Chapter Six

AIG in the Crisis

Abstract: The financial structure of the derivatives insured by AIG with credit default swaps (CDS) was ultimately related to the systemic risk from the inability of the mortgagors to service their debts. AIG made several serious mistakes. First: The estimate of the drift of the capital gain, which drove the bubble, was based upon the unsustainable growth of the housing price index 2004-06. A collapse would occur when the unsustainable capital gain declined below the interest rate. Second, risk was underestimated because AIG ignored the negative correlation between the capital gains and the liabilities/claims. The CDS claims grew when the value of the insured obligations declined. This set off collateral requirements, and the stability of AIG was undermined. The solution for the optimal insurance liabilities on the basis of SOC is derived. The SOC approach is a generalization of the contributions of the economics and actuarial literature. The chapter concludes with an evaluation of the government bailout.

Introduction.

At its peak, American International Group (AIG) was one of the largest and most successful companies in the world boasting a Triple-A credit rating, over $1 trillion in assets, and 76 million customers in more than 130 countries. Yet the sophistication of AIG's operations was not matched by an equally sophisticated risk-management structure. This poor management structure, combined with a lack of regulatory oversight, led AIG to accumulate staggering amounts of risk, especially in its subsidiary, AIG Financial Products (AIGFP). I draw upon the Congressional Oversight Panel Report (COP, 2010) that describes AIG's role in the financial market crisis.

Part 6.1 describes what happened to AIG in the 2007-08 crisis. Part 6.2 sketches the economics literature and the actuarial literature. The conclusions from the economics literature are that "Despite extensive researches about the determinants of corporate capital structure, the theories of capital structure remain one of the most controversial issues in modern corporate finance" (Shim, 2010). The actuarial literature on capital requirements and risk was discussed in chapter four. The stochastic optimal (SOC) approach in the following sections is a generalization of the contributions of the economics and actuarial literature. Its components are: the criterion function, the stochastic differential equations, and the stochastic processes. The solution for the optimal capital requirement on the basis of SOC is in part 6.5. Part 6.6 is an evaluation of the government bailout.

6.1. AIG

AIG occupied an important role in the financial system. Of all the possible losers in the financial crisis discussed in chapter five, AIG should have been the most concerned with risk management. The AIG Financial Products AIGFP subsidiary sold credit default swaps (CDSs) involving three parties. Party 1 the obligor sells the "reference securities" to party 2. The latter are security houses, hedge funds that purchase protection from party 3, who are banks and insurance companies, which issue the protection. In many cases municipalities are required to carry insurance in order to market their bonds, or to obtain a high credit rating. The CDS are privately negotiated contracts that function in a similar manner to insurance contacts, but their payoff structure is closer to a put option.

AIGFP's obligations were guaranteed by AIG's triple-A rating, which facilitated borrowing at low interest rates. Ultimately, however, it made it difficult to isolate AIGFP from its parent, with disastrous consequences. Bernanke characterized AIGFP as a hedge fund attached to a large and stable insurance company. AIGFP entered the credit derivatives market in 1998 when it underwrote its first CDS.

Over time AIGFP became a central player in the fast-growing CDS market. AIGFP's corporate arbitrage CDS portfolio was comprised of CDS contracts written on corporate debt and collateralized loan obligations (CLOs). The collateral pools backing the corporate debt portfolio included baskets of investment-grade corporate bonds and loans of commercial and industrial loans of large banks. The collateral pools backing the multi-sector CDOs included prime, Alt-A, and subprime residential mortgage-backed securities (RMBS), commercial mortgage-backed securities (CMBS), other asset-backed securities (ABS). CDS written on corporate debt, CLOs, and multi-sector CDOs serve as protection against "credit events" of the issuer of the reference obligation, including bankruptcy, failure to pay, acceleration of payments on the issuer's obligations, default on the issuer's obligations, restructuring of the issuer's debt, and similar events.

AIGFP's operating income grew from $131 million in 1994 to $949 million in 2006, 18% pa, paralleling the boom in the overall derivatives market, as well as the CDS market. While the credit markets provided a source of steady profits for AIGFP, the division's operating income represented a relatively small percentage of AIG's total operating income, contributing just 7 percent to firm-wide net income in 2006. More importantly, as events made clear, the risk involved in this business was dramatically disproportionate to the revenue produced. For example*, losses in 2007 totaled $11.5 billion, twice the aggregate net income produced by this division from 1994 to 2006.*

AIG models showed that there would be no defaults on any of the bond payments that AIG swaps had insured. AIGFP did not have its own model or otherwise try to value the CDO portfolio that it guaranteed through CDS nor did it hedge its exposure. AIG mistakenly believed that it would only have to pay counterparties if holders of the super-senior tranches insured incurred actual losses. AIGFP relied on Gorton's actuarial model that did not provide a tool for monitoring the CDO's market value. Gorton's model had determined with 99.85% confidence that the owners of super-senior tranches of the CDO's insured by AIGFP would never suffer real economic losses (FCIC, pp. 266-67). The company's auditor PWC apparently was also not aware of the collateral requirements. PWC concluded that "..the risk of default on the [AIG] portfolio has been effectively removed as a result of a risk management perspective…".

The bankruptcy of Lehman Brothers was a cataclysmic event. Investors began to compare the types of securities held by AIG and by Lehman. Goldman-Sachs was an AIG counterparty, which was very much concerned with the value of AIG's collateral. The G-S executives concluded that the Gorton/AIG models were irrelevant because the contracts required collateral to be posted if market values of the insured securities declined, irrespective of only long term cash losses. G-S estimated that the average decline in the market value of the bonds was 15%. With leverage this would translate into very large declines in equity.

