

**Stochastic Optimal Control and the U.S. Financial Debt Crisis**

Jerome L. Stein

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At one point during the recent financial crisis the queen of England reportedly asked economists at the London School of Economics a seemingly straightforward question: “Why did academic economists fail to foresee the crisis?” This question can be broadened to include central banks, the International Monetary Fund, and technical specialists on Wall Street (“quants”). Jerome L. Stein, professor of economics (emeritus) and research professor in the Department of Applied Mathematics at Brown University, has written a timely book that provides a cogent and convincing answer to this question.

He devotes one chapter to why the Federal Reserve and the Fund failed to anticipate the crisis, and another chapter to the failure of the quants and their mathematical models to properly measure the risks associated with the new financial instruments that they had invented. Unlike the burgeoning literature on the debt crisis, this book develops a theoretically well-based measure of optimal debt that provides a yardstick against which to compare the actual debt level. As the latter rises significantly above the benchmark, there is a growing risk that the debt has become unsustainable—a financial bubble has been generated that is increasingly likely to collapse. Stein applies this approach to show that asset values became vastly out of line with the fundamentals of the U.S. housing market and with the balance sheet of the American International Group (AIG), the insurance and financial firm. Stein’s approach generates an early warning signal of impending financial collapse that he also applies to the bubble in agricultural land prices in the 1980s. In addition, he provides a timely analysis of the financial crisis in Europe and makes a strong case that it reflects just as much excessive private debt as an overindebted government sector.

In chapter 2, Stein discusses why the Fed and the Fund were oblivious to the signs of an emerging bubble in the U.S. housing market and the risk this posed to the wider financial system. One reason for this failure was the lack of adequate economic models, but he does not describe the models then in use or explain their failure. The core of Stein’s argument is that the Fed was not predisposed to attempt to identify financial bubbles because it believed

there was no reliable way to do so; pricking such a bubble prematurely could involve unnecessary costs, and the preferred strategy was to use monetary policy to “mop up” after a bubble had burst of its own accord to deal with any adverse macroeconomic fallout. This hands-off approach for dealing with financial bubbles became known as the “Jackson Hole Consensus,” named after Jackson Hole, Wyoming, where this view was first enunciated at one of the annual summer conferences on monetary economics and policy sponsored by the Federal Reserve Bank of Kansas City. Stein notes that the Fed was lulled into a false sense of security because this strategy was viewed as successful in dealing with previous bubbles; the macroeconomic situation at the time of low inflation and sustained growth—dubbed “the Great Moderation”—was quite benign; and because it was felt that a downturn in the U.S. housing sector would not seriously affect the broader economy. This sanguine view was clearly revealed when the Fed released on January 12, 2012, the transcripts of the meetings of the Federal Open Market Committee in 2006. At the June meeting that year, a Fed economist reported, “We have not seen—and don’t expect—a broad deterioration in mortgage credit quality.” And, at the December meeting, Timothy Geithner, then president of the Federal Reserve Bank of New York, said, “The softer-than-expected recent numbers don’t argue, in our view, for a substantial reassessment of the risks to the outlook.”

Stein notes that some people in the financial industry, state bank regulators, and the Federal Deposit Insurance Corporation warned of the dangers in the housing market, and he cites Yale economist Robert Schiller, who argued in 2007 that it was not possible to explain the boom in terms of such fundamentals as rent and construction costs. Stein presents a revealing chart that shows that by 2006 the ratios of debt service and housing prices relative to disposable income rose to two and three times, respectively, their long-run averages. These real-time data could have set off alarm bells that there was a housing bubble, but the Fed was not looking for signs of a bubble. Stein also cites the report of the Fund’s own Independent Evaluation Office that concluded that the institution had missed key elements that generated the financial meltdown, including in particular the deteriorating lending standards in mortgage financing. The IEO attributed the failure of the Fund to “a tendency among homogeneous groups to consider issues only within a certain paradigm and not to challenge its basic premises.”

