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FOOD POLICY INSTITUTE

Conceptual Issues in Livestock Insurance

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Introduction

Recent epidemics of animal diseases, coupled with the events of September 11/2001 and other incidents of terrorism, have raised issues concerning the risks facing livestock producers and how those risks can be managed through insurance products. In the fall of 2001 the Risk Management Agency of the U.S. Department of Agriculture approved livestock gross margin (LGM) and livestock gross revenue (LGR) insurance policies for swine. In addition to revenue based insurance products there is also considerable interest in livestock insurance products against on-farm diseases and catastrophic losses from the market effects of particular pathogens such as foot and mouth disease[1].

A key policy question is the appropriate role of agricultural insurance in the U.S. (and elsewhere) to reduce losses from animal diseases and market prices. Is a joint policy possible, or should production and market related risks be insured separately? Should insurance policies cover catastrophic risks due to natural or bioterrorist outcomes and can catastrophic risks in the livestock market be reinsured?

The purpose of this paper is to explore, first in a general way, and then more specifically, the attributes of insurance for livestock producers. First, a general model is used to illustrate the complexity of the risks at the farm level, and several possibilities for insuring all risks are discussed in a qualitative way. Second, a more specific class of net revenue insurance models are presented and empirically evaluated. These models assume certainty in production and feed use, but allows for variability in livestock and feed prices. Monte Carlo approaches to calculating the value of several conventional and path-dependent livestock net revenue insurance possibilities are illustrated assuming the existence of a futures market. Third, insuring catastrophic market risks arising from the introduction of a disease that would cause market livestock prices to evaporate is modeled as a jump process with a disease arriving at unknown times, but with known frequency. Calculation of a Poisson-induced indemnity as an insurance product could be

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[1] Several definitions of catastrophic risks have emerged. Schlesinger (1999) refers to catastrophic risks as extreme events found and rarely occurring in the extreme tails of a probability distribution. Likewise, Duncan and Myers (2000) define catastrophe as an infrequent event that has undesirable outcomes for a sizeable subset of the insured population. To be insurable, Kunreuther (2002) points out that the risks have to be identifiable in probability space, and if it occurs the extent of loss must be calculable.

considered in addition to conventional livestock or revenue insurance, or the revenue insurance should be adjusted to include the probability of catastrophic market risk.

A background on some major disease outbreaks is discussed in the next section. This is followed by three sections on the principles of 1) livestock insurance, 2) Net revenue insurance and 3) catastrophe insurance. The paper then concludes.

Background

Epidemic animal diseases have always had significant effects on animal populations and ecology. The diseases arise naturally or are brought in by man through trade or war, accidentally or on purpose. For example, following the many waves of military campaigns from Asia to Europe, rinderpest, or cattle plague, swept Western Europe killing over 200 million head of cattle. The 1857-1866 epidemic killed most cattle in Europe, and in 1889 the "Great Rinderpest Pandemic" was introduced to Africa by invading Italian troops. Over 90% mortality in cattle and oxen were found in some regions. Giraffe and African buffalo populations were also severely affected. The story as told by Torres (1999) shows how disease had shaped policy and cultures. Rinderpest epidemics led to the formation of the first bio-strategies in 1741 which included quarantine and burial, as well as to the foundation of the first veterinary school in the UK . In Africa it caused the weakening of cattle keeping tribes in Africa and altered the ecological balance of game species of East Africa.

Animal pathogens have also been used in warfare. During World War I, German agents used anthrax and glanders as an equine disease to infect livestock and pack animals used for transporting supplies. During the Second World War Britain stockpiled 5 million anthrax-laced cattle cakes to be dropped from aircraft, and had a program underway for the use of foot-and-mouth disease and plague. Between 1970 and 1990 the Soviet Union Soviets used ticks to transmit foot-and-mouth disease. They also conducted experiments with rinderpest, African swine fever, bovine pleuropneumonia, mutant forms of avian flu, and ecthyma in sheep (Alibek 1999). Soviet troops might have employed glanders against the Mujaheddin in the mountains of Afghanistan (Alibek 2000) during the Soviet invasion of Afghanistan in the 1980's. Alibek (1999) points out that glanders would have had the dual effect of sickening the Afghan soldiers and killing their horses. The story was told to Alibek by a senior officer but has never been confirmed.

Foot and mouth disease has been a persistent problem in livestock production and is still endemic in some countries. The last Canadian outbreak of FMD was in 1951-1952. Affecting only 2,000 animals, the outbreak was small and easily contained through eradication at a cost of $2 million   Although the outbreak was small and rapidly contained, the loss in trade amounted to $U.S. 2 Billion (current dollars) (Casagrande 2002). In 1997 an outbreak of FMD in Taiwan devastated the hog market. From the time the disease was exposed on a single farm, to the time it was announced, 27 other farms were infected. Within a week, 717 farms were infected and within three months Taiwan was fully infected and 4 million hogs and in excess of 500,000 tons of pork was destroyed (Casagrande 2002). A ban on Taiwan's pork exports resulted in a drop of Taiwan's GDP by 2% (Chalk, 2000). Direct costs of eradication were more than $5 billion. As Taiwan lost its principal export markets for pork, e.g. Japan, prices fell. Within one week of the outbreak, swine prices dropped by 60% ,about 50,000 people became unemployed and $6.9 billion was lost in export revenue. Three years later Taiwan had still not fully regained its export markets.

In 2001 an outbreak of FMD in Great Britain prompted the slaughter of more than 4 million farm animals, out of herds of approximately 60 million and caused billions of dollars in losses to farmers. It also lowered domestic consumption of beef in the U.K and reduce British beef exports, disrupting international trade. When FMD was discovered in April/March of 2001 prices to farmers in the UK evaporated so completely that prices for cattle and sheep are not even recorded by the Department for Environment, Food and Rural Affairs from March 2001 and February 2002 [2]. Sheep exports fell from 142 and 124 thousand tonnes in 1999 and 2000 to only 38 thousand tonnes in 2001.