Until the dispute with G-S, AIG relied on Gorton's model that did not estimate the market value of the underlying securities. So G-S mark to market caught AIG by surprise. By August 2007 AIG publicly disclosed, for the first time, the $79 billion in

CDS's on super-senior CDO tranches. Sixty four billion were backed by subprime and nineteen billion were written on risky BBB collateral. By January 2008, AIG still did not have a reliable way to determine the market price of the securities on which it had written credit protection.

AIG valued its Alt-A and subprime mortgage backed securities at 1.7 – 2 times the values used by Lehman. During the summer of 2008, AIG faced increasing demands from their CDS customers for cash security – collateral calls – totaling tens of billions of dollars. AIG was not able to provide the required additional collateral. This put AIG's credit rating under pressure, which in turn led to even greater collateral calls, creating even greater pressure on AIG's credit.

In September 2008, AIG suffered a liquidity crisis, because the firm lacked the liquidity to meet collateral demands from its customers. In only a matter of months AIG's worldwide empire had collapsed, brought down by the company's underestimation of risk. The AIG liquidity crisis led to the largest government bailout of a private company in US history, totaling $182 billion. Maurice Greenberg, the former CEO, characterized the bailout as a nationalization of AIG, was bewildered by the situation and was at a loss over how the entire situation got out of control as it did.

The resulting downgrades of AIG securities were, in the opinion of Charles Prince, the precipitating event in the financial crisis. The Office of Thrift Supervision (OTS) was the only regulator that had explicit authority to look at the entire company, and the only regulator with any authority over AIGFP. Acting Director Polakoff acknowledged that AIG did not foresee the extent of risk concentration and profound systemic impact CDS caused within AIG. He stated that OTS should have directed AIG to stop originating CDSs and begin reducing its CDS portfolio before December 2005.

Table 6.1 shows that the crisis of both AIG and of the financial sector was *unexpected by the market and pervasive*. Column 1 is the spread TED between the interest rate on interbank loans and the US Treasury bill rate. Column 2 is 3- month LIBOR – OIS overnight index spread rate. It is a measure of how likely borrowing banks will default. Column 3 is a measure of the cost of insurance, based upon CDS.

Table 6.1 AIG and the Financial Crisis, fall 2008

Date 2008	(1) TED spread bps	(2) 3-month Libor – OIS spread bps	(3) AIG CDS spread bps	(4) AIG stock price ($)	(5) 3-month treasury bond yield (%)	(6) D-J industrial average
Aug. 15	96	77	300.7	459.8	1.85	11,659
Sept. 15	180	105	1527.6	95.2	1.02	10,917.5
Oct. 15	433	345	1816.9	48.6	0.22	8577.9
Nov. 7	198	176	2923.9	42.2	0.31	8943.8

Source: COP (2010, Figure 14). (1) Interest rate on interbank loans – US Treasury bill rate; (2) 3- month LIBOR – OIS overnight index spread rate; (3) A CDS rate of y basis points (bps) means that it costs $1000y to insure $10 million of debt for five years..

In August 2008 markets were relatively tranquil. A crisis was not anticipated. One month later the crisis appeared. The cost of CDS insurance (column 3) was five times higher and the stock price of AIG fell by 80%. The financial crisis reached panic proportions in October. Banks were reluctant to lend to each other, as seen in the drastic rises in the TED spread and 3 month Libor – OIS spreads. In October, the CDS spread was six times the August level. The price of AIG's stock was 90% below its August level. The market lost confidence in AIG's ability to insure financial assets. The flight to safety is seen in columns 5 and 6. Treasury bill interest rates fell as the D-J industrial average fell and risk measures rose. The financial collapse was unexpected, sudden and pervasive.

This example leads one to ask the following questions. [Q1]What is an optimal liabilities/net worth or capital requirement for a large (non-life) insurer that balances the expected growth against risk? [Q2]What is an optimal risk? [Q3] What are theoretically founded early warning signals of a crisis? I explain why the application of stochastic optimal control (SOC)/dynamic risk management is an effective approach to answer these questions. The theoretically derived early warning signal of a crisis is the excess liability ratio, equal to the difference between the actual and optimal ratio. This SOC analysis should be used by those charged with surveillance of financial markets.

6.2. The economics and actuarial literature

Since the Modigliani-Miller irrelevance proposition, and despite extensive research for decades, there is little consensus on how firms choose their capital structure (Shim, 2010). Both the literature and regulations have departed greatly from the irrelevance proposition. The banking studies use the ratio of risk weighted assets/total assets as a measure of portfolio risk (Aggarwal-Jacques, 2001). It is based upon the view that portfolio risk is mostly determined by how assets are allocated and the different risk types. This is inadequate for an insurance industry, since the liability side of the portfolio must also be taken into account. Hence an alternative measure of portfolio risk for an insurer is the volatility of asset/liability ratio (Cummins and Sommer, 1996). This measure takes into account the variance/covariance matrix between the vectors of assets and liabilities. The appropriate level of capital is determined mostly by the insurer's risk exposure.

There is a variety of theories. The tradeoff theory postulates that firms seek to maintain a target/optimal debt ratio by balancing the tax advantages of debt financing against the costs of financial distress (Meyers, 2001). The target ratios may vary from firm to firm. The pecking order theory of capital structure states that firms prefer retained earnings as the main source of financing new investment followed by debt financing followed by new issues of equity. Thus more profitable firms have less need for leverage. The financial theory suggests that capital structure is determined by firm specific characteristics such as profitability, growth opportunities and size of firm.

Korteweg (2010) reviews the literature on net benefits to leverage and then estimates the market's valuation of the net benefits to leverage by using panel data from 1994 to 2004, identified from market values and betas of the company's debt and equity. The literature tests the trade off between debt versus equity financing by running cross sectional regressions of leverage on a set of variables that proxy for the benefits and costs of leverage. The problem with this regression approach is that it is not possible to detect whether firms have too much or too little debt. The implicit assumption is that firms are on average optimally leveraged. This assumption lacks cogency in light of the analysis especially in chapter three above. High profits mechanically lower leverage debt/equity so that cross section regressions show a negative relation between profitability and leverage, even though optimal debt ratios are positively related to profitability.