With a few exceptions, there was also groupthink among the computer scientists, mathematicians, and physicists who were attracted to Wall Street and who are collectively referred to as “quants.” Stein shows in chapter 3 that the finance models used by the quants grossly underestimated risk. The quants used the basic building blocks of modern finance—the capital asset pricing model, the Black-Scholes-Merton options pricing model, and the efficient market hypothesis—to construct new financial instruments that were thought to enable investors to reduce risk. These included credit default swaps, essentially insurance contracts on bonds and other financial instruments, and collateralized debt obligations, which are bundles of securities, such as credit-card debt and mortgages. In the case of CDOs, large numbers of mortgages were securitized into bundles by financial intermediaries who then sold the packages to large investors, mutual funds, pension funds, insurance companies, and hedge funds. The quants worked out a method of prioritization in which tranches in the pool of mortgages were sold with different risk ratings. Losses or defaults in the bundle would be borne first by investors who held the lowest (equity) tranche; when losses in the underlying mortgages exhausted this tranche, the holders of the medium (mezzanine) tranche would be affected; but the top or senior AAA tranche holders would lose money only if losses exceeded the assets in all the tranches. The attribution of different levels of risk—from AAA to BBB or lower—to specific tranches enabled the sellers of the bundles of mortgages to satisfy the specific risk preferences of investors.

Stein makes a major contribution in this chapter by explaining the many flaws in that strategy. First, the financial intermediaries that bundled the mortgages did not undertake due diligence to assess the risk associated with the individual components of the bundle. Second, the strategy assumed that the tranches were statistically independent in the population (bundle), but no analysis was undertaken to support this dubious assumption by analyzing conditional probabilities of default across tranches. Third, the method used by the quants to measure the risk of a tranche assumed a stable distribution of house price increases that was patently unrealistic, as it was based on the continuation of past price increases and thus made no allowance for the possibility of price declines. Stein notes that this flawed methodology falsely suggested AAA securities could arise out of risky mortgages, an illusion that fostered very high leverage. When

the housing bubble burst, the sale of supposedly AAA assets at fire sale prices had a cascading effect on the rest of the financial system as the house of cards created by the quants collapsed. In light of this devastating critique of quant methodology, one wonders whether the defects identified by Stein have been corrected, or at least ameliorated. It would have added to the book's relevance if he had provided some answers to that question.

In chapter 4, Stein explains the rationale for his approach for identifying an asset bubble—stochastic optimal control (SOC)—and then applies this technique to three areas of the U.S. economy in chapters 5–7. He is motivated by the keen desire to use a well-founded analytical framework to establish a benchmark against which to assess the actual level of debt and to evaluate whether it is excessively risky. This benchmark is the optimal level that balances risk against the expected growth in the value of the asset acquired by taking on the debt. As actual debt rises above the optimal level and becomes excessive, expected growth declines, risk increases, and the probability of a debt crisis rises. The basic equation relates the change in net worth of the mortgagor positively to the capital gain and the productivity of the real estate purchased with the bank loan, and negatively to the interest rate paid on this loan and the consumption of the mortgagor. Both the productivity of the asset and consumption are assumed to be known, whereas the capital gain on the asset and the interest are stochastic variables that are negatively correlated. In his model, Stein rules out what he calls a “free lunch” and constrains the drift in the capital gain not to exceed the mean rate of interest, although he emphasizes that such a free lunch helped generate the housing bubble. Optimal debt is generated by the maximization of a concave function of net worth at a terminal date  $T$  subject to the dynamic stochastic processes.

On the assumption that the stochastic variables follow Brownian motion, the maximization results in an intuitively satisfying result where the optimum net worth is determined by the maximum distance between the growth of net worth (a linear function of the level of debt) and the mean risk (a convex function of the level of debt), which is shown graphically in Figure 4.1 in the book. The corresponding optimum debt ratio is positively related to the difference between the return on the asset and the interest rate, and negatively related to the variances of these two variables and the negative covariance between them. Thus, the SOC approach used by Stein

yields a simple expression for the optimal debt ratio that rigorously incorporates the key elements of risk and return: the optimal debt ratio is a function of (net return – risk elements)/risk.

Stein provides an empirical implementation of this theoretical approach in chapter 5. He makes the strong assumption that the mean rate of appreciation of housing prices is equal to the mean interest rate on mortgages, and therefore these two key variables drop out of the empirical part of his analysis. The other component of the return on housing, namely, the productivity of the stock of residential capital, is approximated by the ratio of rental income to an index of housing prices (RENTPRICE). Stein gets around the problem that these two variables are in different units by normalizing the ratio—that is, subtracting the mean of RENTPRICE and dividing by its standard deviation. Stein argues that this procedure removes the risk elements in the basic equation for the optimal debt ratio, even though the variances of the capital gain and the interest rate, as well as their covariance, are integral to the determination of the optimal debt. The level of the debt ratio is approximated by the ratio of household debt service payments to disposable income, and this variable, DEBTSERVICE, is normalized in the same way as RENTPRICE. Finally, Stein measures excess debt as RENTPRICE – DEBTSERVICE, and when he plots this difference, he finds that it is on a sharply rising trend from the mid 1990s, and that by 2005 it was about two standard deviations above the mean. As this year roughly coincided with the peak of the housing price bubble, Stein is quite justified in claiming that it is a useful warning signal of an overheated and unsustainable boom in the U.S. housing market. The subsequent default of vast quantities subprime mortgages then led to a financial meltdown on account of excess leverage and the close web of connections linking financial intermediaries which Stein describes in the last section of chapter 5.