In 1997-1998 an outbreak of classical swine fever in the Nether-lands infected 20 new herds every week, despite vigilant containment efforts (Casagrande 2002) The introduction of classical swine fever illustrates that FMD is not the only non endemic contagious disease to affect livestock in developed economies.

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[2] See http://www.defra.gov.uk/esg/excel/wplivest.xls

BSE was first diagnosed in 1986 and linked to human disease in the form of Creutzfeldt-Jakob Disease in 1995 making it one of the most debilitating zoonose viruses. By 1998 174,000 cattle had been reported infected with the disease, but estimates of actual diseased cattle exceed 1 million (Murphy 1999). It is believed that the disease morphed from sheep scrapies to BSE and then to CJD. In 1996 all cattle over the age of 30 months in the U.K. were ordered slaughtered (Brown 1999). In addition, worldwide bans imposed on British beef products contributed to the cutback of export markets worth at least $2.4 billion as the export price of beef went to zero in the U.K. when the link between BSE and CJD was discovered (Brown 1999). In 1995 cattle prices in the UK ranged between 127 and 118 pence/kg but fell dramatically to a low of 93.0 pence/kg in 1996 (a drop of about 27% from the 1995 high). Low prices persisted with a low of 88.8 pence/kg and 76.7 pence/kg in 1997 and 1998, increasing slightly over the range 82.1 pence/kg and 92.5 pence/kg in 1999. Over this period, exports dropped precipitously as fear of CJD reduced demand for UK cattle. In 1994 and 1995 exports to the EU and the rest of the world were 293 and 335 thousand tones respectively. Once a possible relationship between BSE and CJD was reported, exports fell to 80 thousand tonnes in 1996, 14 thousand tonnes in 1997 and about 9 thousand tonnes thereafter. In the 1990s, the outbreak of BSE cost the UK government between $9 and $14 billion in compensation costs to farmers affected by the slaughter of their cattle, and employees laid off in the dairy and beef industries. In 2001/2 three cases of BSE in Japan caused a 50% drop in beef sales (Wheelis et al 2002, Watts 2001)

In 2001, Chronic Wasting Disorder, a transmissible spongiform encaphalopathies, similar to BSE in cattle and scrapie in sheep was discovered in wild and captive elk and deer herds in Wyoming, Colorado, Nebraska, Oklahoma and South Dakota. An eradication program was undertaken by U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (APHIS) with expected costs of about $14.8 million required to depopulate herds in 2001. In April of 2002 the USDA agreed to buy 1,000 elk from 15 ranches in Colorado for a maximum of $3 million. An eradication indemnity equal to the fair market value (meat or breeding) of cervids in infected herds was set in September 2001 to encourage voluntary control. Ranchers would have to agree to repopulate with beef, swine or sheep only (APHIS Web site) .

In 1983 and 1984 a highly contagious avian influenza (AI) epidemic, caused the complete depopulation of chickens and decontamination of premises in Pennsylvania. Eradicating the pathogenic strain of avian influenza (AI) in Pennsylvania was about $465 million in direct costs and $150million in lost trade. So significant was its effect on supply that it contributed to a $349 million rise in turkey, chicken and egg prices in the first six months of the outbreak. However it was also estimated that had repopulation not taken place the economic costs would have risen to $5.4 billion (1984) dollars (Brown 1999). An outbreak of low pathogenic avian influenza was also detected in the Shenandoah Valley of Virginia in 2002. By the time the epidemic finished in July 2002, 197 farms in six counties had been repopulated for a total of 4,743,560 birds. Regulations required a flock be destroyed within 24 hours of detection, and removal of carcasses no less than 12 hours later. News releases from the Virginia Department of Agriculture and Consumer Affairs (http://www.vdacs.state.va.us/news/releases-a/ avianupdate.html) reveal how fast the influenza spread. The first report indicated 6 flocks euthenized by March 29th, 2002. Five days later, on April 3rd, 23 flocks of chickens and Turkeys were reported depopulated. By April 17, 2002, only nineteen days after the first press release, it was reported that over 1.15 million birds had been destroyed.

Another avian disease, Exotic Newcastle Disease, was discovered in California in 2002. Exotic Newcastle Disease infected about 60 locations in Riverside, San Bernardino and Los Angeles counties requiring quarantine. More than 5,600 backyard hens, roosters, show fowl and other birds were killed to stop the spread of the disease. The disease did not infect commercial flocks. But producers and state agricultural officials worried about its quick spread to egg farms. An ‘extraordinary emergency’ was declared on January 6, 2003 in California, followed by declarations 11 days later, in Nevada on January 17th, 2003 and just over a month later in Arizona on February 10th 2003. Costs associated with the 2002/2003 epidemics are not available. But stopping the Newcastle disease that struck California's poultry industry in the 1970s, involved destruction of nearly 12 million chickens and cost $56 million.

Theoretical Considerations

The purpose of this section is to explore in a very general way the randomness affecting a livestock operation. It is first assumed that the farmlevel operations involve the production of cattle and the use of feed corn as an input. The net revenues per head are given by

(1) $$R = \theta p - \omega f$$

where p is the price of livestock and f is the price of feed. The symbols θ and ω refer to production coefficients on output and feed respectively. For example if θ represents 1 lbs of growth then ω represents the amount of feed required for 1 lbs of growth. If (1) is viewed as an expectation then the total derivative of equation (1) illustrates the total possible change in net revenues from all sources of risk, as shown in equation (2).