The article by Volchan (2007) reflects the state of the art in actuarial risk science. In chapter four, I focused upon Volchan's excellent discussion of the Cramér-Lundberg model, and I generalized the Classical gambler's ruin problems. My conclusions in chapter four were that the Cramér-Lundberg analysis is inadequate to evaluate the risk/return in the AIG case. First, the asset side of the equation for the change in surplus is ignored. The insurance company has assets against the liabilities that bring in income. Second, the value of the claims against AIG are highly negatively correlated with the value of the assets. When the market value of the insured assets decline, AIG must either compensate the insurer for the difference or put up more collateral. Third, the assets that are insured by AIG are quite closely correlated with the assets in AIG's portfolio.

6.3 Stochastic Optimal Control (SOC) approach to optimal liabilities of a large insurer

The message from the actuarial literature above is that a risk measure should reflect the economic elements to measure risk, the economic situation, and that the problem is to find the optimal "required capital", liabilities/net worth, and risk to maximize expected surplus. Neither the economics literature nor the Cramér-Lundberg literature surveyed above answers questions [Q1]-[Q3] whereas the (SOC) approach is directly concerned with these questions. As described above, the AIGFP followed policies that were far from optimal, which led to the collapse of AIG. I derive a warning signal of financial difficulty by focusing upon the difference between the actual liabilities and the optimal liabilities.

SOC is a dynamic optimization, where key variables are stochastic*,* that I apply to the AIG case. Technical mathematical details are in the appendix to chapter four.

My criterion function is the maximization of the expected logarithm of surplus (net worth) at a future date. Surplus X = A – L is assets A less L liabilities. This is: V(X) = max ln X(T) at terminal date T. There are several advantages of this criterion. First, it is a risk averse strategy because the logarithm is a concave function. Unexpected bad events are weighted more heavily than unexpected good events. Second, the focus is upon the surplus X, which is an objective measure of economic performance. This measure of performance is relevant for stockholders, the parties that are insured by the firm and regulators. The control variable of the insurance company is the ratio of insurance liabilities/surplus. The ratio of assets/surplus = leverage is equal to one plus the ratio of liabilities/surplus.

The dynamics of the surplus, equation (6.1) is the sum of several components.

Change in surplus = (premium rate) liabilities + (return + capital gain) assets
– (claims on the company related to liabilities) *(6.1)*

The first term in the change in surplus is the premiums, equal to the premium rate times the insurance liabilities. The second term is the return on assets, which has two components. The first is the *productivity of assets*, which is deterministic, and the second is the *capital gain* on the assets. The third term concerns claims on the company that reduce the surplus. Claims may be losses to the insured parties and/or collateral calls by the parties that have insured assets whose Mark-to-Market (M-t-M) prices have fallen, as discussed above.

An increase in the liability ratio will increase expected growth of surplus if the return on investment plus premiums exceeds the claims. There are two stochastic variables in this model. First, the productivity of assets is observed, but the future capital gains are unknown when the investment decision is made. Second, the future claims are unknown when the insurance policies are sold. Third, there will be a correlation between the capital gain on assets and the claims. Most certainly, the correlation is negative. When asset prices, such as the index of housing prices fell, the claims against AIG increased, either for defaults or for collateral calls. The latter is what led to AIG's downfall.

The SOC approach derives an optimal liability ratio conditional upon the stochastic processes. The true stochastic process is unknown. Alternative stochastic processes imply different optimal liability ratios or optimal leverages. I start with a general model of the stochastic process and derive the optimal liability/surplus ratio, optimal risk, and optimal expected growth. Then I consider several specifications of the stochastic processes, as was done in chapters four and five. These are special cases of the general model. In all cases, the capital gain and claims rate are negatively correlated. When asset prices fall, insurance claims rise.

A standard of optimality must be based upon sustainable stochastic processes. By contrast, the market optimized on the basis of unsustainable stochastic processes, which led to the bubble and its subsequent collapse.

Given the stochastic process, an optimal liability ratio is derived using the method explained in chapter four, making the appropriate changes. The expected growth of surplus or net worth is a concave function of the liability ratio, figure 4.2. It is maximal when the optimal ratio is chosen. As the liability ratio exceeds the derived optimal, the expected growth declines and the risk (variance) rises, figures 4.1, 4.3. If the liability ratio is less than the optimal, expected growth is unduly sacrificed to reduce risk. Leverage is equal to one plus the liability ratio; and the capital requirement is the inverse of the leverage. I focus upon the liability ratio, and the optimal capital requirement and optimal leverage follow.

The main theoretical results are as follows. (1) The optimal liability ratio is not a number, but a function. It is proportional to: the drift of the capital gain less the drift of the claims plus the current productivity of capital plus the insurance premium rate less a risk premium. The factor of proportionality is the reciprocal of risk elements. Therefore the optimal liability ratio or capital requirement will vary over time. (2) Define the excess liability ratio as the actual liability ratio less the optimal ratio. For a sufficiently high excess liability or debt, the expected growth is zero or negative and the variance is high. See figures 4.1, 4.2. *The probability of a decline in net worth or a debt crisis is directly related to the excess liability or debt ratio.* This is our Early Warning Signal (EWS) of a crisis.

