instance plain food, which a man has to consume increases, so the utility or benefit from the last portion used decreases in degree." In another letter he expanded on this discovery, giving a succinct explanation of marginal theory and the implications of the relationship between profits and capital: "The common law is that the demand and supply of labor and capital determine the division between wages and profits. But I shall show that the whole capital employed can only be paid for at the same rate as the last portion added; hence it is the increase of produce or advantage, which this last addition gives, that determines the interest of the whole."

Jevons wrote up his ideas in a paper, "A General Mathematical Theory of Political Economy," first presented in 1862, and these ideas gained broad notice with the publication of his 1871 book, *The Theory of Political Economy*. The temple of classical economics shuddered to a sudden collapse with this publication, which was as much a manifesto against the prevailing wisdom, a call to "fling aside, once and for ever, the mazy and preposterous assumptions of the Ricardian School," as it was a scientific treatise on economics theory.[15]

Not long afterward, others were hot on the marginalist trail.[16] And the concepts of marginal utility and the application of mathematical methods seemed to find precursors in many places, leading Jevons to complain that books were appearing "in which the principal ideas of my theory have been foreshadowed." He found himself in the "unfortunate position that the greater number of people think the theory nonsense, and do not understand it, and the rest discover that it is not new." Jevons gave up on the hope that he would be able to establish a first claim to the concepts, but took comfort that "the theory . . . has in fact been discovered 3 or 4 times over and must be true."

Blinded by Sunspots: Jevons's Quest for a Scientific Cause of Crises

Jevons not only brought mathematical rigor to the field but also was the first economist to focus on the sources of economic crises. He had personal reasons for this focus. Not only had his father suffered a failure during the railroad bubble while Jevons was still a boy, but others in his extended family had suffered through similar difficulties. And he was brought up in Unitarian circles where social inequities were a point of concern. He was socially aware, and would take walks though the poor and manufacturing districts of London to observe social costs up close.

Jevons viewed an understanding of crises as the key test of economics. He believed that if economics could not explain market crises and "detect and exhibit every kind of periodic fluctuation," then it was not a complete theory.[17] The inquiry into the causes of phenomena as complex as commercial crises could not approach the rigor or mathematical purity of a science unless Jevons purged this subject of all traces of human emotion, unless he assumed—even if he could not prove—that some physical cause was acting on events others might describe as socially driven. Without some observable natural phenomenon to serve as causal agent, commercial crises threatened to become uninterpretable, limiting the claim of economics to be a science.

Because Jevons patterned his economic methods after the scientific methods used for studying the natural world, he looked for a natural phenomenon as the anchor for his study of otherwise unexplainable crises. This led him to theorize that sunspots were the culprit.[18] He was determined to link sunspot periodicity to the periodicity of commercial crises. And Britain

had certainly been subject to them, most recently the 1845–1850 railway mania bubble, which, like all bubbles, did not end well.

Jevons's interest in sunspots was not mystical. He hypothesized that the success of harvests might be one of many causes that could precipitate a panic: "It is the abnormal changes which are alone threatening or worthy of very much attention. These changes arise from deficient or excessive harvests, from sudden changes of supply or demand in any of our great staple commodities, from manias of excessive investment or speculation, from wars and political disturbances, or other fortuitous occurrences which we cannot calculate upon and allow for."[19]

Jevons used a sunspot cycle that had been determined by earlier researchers to be 11.11 years. All that remained, then, was to show that the cycle for commercial crises followed a similar course. A simple attempt at matching the two came up short, but, convinced that this theory—attractive from the standpoint of bringing economics into the fold of the natural sciences—was correct, he looked past the contemporary data and reached back to data from the thirteenth and fourteenth centuries. This attempt also failed, because data were scant on both sunspots and commercial cycles.