(2) $$dR = \theta\, dp + p\, d\theta - \omega\, df - f\, d\omega$$

For the purpose of this paper it is assumed that dθ=0, dω=0 while dp, and df are random variables with expected values of zero, with standard deviations σ_p and σ_f respectively, and covariance $\sigma_{p,f}$. The variance of net revenue is then

(3) $$\mathrm{VAR}(dR) = \theta^2 \sigma_p^2 + \omega^2 \sigma_f^2 - 2\, p\, f\, \sigma_{p,f}$$

and the joint distribution of net revenue is

(4) $$\mathrm{E}(R) = \int\int [\theta p - \omega f]\, g(p, f)\, dp\, df$$

Where g() represents the joint probability distribution between cattle prices and feed[3]. However, equations (1) through (4) represent the variability in net revenue per animal if the animal survives. If the animal dies from disease the expected payoff changes and expected revenue is given by

(5) $$\mathrm{E}(R) = \begin{cases} \int\int [\theta p - \omega f]\, g(p, f)\, dp\, df & deathloss = 0 \\ 0 & deathloss = 1 \end{cases}$$

[3] There are of course legal avenues when it comes to the purchase of poor feed. Civil liability may substitute for insurance.

The question remaining is whether it makes sense to design livestock insurance products that attempt to capture the complex risks of equations (4) and (5). In other words should a single insurance contract be constructed to protect farmers against both net revenue loss originating from market risk and farm-level diseases, or should separate insurance contracts be written for each source of risk?[4] The degree of correlation between market risks and on-farm risks is also problematic. If the market risks were statistically independent from on-farm disease risks, then attempting to provide a net revenue insurance policy that attempts to encapsulate all sources of net revenue risk would be futile. Rather, it would be sensible as suggested by Hart, Babcock, and Hayes (2001), to focus net revenue products on the correlated livestock and feed prices as one product, and animal diseases as another product. On the other hand, in many instances disease occurrence can not only affect death loss on an individual farm, but can also have negative impacts on market prices. The impact of disease on market prices will depend largely on whether the disease is harmful to consumers in domestic and foreign markets (e.g. BSE), or will cause trade sanctions from foreign markets (e.g. FMD). Not all epidemics will result in price decreases. As discussed above an outbreak of avian influenza may be sufficiently broad to increase domestic prices as supply falls. Since the influenza itself is not harmful to humans, domestic demand is unaffected, and since the export of live chickens from the infected areas is so small, price effects due to diminished exports is minimal. From a catastrophic insurance point of view, it is unlikely that avian flue would be insurable since the emergence of such a disease has minimal (if any) negative impact on poultry product prices, whereas the emergence of BSE or FMD would have significant negative price impacts.

There are then, three candidate insurance products for livestock producers. The first, livestock production insurance, would protect farmers from loss and business interruption due to illness or death, as well as recovery of veterinary costs due to on-farm diseases; The second, net revenue insurance, would protect farmers against losses from the market place; and the third, catastrophe insurance, would protect farmers against extreme price losses due to the emergence of a disease that correlates with rapid decreases in market prices. The first two policies arise from the statistical independence between market prices and farm disease, while the third arises from

[4] Endogenous, non-systematic risks are controllable at the farm level, and unlike the exogenous, systematic risks, can be influenced by the individual producer. Moral hazard is an issue. Would the mere existence of a revenue insurance contract that covers lost productivity be sufficient to cause farmers to act less diligently in mitigation?

the remote probabilities of a catastrophic epidemic of a disease that will be negatively correlated with the market price of livestock. The principles of these three insurance contracts are discussed in the following sections.

Principles of Livestock Production Insurance

Livestock production insurance resulting from disease should be founded on three basic principles; frequency, duration, and intensity. Frequency refers to the likelihood that in any given period of time (e.g. year) a disease will occur in the herd. Some diseases occur more frequently than others, and therefore all things considered equal, a more frequent liability will cost more. Duration, refers to the length of time (e.g. number of days) that a herd is infected. The longer a pathogen remains in a herd, infecting more animals, the greater and more catastrophic will be the loss. The third principle is intensity. Intensity refers to the degree by which the herd is infected as a function of duration. Not all pathogens have the same intensity. A mild pathogen might infect a herd slowly or result in only moderate losses over a fixed period of time, whereas a more aggressive pathogen with high intensity will result in greater losses sooner. The more susceptible a herd is to a pathogen the greater will be its intensity. The World Organization for Animal Health (OiE) classifies diseases according to contagion and intensity. Table 1 lists some of the diseases from the most contagious List A diseases, to the serious but less intense List B diseases.

The frequency and intensity represent randomness. For example if a pathogen appears only once in five years it will have a 20% prior probability of appearing at any time without warning. Likewise, the duration is a random variable. The duration can be one day or two weeks, again depending on random factors, and other factors such as population medicine and inoculation. The structure of a candidate loss function is presented in equation (5).

(6) $$V(f, \lambda, \beta) = 1000\ f(t) \int \lambda^{(-\beta)}\ g(\lambda)\ d\lambda$$

In (6) the valuation is based upon an indemnified value of $1,000 to cover livestock losses due to veterinary bills, medicines, repopulation and other costs related to business interruption. (However, any unit of measurement can be used.) The function f(t) represents the probability of occurrence and represents the frequency principle. The symbol λ represents the duration, and its probability distribution function is represented by $g(\lambda)$. In general $g(\lambda)$ will be a negative exponential or gamma type distribution. The power function $\lambda^{-\beta}$ captures the intensity. The higher the value of β the greater is the intensity associated with the duration λ. For example if $\beta=0$ there is no loss associated with the pathogen. If $\beta=.5$ the intensity is moderate, but if $\beta=2$ the intensity is high. Essentially, the higher the intensity the faster the $1,000 value will be driven to zero.