It was this web of financial connections that led to the fall of AIG, the subject of chapter 6. This insurance behemoth once had an AAA rating and over a trillion dollars in assets. Through its London subsidiary, AIG Financial Products (AIGFP), it sold huge numbers of CDS contracts to banks and hedge funds that sought to hedge the risk of a decline in the CDOs they owned in the face of the collapsing U.S. housing market. Stein describes how AIG became enmeshed in the financial crisis of 2007–08 because it seriously underestimated the risk it had incurred. It failed to take account of

the negative correlation between the CDOs it insured and its CDS liabilities: the CDS claims on AIGFP increased when the value of the insured CDOs declined. AIGFP did not monitor the market value of the CDOs that were guaranteed by the CDS contracts it had written. Stein evaluates the actuarial literature on optimal risk and capital requirements for insurers and develops a version of the SOC approach that combines the economics and actuarial literature. The chapter concludes with an assessment of the government bailout of AIG.

Chapter 7 moves back in time to the 1980s and examines the crises in the agricultural sector and in the savings and loan associations. Stein describes the common features of the two crises and explains why they remained localized and, unlike the mortgage bubble that came later, did not infect the rest of the financial system. He shows how the same SOC techniques described in earlier chapters could have generated useful early warning signals of the agricultural crisis.

Stein concludes his book with a very timely and perceptive analysis of the ongoing debt crisis in Europe. He argues convincingly that the origin of the crisis lies in the external debts of the European countries, which reflected not only excessive government budget deficits but also an excess of private investment relative to saving. Thus, the exclusive focus of the European Union and European policymakers on the fiscal origin of the crisis is misplaced because it ignores the problem of the excessive external debt of the entire economy. He brings to bear an array of charts and tables to support his case that the origin of the crisis differs widely across eurozone members who were not all fiscal profligates. Stein also provides a theoretical analysis of the origins of the crisis based on his natural real exchange rate model (NATREX) that can explain the simultaneous evolution of two endogenous variables: the real exchange rate and external debt. His NATREX model has been widely used to assess whether observed exchange rates are out of line with their fundamental determinants.

Stein has written a timely book on the financial crisis emanating from the collapse of the U.S. mortgage market, as well as on the European financial crisis. It synthesizes the large economics literature on the former with the mathematics literature on stochastic optimal control. It should appeal both to economists and mathematicians interested in how SOC techniques could have been used to

provide early warning signals of the recent crises, as well as to those interested in risk management. Because it is a readable account of financial crises that have generated incredibly high economic costs, the book should also be read by policymakers. It conveys the very important lessons that early warning signals can be used to detect the emergence of financial bubbles, and that it is incumbent on policymakers to act on this information. Thanks to Stein, the once common view that financial bubbles should be left to work themselves out—as embodied in the Jackson Hole Consensus—is no longer tenable.

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### **Sustaining China's Economic Growth after the Global Financial Crisis**

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As one of the world's leading experts on China's economic reforms, Nick Lardy has produced two earlier books that have become keys to understanding the challenges China faces in making the transition to a market economy and becoming a full-pledged member of the global liberal economic order. His 1998 volume on *China's Unfinished Economic Revolution* and his 2002 text on *Integrating China into the Global Economy* were both published by the Brookings Institution, where he was a senior fellow from 1995 until 2003, at which time he joined the Peterson Institute for International Economics, where he is now Anthony M. Solomon Senior Fellow.

Lardy's new book completes a trilogy by examining China's response to the global financial crisis of 2008–09, and the policy changes that still need to be implemented to sustain future growth. The basic thesis is that fundamental reforms need to be undertaken to rid China's economy of the serious distortions inherent in the present growth model.

The influence of the state in controlling key prices—notably interest rates; the exchange rate; and prices for refined energy products, water, and electricity—politicizes investment decisions, artificially spurs export-led growth, and favors manufacturing.