6.4. Mathematical Analysis

The expected logarithm of the surplus of the insurer is the growth variable that is consistent with the insurance literature. Let V(X,T) be the expected logarithm of surplus X(T) at time T relative to its initial value X(0). The stochastic optimal control problem is to select ratios f(t) = L(t)/X(t) of liabilities L(t) to surplus X(t) during the period (0,T) that will maximize V(X,T) in equation (6.2). The maximum value is V*(X,T). Ratio f*(t) is the optimal leverage, or 1/f*(t) is the optimal capital requirement and will vary over time. The stochastic optimal control tells us what is an optimal and what is an "excessive" leverage.

$$V^*(X,T) = \max_f E \ln [X(T)/X(0)] \tag{6.2}$$

f = L/X = liabilities/surplus, A/X = 1 + f = leverage

As explained in chapter four, an advantage of the criterion function equation (6.2) is that the model can be solved by using the Ito equation rather than dynamic programming, the role of the key variables in deriving the optimal capital requirement is clearly seen, it corresponds to an explicit economic objective and the model can be easily implemented for empirical purposes.

The change in surplus dX(t) in equation (6.3) is equal to the earnings of the insurer plus the revaluation of assets – the capital gains or losses – less the claims paid out. The *earnings* are : (i) the income from premiums π L(t) equal to the premium π per dollar of insurance liabilities times L(t) the liabilities plus (ii) the earnings from the assets βA(t), where A(t) is the value of assets and β is the deterministic rate of return. (iii) The *revaluation of assets,* the capital gain or loss on assets, is [dP(t)/P(t)]A(t), where P(t) is the price index of the asset – such as the house price index in the AIG case. The change in price dP(t) and claims C(t) are stochastic. The first term in brackets is earnings and the second term in brackets is the capital gains. The length of the period is dt.

$$dX(t) = [\pi L(t)dt + \beta A(t)dt] + [dP(t)/P(t))A(t)] - C(t). \qquad (6.3)$$

The dynamics of the process to derive E[ln X(T)] is based upon equation (6.3). There are several possibilities for modeling the stochastic processes for the claims C(t) and capital gains dP(t)/P(t). I work with a general model, as I did in chapters four and five, and then consider specifications as I did in chapter five.

Assume, for simplicity, that the premium rate π is given. At this premium rate there is an elastic demand for insurance and the insurer decides how much insurance L(t) to offer at that rate. L(t)/X(t)= f(t) *is the control variable*. Let the claims C(t) be described by stochastic differential equation (6.4). They are proportional to L(t) the amount of insurance liabilities. Claims are the required payments to the insured holders of CDS, *due to either defaults of the obligors or for collateral calls when the prices of the insured securities decline*. The latter led to the downfall of AIG. The mean of claims C(t) is cL(t)dt. The variance of the claims is $\sigma_c^2 L^2(t)$ dt. Brownian Motion term dw_c has independent and stationary increments, with zero expectations, as assumed in the classical literature.

$$C(t) = [c\, dt + \sigma_c dw_c]L(t). \qquad (6.4)$$

$$E(dw_c) = 0,\ E(dw_c)^2 = dt. \qquad (6.4a)$$

Stochastic differential equation (6.5) concerns the capital gain/loss term dP(t)/P(t). The time varying drift is a(t)dt and the diffusion is $\sigma_p dw_p$. This is a general formulation. The variance of the capital gain is σ^2_p dt. The dw_p term has independent and stationary increments.

$$dP(t)/P(t) = a(t)\,dt + \sigma_p dw_p \qquad (6.5)$$

$$E(dw_p) = 0,\ E(dw_p)^2 = dt. \qquad (6.5a)$$

The two Brownian Motion terms are expected to be negatively correlated, equation (6.6). Correlation coefficient $-1 \leq \rho < 0$. When there is a period with capital losses $dP(t)/P(t) < 0$, then claims against AIG including collateral calls are most likely to be high. This condition accurately described the period of the AIG crisis with CDS, part 6.1.

$$E(dw_p\, dw_c) = \rho\, dt. \qquad -1 \leq \rho < 0 \qquad (6.6)$$

Using equations (6.4) – (6.6) in (6.3), derive the stochastic differential equation (6.7) for the change in surplus dX(t). The first set in brackets contains the deterministic part and the second set contains the stochastic part: the randomness of the price of the assets less the randomness of the claims.

$$dX(t) = [\pi L(t) + \beta A(t) - cL(t) + A(t)a(t)]\,dt + [A(t)\sigma_p dw_p - L(t)\sigma_c dw_c]. \qquad (6.7)$$

X = A-L = surplus, A = assets, L = liabilties, β = return on assets , π = premium rate, C = claims, a(t) = drift capital gain, stochastic BM terms dw_p, dw_c. Correlation between them is $\rho < 0$. Leverage = A/X = (1+f)), debt ratio f = L/X.

I follow the analysis in chapters 4 and 5. The control variable is f(t) = L(t)/X(t) the ratio of liabilties/surplus. Write (6.7) as (6.8) in terms of the liability, or debt, ratio f(t), which is the control variable. Abbreviate it where terms M(f(t)) and N(f(t)) correspond respectively to the two terms in brackets in equation (6.8). Term M(f(t)) is deterministic and N(t) is stochastic with an expectation of N(f(t)) = 0.

$$dX(t)/X(t) = [\pi f(t) + \beta(1+f(t)) - cf(t) + (1+f(t))a(t)\,]\,dt + [(1+f(t))\sigma_p dw_p - f(t)\sigma_c dw_c] \qquad (6.8)$$

$$dX(t)/X(t) = M(f(t))\,dt + N(f(t)).$$

$$M[f(t)] = [\pi f(t) + \beta(1+f(t)) - cf(t) + (1+f(t))a(t)]$$

$$N(f(t)) = [(1+f(t))\sigma_p dw_p - f(t)\sigma_c dw_c].\ E[N(f)] = 0, \qquad E[M(f)dt, N(f)] = 0 \quad .$$