To illustrate how such a loss function works, assume that $f(t)= 0.30$ so that the pathogen arrives on average three out of every ten years. When it arrives it has a mean duration in the herd of 14 days with a standard deviation of 14 days. Assume that $g(\lambda)$ is a gamma distribution with a negative exponential shape so that a short duration has a higher probability of occurring than a long duration. Subtracting the outcome in equation (6) from $1,000 provides an estimate of expected losses. The indemnity function is therefore used to generate the cost of insurance per $1,000 of revenue. Using Palisade Corporations @Risk, the cost to the livestock producer per $1,000 of revenue is $180 for $\beta=0.5$, $235 for $\beta=1$ and $264 for $\beta=2$. The maximum indemnity in all three cases approaches $1,000 asymptotically. Since the frequency variable is a prior probability, the cost of insurance is directly and linearly related to frequency. For example by dividing the above results by 3, the resulting premiums would represent a frequency of occurrence of 1 in every 10 years rather than 3 in every 10 years.

Of course the forgoing represents in a very simple way the essential elements of pricing livestock production insurance. The premium values will differ if a different intensity function is used, if the duration period is changed, or if the frequency changes. However, the results do illustrate several salient points. First, the more frequent is a disease the higher will be the cost of insurance. The longer the duration of a disease in the herd, the greater will be the rate of infection and hence the premiums, and lastly, the susceptibility of the herd to the disease will also lead to increased premiums.

There is also an important policy issue about livestock insurance. It is quite clear that sound population medicine, herd health management, and best management practices will affect all three factors. Frequency will be lower, duration will be shorter, and intensity will be smaller. All three of these factors indicate that mitigation through inoculation or antibiotics will reduce production risks and hence insurance costs. In light of this, consumer perceptions of food safety risk that inhibit, or even laws that prohibit, inoculation can lead to a greater incidence of disease and higher costs of insurance to livestock producers. For example, even though a vaccine for FMD is available, it is not used on North American herds because the presence of the antibodies from the vaccine cannot, given current technology, be distinguished from a live virus. Japan and other trading nations will therefore not accept vaccinated animals. Notwithstanding the importance of trade and the high risk of losing foreign markets versus the relatively low risk of an FMD outbreak, a policy of prohibiting vaccination increases the likelihood of an FMD outbreak and, all other things being equal, higher insurance costs.

But all things are not equal. The increased risk from prohibiting inoculation or vaccination is largely offset by agencies such as the USDA's Animal and Plant Health Inspection Services (APHIS) that provide surveillance and monitoring of livestock infectious/contagious diseases. In 2002, APHIS reviewed its animal health safeguarding system[5]. Safeguarding refers to an integrated system for preventing, detecting and appropriately responding to adverse animal health events resulting from the real or perceived impacts of diseases, pests, vectors or toxins on productivity, trade, or public health. Using Homeland Security funds, money will be used to initiate a network of diagnostic laboratories, strengthen state capabilities to respond to animal disease emergencies and increase surveillance for animal diseases, and place tissue digestors in several states (USDA Oct 2002). The new role of APHIS will address both accidental, natural, or agroterrorist based disease outbreaks. The various roles by APHIS to avoid or detect early outbreaks of newly introduced and/or emerging infectious/contagious diseases in livestock and poultry mitigates the risk considerably[6]. The logical question is whether the increased probability of economic loss from a disease outbreak due to a failure to vaccinate/inoculate is sufficiently offset by mitigation through surveillance and monitoring[7].

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[5] United States Department of Agriculture (2002) "Safeguarding Animal Health" http://www.aphis.usda.gov/oa/pubs/fssafeah.html October

[6] USDA (2002) "Comprehensive Monitoring and Surveillance for Livestock and Poultry Diseases" http//www.aphis.usda.gov/vs/nahps/surveillance/

[7] On April 2, 2003 The Press Association Limited reported that the first tests for mad cow disease in live cattle could potentially be on the market within 18 months. Under current rules farmers who suspect one of their cows is suffering from BSE must have the animal slaughtered to enable it to be tested. Surrey (UK)-based firm Proteome Sciences announced an agreement to develop and produce tests that could render slaughter unnecessary.

Principles of Net Revenue Insurance

This section develops a number of path dependent revenue insurance products that are based on the joint distribution for livestock and feed prices. A path dependent option is one in which the payoff depends, not on the values of livestock and feed prices on a given day (as in a European option), but on the path that prices take over the life of the option or insurance product. Hart, Babcock and Hayes (2001) examine numerous path dependent structures such as Asian options to examine revenue insurance products for hogs. Below we replicate some of their results for beef livestock and examine a range of alternative path dependent options.

Assuming only one source each of input and output price risks, the relevant probability distribution (as presented in equation 4) is given by

(7) $$\mathrm{E}(R) = \int\int [\theta\, p - \omega\, f]\, \mathrm{g}(p, f)\, dp\, df$$

where g(p,f) represents the joint probability distribution function for input and output prices and the expectation is measured assuming fixed coefficients for θ and ω[8]. To solve this problem assume that p and f follow correlated geometric Brownian motions

(8) $$df = \alpha_f f\, dt + \sigma_f f\, dw_f$$

(9) $$dp = \alpha_p\, p\, dt + \sigma_p\, p\, dw_p$$

where α_f and α_p are the drift rates and σ_f and σ_p the volatilities of feed and ouput prices respectively. The terms dw_f and dw_p are Wiener processes and the covariance between feed and livestock prices is

(10) $$cov = \rho\, \sigma_f\, \sigma_p$$

Using Ito's Lemma on equation (1) and equations (8), (9) and (10) the partial differential equation for the change in net revenues is

(11) $$dR = (\theta\, \alpha_p\, p - \omega\, \alpha_f f)\, dt + \theta\, \sigma_p\, p\, dw_p - \omega\, \sigma_f f\, dw_f$$

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[8] In the mathematical analysis that follows as well as the application I assume only one feed input. Obviously livestock feed is a mix of forages, grains and other supplements. If more than one input is required in practice the cost element can be treated as an input portfolio. The weights would represent the proportions in a feed mix and this would be multiplied by ω to convert to total weights. While the resulting formula would be more complex, the financial mechanics would be the same.