After extending his dataset across time failed to prove this theory, Jevons then cast a broader net geographically. He looked at records from India, with the argument that British commerce relied on agricultural activity and raw materials from its colony. This approach also failed. With a view that "the subject is altogether too new and complicated to take the absence of variation in certain figures as conclusive negative evidence," he continued to press forward, expanding the dataset to tropical Africa, America, the West Indies, and even the Levant, stretching the logic of including India, asserting that these parts of the globe also had a demonstrable effect on British commercial activity. In addition to his search for confirming data, he revised his eleven-year cycle, noting recent research that suggested a shorter cycle. His data refused to fit the alternative cycle, too.

Having discovered no evidence for his mathematically driven, mechanistic model of crises in the historical or contemporary records, in the records of Britain, India, or the broader reaches of the globe, or through revisions in the period of the cycle, Jevons still didn't doubt the model. He surmised that observational error must be at the root of his inability to confirm the sunspot theory. So he called for direct observation of the sun. And he also added a further level of causality to his theory, which smacked of astrology: he called for a study of the planets, which had an effect on the

course of the sun and thereby on sunspot activity: "if the planets govern the sun, and the sun governs the vintages and harvests, and thus the prices of food and raw materials and the state of the money market, it follows that the configurations of the planets may prove to be the remote causes of the greatest commercial disasters."

Clearly a man not easily deterred, Jevons continued his advocacy of the sunspot theory in the face of the lack of evidence: "In spite . . . of the doubtful existence of some of the crises . . . I can entertain no doubt whatever." This advocacy, which bordered on the fanatical, was all in the service of his dream of a mathematical foundation for economics that would form a scientific basis to marry the study of economics to that of the natural sciences.

Chasing Sunspots after All These Years

Jevons's unrelenting drive to demonstrate the link between sunspots and crises rests on two ideas: First, for economic theory to be complete and valid, it must extend beyond the everyday and explain crises. Second, economics "is purely mathematical in character. . . . [W]e cannot have a true theory of Economics without its [mathematics'] aid." I agree with his first point. Contemporary economics agrees with his second. And the motivation behind Jevons's preoccupation with sunspots remains at the center of economics, yet an unswerving adherence to mathematics fails in predicting crises today just as surely as did Jevons's unswerving focus on sunspots.

And we do not have to go as far as failures in prediction. It is one thing to predict where a battle line might be breeched. But before and during the Great Recession, economists couldn't even tell whether the forces were on the attack or in retreat. Despite having an army of economists and all the financial and economic data you could hope for, on March 28, 2007, Ben Bernanke, the chairman of the Federal Reserve, stated to the Joint Economic Committee of Congress that "the impact on the broader economy and financial markets of the problems in the subprime market seems likely to be contained." This sentiment was echoed the same day by the U.S. Treasury secretary Henry Paulson, assuring a House Appropriations subcommittee that "from the standpoint of the overall economy, my bottom line is we're watching it closely but it appears to be contained."

Less than three months later, this containment ruptured when two Bear Stearns hedge funds that had held a portfolio of more than twenty billion

dollars, most of it in securities backed by subprime mortgages, failed, marking a course that blew through one financial market after another over the following six months—the broader mortgage markets, including collateralized debt obligations and credit default swaps; money markets, including the short-term financing of the repo (repurchase agreement) and interbank markets; and markets that seemed to be clever little wrinkles but turned out to have serious vulnerabilities, such as asset-backed commercial paper and auction-rate securities.

In early 2008, as the market turmoil raged, Bernanke gave his semiannual testimony before the Senate Banking Committee. He said that there might be failures within the ranks of the smaller banks, but "I don't anticipate any serious problems of that sort among the large internationally active banks that make up a very substantial part of our banking system." That September, ten days after the spectacular collapse of the investment bank Lehman Brothers, Washington Mutual became the largest financial institution in U.S. history to fail. In October and November, the federal government stepped in to rescue Citigroup from an even bigger failure.

Another bastion of economic brainpower, the International Monetary Fund, did no better in predicting the global financial crisis. In its spring 2007 *World Economic Outlook*, the IMF boldly forecast that the storm clouds would pass: "Overall risks to the outlook seem less threatening than six months ago." The IMF's country report for Iceland from August 2008 offered a reassuring assessment: "The banking system's reported financial indicators are above minimum regulatory requirements and stress tests suggest that the system is resilient." A month and a half later, Iceland was in a meltdown. Iceland's Financial Supervisory Authority began the takeover of Iceland's three largest commercial banks, all of which were facing default, with reverberations that extended to the United Kingdom and the Netherlands.