6.5 . Solution of the for the Optimum liability ratio in General Model

As explained in chapter 4/appendix, using the Ito equation, solve equation (6.8) for the expectation of d[ln X(t)]. This is equation (6.9) in terms of M(f(t)), which I call MEAN, and R(f(t)), which I call RISK. A great advantage of this approach is that it can be interpreted as a M-V “Mean-Variance” analysis, as was done in figures 4.1 and 4.2.

$$E[d \ln X(t)] = M(f(t)) - (1/2)R(f(t)) \qquad (6.9)$$

$$\text{RISK} \quad R(f(t)) = [(1+f)^2\sigma_p^2 + f^2\sigma_c^2 - 2f(1+f)\rho\sigma_p\sigma_c] \qquad (6.10)$$

$$\text{MEAN} \quad M(f(t)) = [\pi f(t) + \beta(1+f(t)) - cf(t) + (1+f(t))a(t)] \qquad (6.11).$$

The optimal liability/surplus f*(t) in equation (6.12) is the liability ratio that maximizes E[d ln X(t)] in equation (6.9). Term $\sigma^2 = (\sigma^2_p + \sigma^2_c - 2\rho\sigma_p\sigma_c)$ is in effect the variance of the difference between the capital gains and the claims, var (dP/P – C(t)). The negative correlation $\rho < 0$ increases the risk.

The first term in brackets in (6.12) for the optimum ratio is $(\pi - c)$ the premium less the drift of the claims plus $(\beta + a(t))$ the sum of the deterministic rate of return on assets plus the time varying drift of the capital gain. The second term and the denominator involve the risks of the capital gains and claims.

$$f^*(t) = \operatorname{argmax}_f \{E[d \ln X(t)] = [M(f(t)) - (1/2)R(f(t))]\} \qquad (6.12)$$

$$= [(\pi - c) + (\beta + a(t))] - (\sigma^2_p - \rho\sigma_p\sigma_c)]/(\sigma^2_p + \sigma^2_c - 2\rho\sigma_p\sigma_c)$$

$$\sigma^2 = (\sigma^2_p + \sigma^2_c - 2\rho\sigma_p\sigma_c)$$

6.6. Model Uncertainty and Optimal Liability Ratio

Part 6.1 explained that AIG sold CDS on reference securities/financial instruments that were primarily made up of subprime mortgages. AIG’s downfall stemmed in a very large part from its CDS on multi-sector CDOs, which exposed the firm to the vaporization of the value in the subprime market. The value of the reference securities, the CDOs containing the subprime mortgages corresponds to A(t), and the value of the insurance liabilities CDS corresponds to L(t), in equations (6.3), (6.4).

When the debt ratio f(t) exceeds f-max in figure 4.1, the expected growth is negative and the risk R(f) is high. Thus the excess debt f(t) – f*(t), the actual less the optimal, is a warning signal of a crisis. That is, leverage and risk are "too high". A crucial variable in evaluating the optimal debt ratio and risk is dP(t)/P(t) in equation (6.5). The question is how should one model and estimate the drift a(t) in that equation. This is the issue of model uncertainty.

Fisher Black (quoted in Derman), who would have won the Nobel prize for options modeling – had he lived - explained that a financial theory: "is accepted not because it is confirmed by conventional empirical tests, but because researchers persuade one another that the theory is correct and relevant." Black argues that given the models' limitations, "the right way to engage with a model is, like a fiction reader or a really great pretender, is to suspend disbelief and push it as far as possible... But then, when you've done modeling, you must remind yourself that ... although God's world can be divined by principles, humanity prefers to remain mysterious. Catastrophes strike when people allow theories to take on a life of their own and hubris evolves into idolatry."

The question is what is the optimal liability and the excessive liability that should have been a warning signal for the crisis. How should we model $dP(t)/P(t) = a(t)\,dt + \sigma_p\,dw_p$ that corresponds to HPI/CAPGAIN = [P(t+1) – P(t)]/P(t)? Is the capital gain equal to a constant drift $a(t) = a$ plus a Brownian Motion term, or is the drift ergodic mean reverting to a constant trend plus a Brownian Motion term? Are the capital gains terms independent or are they serially correlated? How can we characterize the distribution of the capital gains?

I approach the problem of deciding on the appropriate way to model the capital gain equation by looking at Figure 6.1. It plots the appreciation of single-family housing prices, CAPGAIN/HPI, a 4 quarter appreciation of US Housing prices HPI, percent p.a. It corresponds to dP(t)/P(t). Figure 6.1 covers a recent period 1991q1 – 2011q1, pre and post, crisis. Consider, however, the information available *before* the crisis. What can one say about the distribution of the change in house prices over the period 1980q1 – 2007q4?

From figures 3.4/5.2, we can reject the hypothesis that the distribution of the CAPGAIN series is normal. Table 6.2 tests for serial correlation of the capital gains. Are they independent? The Q-Statistics reject the null hypothesis that there is no autocorrelation up to order k. This means that the Brownian Motion assumption used in modeling dP/P is questionable.