With expected value at time T (e.g. the date T years from the date that the insurance contract is written) defined by the drift

(12) $$E(dR) = (\theta\, \alpha_p\, p - \omega\, \alpha_f\, f)\, T$$

and variance

(13) $$VAR(R) = (\theta^2 f^2 \sigma_f^{\,2} + \omega^2 p^2 \sigma_p^{\,2} - 2\, \theta\, \omega\, f\, p\, \rho\, \sigma_f \sigma_p)\, T$$

Since equations (7) and (8) are jointly, lognormally distributed by definition, equation (11) is jointly normally distributed with a mean change described by (12) and variance given by (13). In (13), variance is influenced by feed conversion ratios and the covariance between livestock and feed prices. The variance measures in (13) are measures of levels prices, but from (8) and (9), they represent the variance in the percentage change in prices. The feed conversion ratio is a parameter, fixed by the terms of the contract, so there is no possibility of moral hazard in feeding regimes. In terms of covariance, a positive correlation between feed and livestock prices will result in a reduction in overall variance, while a negative correlation will result in an increased variance.

Because (10) is normally distributed, and not a geometric Brownian motion, it is not possible to develop an insurance product based on a Black or Black-Scholes framework[9]. Nonetheless, equation (10) represents time-dependent or path-dependent behavior in that price movements follow a random walk between the times t=0 and T at expiration. Furthermore, since (7) and (8) follow Geometric random walks they can jointly provide the path or evolution of net revenues over time. This feature can be exploited in a number of ways. First, using the normal distribution on time T payoffs can develop a simple net revenue insurance product. However, with knowledge of the underlying stochastic structure it is possible to consider a number of useful path-dependant derivative products that combine both output and input price risks. (See

[9] However, if either price (P or f) is ignored then (11) immediately collapses to a geometric Brownian motion and the conventional approaches to pricing options can be used. For example, removing revenue risk from consideration by setting θ=0 forces dR=df. Making this substitution to the left hand side of (9) establishes the distribution of feed costs as a geometric Brownian motion. Likewise, by setting ω=0 takes feed costs out of consideration forcing dR=dp and converting equation (9) into a geometric Brownian motion for cattle prices. If f and p are in fact futures prices (an assumption I make in this paper) then livestock insurance can be calculated on gross revenues or costs using conventional options pricing techniques. If X is the strike price at contract expiration then the expected values of the payoffs at time T are E{MAX[0,f -X] } for a call option on feed prices, and E{MAX[0, X - p] } for a put option on livestock prices.

Hart, Babcock and Hayes (2001) for a similar examination of path dependent revenue insurance products for liver hogs.) The terminal boundary condition at time T for this joint distribution is given by E{MAX[0,X– R(T)]} to protect against net revenue shortfalls. The mechanics are the same as in conventional options pricing, but the solution is different [10].

Asian Options

A path dependent option is defined as one whose payoff at expiration, T. is contingent on the path or evolution of prices prior to T. An Asian option for example is an option whose payoff is dependant on the average price or revenue over some period T-t, where t can take on any value from $0 \leq t < T$. For example, define

$$J = \left[\frac{1}{t_2 - t_1}\right] \int_{t_1}^{t_2} R(t)\, dt \tag{14}$$

Where t_1 represents the beginning of an averaging period, t_2 is the end of an averaging period, and R(t) is the realization of equation (4) at time=t. An option based on E{MAX[0,X - J]} with J defined by (14) is referred to as an Asian option. It is path dependent because the payoff depends on the evolution of R(t) over the time horizon t_1 to t_2 [11]. Since J represents the average realization of R(t) the Asian option states that if the average realization of R(t) (i.e. J) is less than the strike price X, at expiration, then the insurance pays the difference between the strike and the average. An Asian option will generally be lower in price than the basic option since the reference value J taken as the average across time, will generally eliminate (at least in repeated sampling) extreme highs or lows making it more likely to be in the money, but less likely to have a large payoff. Nonetheless, for livestock revenues that are, on average, lower than the strike over a given period of time, this type of option can provide considerable protection.

An alternative form of an Asian option is to set the strike value as the average realization. This is referred to as an Average Strike Option. Here the payoff function is given by MAX{J - R(T), 0}. Suppose that net revenues have on average been higher than R(T), which implies that

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[10] Further discussion of exotic and Asian options can be found in Hull and/or Willmot. For specific applications of revenue insurance to agriculture see Turvey; Stokes; Stokes et al; and Tirripatur et al. For pricing of options on the cash commodity, when the cash commodity is driven by futures contracts in a foreign currency and basis risk is present, see the quantos model developed in Turvey and Yin. A similar analysis has been done by Hart, Babcock and Hayes (2001).

net revenues are falling as $t \rightarrow T$, then the average strike option will pay off. If net revenues are rising, and are above the average net revenues for the time period considered then $R(T)>J$ and the option expires worthless. These kinds of options are invaluable to the producer who does not want to do worse than the average realization in the given year. Note, however that this is truly path dependent and time dependent since the strike value changes as market conditions change. In contrast, the conventional Asian option fixes the strike or target revenue, and pays off only if average realizations are below the strike.

Lookback Options

A second type of path dependent option is called a Lookback Option. This option has a payoff at expiration that is equal to the difference between the maximum value recorded over the time horizon and the time T value. From t=0 to T let $J = MAX(R(t))$ be the maximum valued occurrence. Then the payoff at expiration is $MAX\{J - R(T),0\}$. Essentially, if ever over the life of the contract the value of equation (14) valued at the instantaneous prices f_t and p_t exceeds the expiration value based on f_T and p_T, a payoff is made. The lookback option differs from the Asian option in one significant respect. The payoff is on the extremes rather than on the average. Therefore, the cost of a lookback option will be significantly higher than that of an Asian option, but will provide a higher expected payoff in a regime in which R(t) is falling as $t \rightarrow T$.