Economic theory asserts a level of consistency and rationality that not only leaves the cascades and propagation over the course of a crisis unexplained but also asserts that they are unexplainable. Everything's rational, until it isn't; economics works, until it doesn't. So economics blithely labors on, applying the same theory and methods to a world of its own construction that is devoid of such unpleasantries. The dominant model postulates a world in which we are each rolled up into one representative individual who starts its productive life having mapped out a future path of investments and consumption with full knowledge of all future contingencies and

their likelihood. In this fantasy world, each of us works to produce one good and conveniently—because who wants to worry about financial crises?—lives in a world with no financial system and no banks!

Lucas is right in his assessment that economics cannot help during financial crises, but not because economic theory, in its grasp of the world, has demonstrated that crises cannot be helped. It is because traditional economic theory, bound by its own methods and structure, is not up to the task. Our path cannot be determined with mathematical shortcuts; we have to follow the path to see where it leads. Which might not be where we intended. As the boxer Mike Tyson noted, everyone has a plan until they get punched in the mouth.

This book explores what it would mean to follow the path to see where it leads. It provides a nontechnical introduction to agent-based modeling, an alternative to neoclassical economics that shows great promise in predicting crises, averting them, and helping us recover from them. This approach doesn't postulate a world of mathematically defined automatons; instead, it draws on what science has learned recently from the study of real-world complex systems. In particular, it draws on four concepts that have a technical ring but are eminently intuitive: emergent phenomena, ergodicity, radical uncertainty, and computational irreducibility.

Emergent phenomena show that even if we follow an expected path, whether choosing to drive on a highway or buy a house, we'll miss insight into the overall system. And it is the overall system that defines the scope of the crisis. The sum of our interactions leads to a system that can be wholly unrelated to what any one of us sees or does, and cannot even be fathomed if we concentrate on an isolated individual.

The fact that as real-world economic agents we couch our interactions in our varied and ever-changing experience means that we are a moving target for economic methods that demand *ergodicity*, that is, conditions that do not change.

And we don't even know where to aim, because of *radical uncertainty*: the future is an unknown in a deep, metaphysical sense.

Neoclassical economic theory cannot help because it ignores key elements of human nature and the limits that these imply: *computational irreducibility* means that the complexity of our interactions cannot be unraveled with the deductive mathematics that forms the base—even the raison d'être—for the dominant model in current economics. As the novelist Milan Kundera has written, we are in a world where humor resides, a world filled

with "the intoxicating relativity of human things," with "the strange pleasure that comes of certainty that there is no certainty."[20] It is humor, intoxication, and pleasure that economics cannot share.

These limitations are also at work in our day-to-day world even though they are not very apparent or constraining. Lucas acknowledges that "exceptions and anomalies" to economic theory have been discovered, "but for the purposes of macroeconomic analyses and forecasts they are too small to matter."[21] A more accurate statement would be, "but for the self-referential purposes of macroeconomic analyses and forecasts viewed through the lens of economic theory, they are too small to matter." Are the exceptions and anomalies manifestations of the limits brought about by human nature?

The performance of economics during crises is a litmus test for its performance in other times, where the limits might be ignored, cast aside as rounding errors. Thus, understanding crises provides us a window into any broader failure in economics. Crises are the refiner's fire, a testing ground for economic models, a stress test for economic theory. If standard economic reasoning fails in crises, we are left to wonder what failings exist in the noncrisis state, failings that might not be so apparent or that can be covered by a residual error term that is "too small to matter." Small, perhaps, but is it a small smudge on the floor or a small crack in the foundation?

Expecting rationality, casting the world in a form that is amenable to mathematical and deductive methods while treating humans as mechanistic processes, will continue to fail when crises hit. And it might also fail in subtle and unapparent ways beyond the periods of crisis. But what can replace it?