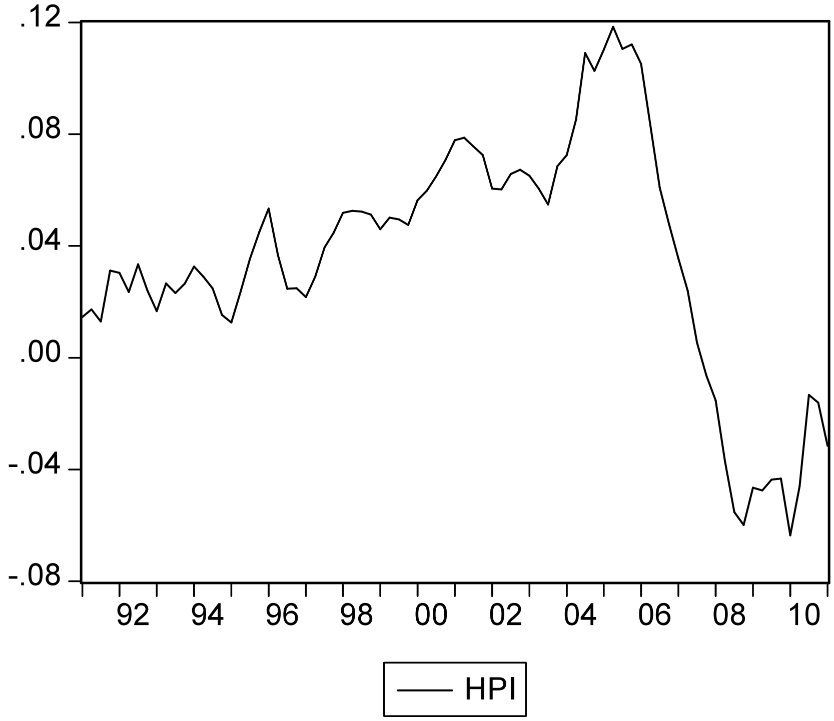

Figure 6.1. HPI/CAPGAIN Capital gains [P(t) – P(t-1)]/P(t-1), percent change in index of house price HPI, sample 1991q1 – 2011q1.

Table 6.2. Tests for Autocorrelation
CAPGAIN(t) against CAPGAIN (t-k)

Sample: 1980Q1 2007Q4
Included observations: 111

		lag	AC	PAC	Q-Stat	Prob
Autocorrelation AC at lag k = Sum [covariance Y(t+k), Y(t)]/variance Y(t)	Q-Stat Probability = probability of null hypothesis that there is no autocorrelation up to order k	1	0.929	0.929	98.423	0.000
		2	0.847	-0.118	180.98	0.000
		3	0.748	-0.164	245.97	0.000
		4	0.628	-0.204	292.17	0.000
		5	0.545	0.246	327.30	0.000
		6	0.466	-0.028	353.20	0.000
		7	0.390	-0.087	371.51	0.000
		8	0.331	-0.011	384.89	0.000

In chapters four and five, two models for the capital gain term were considered. In model I the price P(t) was ergodic mean reverting to a constant trend plus a BM term. In model II, the capital gains term was BM with a constant drift. The choice between the models depends upon a unit root test. Table 6.3, which tests for a unit root, is concerned with the question whether or not the capital gains term is stationary. This is the null hypothesis

Ho: r = 1, CAPGAIN(t) = r CAPGAIN(t-1) + e(t), e(t) random.

If the null r = 1 is not rejected one can conclude that a BM with drift is the appropriate way to model the capital gains equation. If the null hypothesis is rejected, the appropriate way to model the capital gains equation is ergodic mean reversion with a BM term. The conclusion of the unit root test in table 6.3 is that: One cannot reject the null hypothesis at the 5% level, but can at the 10% level. *Neither hypothesis is inconsistent with the data.* Since there is model uncertainty, my approach is to consider a general formulation for the optimal debt liabilities in equation (6.12) and compare it with the actual debt liabilities.

Table 6.3. Unit root tests

Null Hypothesis: CAPGAIN has a unit root; Ho: r = 1.
CAPGAIN(t) = r CAPGAIN(t-1) + e(t).
Exogenous: Constant
Lag Length: 5 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.662054	0.0841
Test critical values:	1% level	-3.493747	
	5% level	-2.889200	
	10% level	-2.581596	

*MacKinnon (1996) one-sided p-values.

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6.7. Early Warning Signals

The optimal debt ratio f*(t) is positively related to the drift of the *capital gain* and negatively related to the drift of *claims*. The negative correlation between the capital gains and the claims reduces the optimal debt ratio, because it increases the total risk.

The early warning signal follows the analysis in chapters four and five. The excess debt of the mortgagors/households is the difference between the actual debt ratio and an upper bound f**(t) of the optimal liability ratio. The use of f**(t) the upper, bound allows the analysis to be done on the assumption that either model is correct. The Ψ (t) = EXCESSDEBT = [f(t) – f**(t)] is plotted below as figure 6.2. The greater is the value of Ψ (t): (a) the lower is the expected growth of surplus and the greater is the risk, as is seen in figure 4.1 and (b) it is more likely is it that households/mortgagors will default on the mortgages thereby increasing the claims on AIG.

My strategy is to compare this measure Ψ (t) = EXCESSDEBT of the mortgagors with the actual liabilities L(t) of AIG to derive a warning signal. *If actual liabilities L(t) are rising* when *Ψ (t) is increasing, the liklihood of claims on AIG and a crisis is more probable.*

Consider AIG liabilities, L(t) or f(t). AIG's business of offering credit protection on assets such as mortgage backed securities and CDO's grew from $20 billion in 2002 to $211 billion in 2005 and $533 billion in 2007. (FCIC, 141). The company as a whole had a much higher leverage ratio than did other insurance companies. As of December 2007, leverage for AIG was 11:1, whereas leverage for Berkshire Hathaway 2:1, Travelers 4:1 and Chubb 4:1. A nine percent decline in the value of assets of AIG would wipe out surplus.

The EXCESSDEBT rose considerably from 2002 to 2007 by more than two standard deviations, whereas the actual AIG liabilities rose, L(2007)/L(2002) = 533/20 = 26.6 during this period. This means that the probability of large claims was very high. When the value of house prices P(t) declined, the value of the CDOs insured by AIG declined. AIG's credit rating was downgraded, it had to post additional collateral or compensate the insured for the difference between the notional and market values of the reference securities. However, AIG lacked the liquidity to meet the collateral calls and banks refused to refinance. This led to the crisis of AIG. Part 6.1/table 6.1 shows that the crisis was not predicted and came as a shock- contrary to Gorton's model (see part 1 above). On the other hand, the SOC analysis provided a good early warning signal.