Barrier Options

A third type of path dependant option is referred to as barrier options. A 'knock in' barrier option is initially worthless at t=0 and then becomes 'active' only when a particular economic condition arises. For example, if a cattle rancher places some reservation value on R(t), say R*, then if ever R(t) falls below R*, a put option is triggered with a strike price X . This is referred to as a 'Down and In' barrier put option and becomes more valuable as the option moves into the money as R(t) falls. Alternatively a knock-out option can be written such that a put option with strike price X, originally alive at t=0 is knocked out, or made worthless if at any t, R(t) > R*. This is referred to as an 'up and out' barrier put option and it becomes less valuable as the option moves out of the money as R(t) rises above X [12].

[11] If the payoff is dependent only on the realization at T, that is R(T) as discussed above, it is not path dependent.
[12] We are concerned here with put options only. For Call options the equivalent barriers are 'down and out' for the knock out call, and 'up and in' for the knock in call.

Such options are valuable because they limit the exposure to unnecessary time value. The probability set is comprised of two basic elements. The first is the likelihood that the option will become active or inactive (the probability that it will cross the barrier at R*), and the second is the probability that when active it will expire in the money. While active, the barrier options value is the same as that of a conventional option but has a value of zero when inactive. As long as the probability of crossing the barrier at R* is positive, the barrier options will always have a value less than that of conventional options.

The path dependent options discussed above can be expanded in definition to examine a subset of options of use to livestock net revenue insurance. For example, the variable J in the Asian option (equation 14) can be averaged over the time interval 0,T or any other suitable interval. For many stabilization and crop insurance programs the price attached to yields is often set equal to the average commodity price in the primary harvest month, or over a two to three month period. Likewise, a livestock producer may want to accept slightly higher risk by setting J in equation (14) as the average over a shorter period of time, say t_1 to T, with $t1>0$. Obviously if $t_1=T$, then the value of the option will be identical to a plain vanilla option, which will be of higher risk.

Barrier options can provide particularly interesting flexibility for the net revenue model discussed since the barrier can not only be established relative to net revenues R* , but p* or f* as well. In other words if a cattle producer knows that the greatest uncertainty is in feed costs, then he may wish to establish a barrier option which will activate or deactivate if and only if the price of corn crosses a barrier at f*. Likewise, if cattle price is more important then the barrier can be tied to the price of cattle at p*. More complex structures can also be envisioned. For example a barrier option that is activated if ($p<p^*$ OR $f>f^*$); or more complicated yet, ($p<p^*$ AND $f>f^*$).

Monte Carlo Approaches to Options Pricing

This paper examines a number of net revenue options. While many of the options such as plain vanilla and path dependant, have available solutions, these solutions are sometimes complex and cumbersome. In the alternative, Monte Carlo approaches can be used.

Data and Estimation

The Monte Carl simulations assume the existence of futures contracts for cattle and corn and the insurance contract is based on the performance of the futures markets rather than the cash market. That is, the approach used does not necessarily eliminate basis risk. Summarized in Table 1, the data represent 950 matched daily observations from 1996 through February 7, 2001 on the nearby futures price. The futures contracts include live cattle and grain corn traded on the Chicago Mercantile Exchange (CME) and the Chicago Board of Trade (CBOT) .

The sample means and range are given in Table 2. In the last two columns the annualized geometric growth rate and volatility based on a 250-day trading year are presented. The results show that corn faced a general decline of about 15%/year while live cattle had an increase of about 2%/year. The price of corn ranged from \$5.48/bu to \$3.69/bu while the ranges for live cattle were \$73.64/cwt to \$54.80/cwt. On average, volatility exceeded 20% per year. The most volatile commodity was corn at about 30%, while the livestock contracts had annualized volatility of about 21%. Table 3 provides the correlations between the commodities. The correlation between daily changes in corn and live cattle prices was -0.56.

The correlations are important to what follows. Recall that the variance of the net revenue is negative in correlation, meaning that an actual negative correlation increases variance. This result implies that, quite generally, a percentage increase in the price of cattle corresponds with a percentage decrease in the price of corn. Since a decrease in the price of corn corresponds with a reduction in cost, it also contributes to an increase in net revenues. That is, a negative correlation between a revenue item and a cost item will ultimately increase overall variability.

Finally, the modeling and pricing approach used requires that cattle and corn prices follow a geometric Brownian motion. The two price series were tested specifically for the two properties that define a random walk. First, according to Geometric Brownian motion the variance of futures prices should increase linearly in time. That is, the variance of prices over 2 days should be twice the variance of prices for 1 day and so on. A variance ratio test fails to reject the null hypothesis of a random walk for corn and live cattle futures prices. The second property is that the mean rate of changes in prices is linear in time. This implies that the rate of change in prices over a 250 trading day year should be 250 times the daily rate of change. Tests fails to reject the null hypothesis of linearity in mean rates of change. Failure to reject these conditions provides confirmation that the time series are non-stationary and independent across time.

Monte Carlo Simulations

This section describes the initial conditions for the Monte Carlo simulations and the modeling approach used. The prices for cattle and corn were $0.70/lbs and $2.50/bushel respectively. These prices are within the neighborhood of current prices as well as the prices used to calculate historical volatilities. The historical volatilities were .20 and .30 for cattle and corn respectively. Because futures contracts are used as the underlying risk instrument, it is assumed that the underlying risks can be spanned and therefore a risk-neutral valuation is used and the risk-neutral growth rate was set to 5%[13].

For purposes of these simulations a 120 day horizon was used. Assuming an average daily gain of 4.58 lbs, a stocker can be fed from 500 lbs to 1050 lbs, for a 550 lbs gain. Assuming further a feed conversion rate of 4.5 lbs of feed per lbs of gain implies that 2,475 lbs of corn is required. Converting lbs to bushels is accomplished by dividing 2,475 lbs by 39.6 lbs/bu. This suggests that 62.5 bushels of corn are required to achieve the desired weight. The initial conditions are thus established. The initial revenue expectation is 550 lbs * $0.70/lbs = $385 and the initial cost expectation is $156.25 for a net revenue expectation of $228.75 [14].

As indicated above, the evidence supports the underlying proposition that cattle and corn futures prices follow a random walk. The simulations were operationalized using Palisade Corporations @RISK computer program. At expiration (T=120 days) the revenue measure was calculated from equation (15)

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[13] The assumption of risk neutral valuations follows from the proposition in Cox and Ross, and Cox, Ingersoll and Ross. If the underlying risks can be traded then a hedging regime can be constructed to eliminate risk. Under such a condition the natural growth rates in the price series are replaced by the risk free rate. If instead the prices were on non-traded feeds or livestock, the problem becomes somewhat more complicated since the risk neutral growth rate would be set to the actual growth rate (or drift rate) less the market price of risk. See Yin and Turvey's (2003) comment on Stokes et al .

[14] In this model only the net gain is considered. This naively assumes that the purchase price of the calf is sunk. However, another form of the model would be to set revenue expectations at total weight (1,050 lbs) so that the net revenue would be initialized at 1,050*.70 – 156.20 = $578.8. Using gross weight rather than net weight will increase the cost of insurance since overall variability will increase.

(15) $$Revenue_T = Q\left(p_T - \{\frac{4.5}{39.6}\}\, f_T\right)$$

where the prices of corn and cattle evolved dynamically according to

(16) $$f_t = f_{t-1}\,\mathbf{e}^{\left(\frac{r-.5\sigma^2}{250} + \frac{Z\sigma}{\sqrt{250}}\right)}$$

and

(17) $$p_t = p_{t-1}\,\mathbf{e}^{\left(\frac{r-.5\sigma^2}{250} + \frac{Z\sigma}{\sqrt{250}}\right)}.$$

Equations (16) and (17) are mathematical statements that the current futures price is equal to the previous days futures price plus a lognormally distributed shock. The number 250 in (16) and (17) converts annual interest rates, r, and volatilities, σ, to a daily rate based on a 250-day trading year. The symbol Z represents a standard normal deviate with a mean of zero and standard deviation of 1. Choosing a new value of Z for each of 120 days and for each price series generates the lognormally distributed price series. Substituting the random prices on each day into a time-t version of equation (15) generates the time path for net revenues based on changes in the futures prices. Finally, while the random deviates were generated as time-independent shocks, the daily variants were generated from a joint normal distribution with a correlation coefficient of -.57.

Options prices and simulations were calculated for

(a) Uninsured net revenue (the base case)
(b) A put on net revenue, with strike price equal to t=0 expectation of $228.75
(c) A put on the cattle price with strike = $0.70/lbs and a call on the corn price with a strike of $2.50/bushel
(d) A put on the cattle price with strike of $.70/lbs and no call on corn price
(e) A call on the corn price with strike of $2.50/bu withy no put on the cattle price
(f) An Asian put option on average net revenues with a strike of $228.75

(g) A Put Option on the average strike, where the strike price becomes a random variable

(h) A Lookback option with put payout based on a strike equal to the maximum net revenue observed over the 120 days

(i) A down an in barrier option with barrier set at .90*228.75, and

(j) An up and out barrier option with barrier set at 1.10*228.75

The Monte Carlo approach used 10,000 iterations. Each iteration comprised the generation of 120 days of prices and net revenues, and the calculation of the net revenues and options payout for that particular iteration. The value of the option was taken as the average payout across all 10,000 iterations. The procedure involved two steps. The simulations were first run to capture the values of the various option premiums. In the second step, the model was run again, using the same seed value as the first, to capture the net effects of the insurance. The net effects were estimated as net revenue plus option payout less the cost of the option.

Results From Net Revenue Insurance

The results of the analyses are presented in Tables 5 and 6. Using conventional options to hedge, Table 5 shows that the unhedged position has the highest overall variance as expected. The skewness of approximately 0 and kurtosis of approximately 3, confirms the normality of the net revenue distribution. In terms of variance the greatest amount of risk reduction is with the cattle put plus the call on the corn, an expected result given the negative correlation between the two prices. However in terms of downside risk, the row indicating 5% reveals that insuring net revenue directly will have a slightly better result. A 5% chance of revenues falling below $199.39 dominates a 5% chance of revenues falling below $195.51. Likewise, since the insurance costs of net revenues is lower than the insurance costs of independent puts and calls, the upside potential is also dominant. The last two columns examine the conventional use of one option or the other. Variance is lower for the put and call scenarios than the base case, but is higher than insuring both, so the benefit of insuring net revenues is evident. Likewise, the downside risk assessment at the 5% level indicates that downside risk is higher under these two scenarios than the net revenue scenarios, but these strategies still dominate the no-insurance case. The upside is higher for these strategies since the cost of the insurance is lower. In terms of skewness, the net revenue insurance policy dominates, followed by the put plus call strategy, and then the individual option strategies. The cumulative distribution functions for these scenarios are presented in figure 1. The net revenue insurance distribution is truncated at the strike and there is a quasi (imperfect) truncation for the put plus call strategy. The individual options strategies are characterized by continuous distribution functions, but they are not truncated. Rather, the distributions reveal a shift of probabilities from the downside towards the central core.