The market did not exhibit qualms about AIG. Table 6.4 shows the total notional amounts of CDS outstanding in column (1). Column (2) is the CDS rate on AIG, which reflects the probability that AIG will default. Note the AIG-CDS rate declined from 30.7 in 2005h1 to 11.5 in 2007h1, while the notional total of CDS outstanding rose from $12429 billion in 2005h1 to $62173 billion in 2007h2. The price of AIG insurance declined while (a) the total amount of insurance increased and (b) The EXCESSDEBT rose considerably from 2002 to 2007 by more than two standard deviations. The market was taken by surprise because it ignored available information on household debt.

Figure 6.2. Ψ (t) = EXCESSDEBT, normalized excess debt ratio of the mortgagors/households

Table 6.4. Notional amount CDS outstanding $billions, AIG-CDS rate 2001h1 – 2010h2

Date, half year	(1) Notional amount CDS outstanding, $billions (rounded)	(2)AIG-CDS rate
2001h1	631	15.57
2001h2	918	22.64
2002h1	1563	37.3
2002h1	2191	64.11
2003h1	2687	40.4
2003h2	3779	27.74
2004h1	5441	22.11
2004h2	8422	21.25
2005h1	12429	30.7
2005h2	17096	23.8
2006h1	26005	18.13
2006h2	34422	11.82
2007h1	4564	11.5
2007h2	62173	48.95
2008h1	54611	153.7
2008h2	38563	938.8
2009h1	31223	1487.9
2009h2	30428	935.6
2010h1	26263	417.4

6.8. An Evaluation of The Bailout

The COP Report (2010) evaluates the Federal Reserve and Treasury justifications for the bailout. I paraphrase this Report, which is a suitable closing for this chapter.

6.8.1. Government's Justification for Rescue

The Federal Reserve was the only governmental entity at the time with the legal authority to provide liquidity to the financial system in emergency circumstances. The Board and FRBNY ultimately chose to provide AIG with assistance after identifying the systemic risks associated with the company and contemplating the consequences of an AIG bankruptcy or partial rescue. On September 16, the Board, with the full support of Treasury, authorized Federal Reserve Bank of New York (FRBNY) to lend up to $85 billion to AIG in order to assist the company in meeting its obligations as they came due. The Board determined that, in the then-existing environment, "a disorderly failure of AIG could add to already significant levels of financial market fragility and lead to substantially higher borrowing costs, reduced household wealth, and materially weaker economic performance."

The Federal Reserve's actions were based upon its judgment that an AIG collapse would have been much more severe than that of Lehman Brothers because of its global operations, substantial and varied retail and institutional customer base, and the various types of financial services it provided. At September 2008 the time of the initial decision to assist AIG, the Federal Reserve and Treasury publicly identified three primary ways in which an AIG failure posed systemic risk. First, they concluded that, given AIG's role as a large seller of CDSs on CDOs, an AIG failure could have exposed its counterparties to large losses and disrupted the operation of the payments and settlements system. According to Secretary Geithner, if the AIG parent holding company had filed for bankruptcy, defaults on over $100 billion of debt and on trillions of dollars of derivatives would have resulted. The Federal Reserve and Treasury argued that this would have adversely impacted numerous financial institutions and the financial system as a whole. The primary fear of the Federal Reserve and Treasury was that defaults directly related to AIG would have spread throughout the financial system, affecting transactions between other counterparties, negatively affecting investor confidence, and further destabilizing the economy. Second, the Federal Reserve and Treasury concluded that an AIG default on its commercial paper could have adversely impacted money market mutual funds since AIG had issued $20 billion in commercial paper to money market mutual funds, approximately four times as much as Lehman Brothers. In the government's view, this could have substantially disrupted the commercial paper market by reducing credit availability for borrowers even on a short-term basis and causing higher lending rates. This concern escalated after the money market disruptions that occurred in the wake of the Lehman Brothers bankruptcy filing, including the "breaking of the buck" at the Reserve Primary Fund.

Third, the Federal Reserve and Treasury asserted that they feared that an AIG failure could have undermined an already fragile economy by weakening business and investor confidence. After the placement of Fannie Mae and Freddie Mac into government conservatorship on September 7 and the Lehman Brothers bankruptcy filing on September 15, financial markets destabilized considerably. AIG maintained financial relationships with a large number of banks, insurance companies, and other market participants across the globe. A failure of AIG in this environment, according to the Federal Reserve and Treasury, could have further shaken investor confidence and contributed to increased borrowing costs and additional economic deterioration.
In this context, the Federal Reserve and Treasury officials stated that they believed that the unfolding crisis and the increasingly fragile state of the economy necessitated swift action to prevent a total collapse of the financial system.

6.8.2. Panel's Analysis of Options Available to the Government and Decisions

The Panel recognized that policymakers faced a deepening financial crisis and that there were many issues of serious concern and a limited amount of time in which to respond to AIG in September 2008. The Panel stated that FRBNY's decisions were made in the belief that it alone could act and that it had to choose between options that were all unattractive. There is nothing unusual about central banks acting as the lender of last resort. However, by adopting the terms developed by the private sector consortium and retaining most of its terms and conditions, FRBNY chose to act in effect as if it were a private investor in many ways, when its actions also had serious public consequences whose full extent it may not have appreciated. FRBNY also failed to recognize the AIG problem and get involved at a time when it could have had more options.

While the reasons for FRBNY's failure are not clear, it is clear that when FRBNY finally realized AIG was failing and that there would be no private sector solution, *Chairman Bernanke and President Geithner failed to consider any options other than a full rescue. To have the government step in with a full rescue was not the approach used in prior crises, including Bear Stearns and Long-Term Capital Management.* FRBNY chose lawyers from a limited pool and did not seek legal advice from a debtor's counsel (such as AIG's bankruptcy counsel or independent bankruptcy counsel). As a result, there were many options FRBNY evidently did not consider, including a combined private/public rescue (which would have maintained some market discipline), a loan conditioned on counterparties granting concessions, and a short-term bridge loan from FRBNY to provide AIG time for longer-term restructuring. *Providing a full government rescue with no shared sacrifice among the creditors who dealt with AIG fundamentally changed the relationship between the government and the markets, reinforcing moral hazard and undermining the basic tenets of capitalism*. The rescue of AIG dramatically added to the public's sense of a double standard – where some businesses and their creditors suffer the consequences of failure and other, larger, better connected businesses do not. The FRBNY's decision-making also suggest that it neglected to give sufficient attention to the crucial need – more important in a time of crisis than ever – for accountability and transparency.

The Panel asked: Was It Truly an All-or-Nothing Choice? The Treasury/Fed presented the decision to rescue AIG as an all-or-nothing "binary" decision. In other words, the government asserted that it was necessary to rescue AIG in its entirety or let it fail in its entirety. It was not possible to pick and choose which businesses or subsidiaries could be saved. The Panel tested this assertion and considered whether bankruptcy had to be an all-or-nothing option, in terms of the entities covered, the obligations covered, or in terms of timing. If a bankruptcy was not a real option in September 2008, was it later?

The potential impact of an AIG bankruptcy can be guessed by examining how the markets continued to deteriorate even after AIG was rescued. As shown in the Table 6.1 above, the spread between the London Interbank Offered Rate (LIBOR) and the Overnight Index Spread Rate (OIS) – used as a proxy for fears of bank bankruptcy – dramatically increased in September 2008 amid the growing concerns of financial collapse. Former Federal Reserve Chairman Alan Greenspan stated that the "LIBOR-OIS spread remains a barometer of fears of bank insolvency." In the immediate aftermath of the Lehman bankruptcy this spread spiked to a level indicating actual illiquidity in the interbank market – not merely a high cost for obtaining funds – meaning that banks were not willing to lend to one another. Prior to the beginning of the credit market crisis in August 2007, the LIBOR-OIS spread was 10 basis points. The LIBOR-OIS spread reflected the contraction of liquidity that crippled the financial markets in 2008, as seen in table 6.1.

The Panel recognized that the government was faced with a deepening financial crisis, and its attention was on a number of troubled institutions besides AIG in the course of just a few days. Given this context, the government took actions that it thought would facilitate rapid intervention in the midst of deteriorating economic conditions. Nonetheless, if the government concluded that it could not impose conditions on its assistance once it had decided to backstop AIG with taxpayer funds, or that other possible rescue alternatives were unattractive or impracticable, then it had an obligation to fully explain why it decided what it did, and especially why it was of the opinion that *all AIG's creditors and counterparties would receive all amounts they were owed.* In addition, while the Panel acknowledged the number of complex issues and troubled institutions that policymakers were concerned with at the time, it appears that the government was neither focused on nor prepared to deal with the AIG situation. By placing a tremendous amount of faith in the assumption that a private sector solution would succeed in resolving AIG, the government had no legitimate alternative on the table once that assumption turned out to be incorrect. In its assessment of government actions to deal with the current financial crisis, the Panel has regularly called for transparency, accountability, and clarity of goals. These obligations on the part of the government do not vanish in the midst of a financial crisis. In fact, it is during times of crisis, when difficult decisions must be made, that a full accounting of the government's actions is especially important.

6.9 Conclusions: Lessons to be learned

From 1994-2006 AIGFP operating income grew by 18% pa paralleling the boom in the overall derivative market as well as in the CDS market. The risk involved in this business was dramatically disproportionate to the revenue produced. Losses in *one year* 2007 totaling $11.5 billion were twice the aggregate net income produced by the division over the *entire period* 1994-2006.

AIGFP relied on Gorton's actuarial model that did not provide a tool for monitoring the CDO's market value. Gorton's model had determined with 99.85% confidence that the owners of super-senior tranches of the CDO's insured by AIGFP would never suffer real economic losses. The company's auditor PWC apparently was also not aware of the collateral requirements. PWC concluded that "..the risk of default on the [AIG] portfolio has been effectively removed as a result of a risk management perspective…". AIG was led to accumulate staggering amounts of risk, especially in its Financial Products subsidiary.

What lessons can be learned from AIGs experience? AIG made several serious mistakes. First, the financial structure of derivatives CDS insured by AIG, was ultimately based upon the systemic risk from the inability of the mortgagors to service their debts. The exaggerated view of the drift of the capital gain, which drove the bubble, was based upon the growth of the value of housing, the housing price index 2004-06. This growth ranging from 10-14% pa exceeded the mean interest rate. Mortgagors consumed the difference between the refinancing of the loan and the associated debt. They expected to service their debts from the appreciation of the housing price in excess of the rate of interest. *This free lunch would disappear when the unsustainable capital gain declined below the interest rate.*

Second, risk was underestimated because AIG ignored the negative correlation between the capital gain and the claims. The CDS claims grew when the value of the insured obligations CDO declined. This set off collateral requirements and the stability of AIG was undermined.

Acting Director of the OTS Polakoff acknowledged that AIG and OTS did not forsee the extent of risk concentration and profound systemic impact CDS caused within AIG. The AIG crisis leads one to ask the following questions. What is an optimal liability ratio or capital requirement for a large insurer of financial derivatives that balances the expected growth against risk? What is an optimal risk? What are theoretically founded early warning signals of a crisis? Neither the economics literature nor the Cramér-Lundberg literature answers these questions. I explained why the application of stochastic optimal control (SOC)/dynamic risk management is an effective approach to answer these questions. The theoretically derived early warning signal of a crisis is the excess liability ratio, equal to the difference between the actual and optimal ratio. This SOC analysis should have been used by those charged with surveillance of financial markets.

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