The four exotic options are presented in Table 6. The down and in option most closely resembled that of the net revenue put. Recall that the down and in option only becomes activated if revenues hit a barrier or threshold. For these simulations this barrier was set at 90% of the strike, so the result simply states that in the majority of cases net revenues fell below the barrier. The option price of 29.22 is only slightly lower than the 29.36 value of the net revenue insurance and reflects a very low probability that the barrier set would not be breached.

The Asian option, with a value of $16.82 reduces risk by approximately 50% of the net revenue insurance. However it does protect the downside by shifting probabilities from the lower partial moments to the mid partial moments as can be seen by the increased skewness. The minimum revenue under the Asian option was $52.28 compared to $-67.92 for the uninsured case and $199.39 for the net revenue insurance case. With net revenue insurance there is a 95% chance of exceeding $199.39 but with the Asian option there is a 95% chance of exceeding $141.13. The results for the average strike option are very similar to that of the Asian, but it is worth reiterating the differences. With the Asian option a payout is made if the average net revenues across 120 days falls below the strike price, which is fixed. In contrast, the average strike put recalculates the strike for each iteration, setting the strike equal to the 120 day average. If the average strike, representing average revenues, exceeds the net revenue at expiration, a payout is made. The average strike option insures that the producer at least receives the average of revenues, whereas the Asian option insures that the producer does no worse than the average. The probability space of the payoff functions for these options will differ under identical states of nature, but the aggregated outcomes across all states of nature are similar because in both cases the payout is based on the average, and the distribution of revenue itself is normal.

The last of the exotics is the Lookback option. This option looks back over the 120 days and picks the maximum net revenue observed. If this net revenue exceeds the net revenue at expiration then a payout is made. In terms of downside risk protection this option is more skewed than the Asian options. Its minimum was $171 and is more positively skewed than the average options. However, its cost at $9.64 is quite low relative to the other options types. The cumulative distribution functions are presented in Figure 2.

Principles of Catastrophic Insurance

In this section I present a poisson probability model that can easily be used to calculate the losses from a rapid decline in market prices due to the emergence of an infectious disease. As discussed in the introduction a finding of BSE on a U.S. farm will cause an immediate and precipitous decline in market prices as consumer concerns about food safety cause demand to fall. A finding of FMD will have a similar effect as export demand falls and domestic supply increases. A common approach to measuring jump processes in prices is to define the stochastic differential equation as

(18) $$\frac{dp}{p} = \alpha_p \, dt + \sigma_p \, dw_p - dq$$

where $dq = \begin{cases} 0 & probability = 1 - \lambda \, dt \\ \theta & probability = \lambda \, dt \end{cases}$

Equation (18) states that the occurrence of the event with probability λdt results in a loss of θp. If the event does not happen (with probability 1-λdt) then the price path follows that of the original Brownian motion. We can then write

(19) $$\frac{dp}{p} = (\alpha_p - \lambda \, \theta) \, dt + \sigma_p \, dw_p$$

with

(20) $$\mathrm{E}(dp) = (\alpha_p - \lambda \, \theta) \, p \, dt$$

and

(21) $$\mathrm{VAR}(dp) = [p^2 \sigma_p^{\,2} + p^2 \theta^2 \lambda]\, dt\ .$$

Equation (20) identifies the drift of the price process. Under normal economic conditions the mean change in prices is given by αp. In the event of a disease outbreak, the drift is adjusted downward by the jump factor $\lambda\theta$. Equation (21) gives the variance term, now comprised of two separate, but uncorrelated, components. The first term is the instantaneous variance of the normal price process, whereas the second term is the additional increase in variance due to the possibility of a shock to prices.

Under a general jump process multiple events can occur, but in terms of livestock prices a single jump will be sufficient to cause wide spread price reductions. Since such jumps will not normally be considered in any of the revenue insurance possibilities discussed in the previous section, this section outlines a simple approach to considering the impacts of an event.

The simplest approach would be equivalent to a knockout option. In this context a knockout option is one option that substitutes, or knocks out, another option when a specific event happens. For convenience, suppose that the event is the occurrence of FMD or BSE on U.S. soil. Furthermore, suppose that in the event of an occurrence it is expected that prices will fall by (1-θ%). If the current price is P_0 then should the event happen the payout is P_0-(1-θ%)P_0 or θP_0 . Let F(QP,t) represent the actuarial value of a price-insured revenue insurance option available to farmers and θQP_0 be the value of a payout if BSE or FMD occurs. An example of F(QP,t) is the price insurance product in the fourth column of Table 5. The value of the knockout option is then G(QP,λ,t) = MAX(F(QP,t), θ QP_0) or

(22) $$G(Q\,P, \lambda, t) = \begin{cases} F(QP, t) & probability\ = 1 - \lambda\, dt \\ \theta\, Q\, P_0 & probability\ = \lambda\, dt \end{cases}$$

and

(23) $$G(Q\,P, \lambda, t) = (1 - \lambda\, dt)\, F(QP, t) + \lambda\, dt\, \theta\, Q\, P_0$$

As an example, assume that the probability of a disease outbreak is 5% /year and when that event happens prices are expected to fall by 75%. Then a \$70/cwt price falls to \$17.50/cwt for a payout \$52.5. The probability of this occurring is 5%/year or 1.67% over a 120 day period, so the expected cost per cwt is \$0.875/cwt. For a 550 lbs gain as assumed in the previous section the marginal cost per animal is \$4.813.

In the 5th column of Table 5, it is shown that the cost and expected payout of a price-based insurance product is F(QP,t) =$18.25 for 5.5 cwt of gain. Under the knockout option policy this occurs with a 98.33% probability while the disease event, with a payout of $52.5/cwt*5.5cwt=288.75 occurs with a 1.67% probability. The value of the knockout option is the probability weighted sum of the two payouts, i.e. G(QP,λ,t)= 0.9833*18.25+0.0167*288.75 =$22.77 or $4.14/cwt.

Based on these assumptions, the incremental increase in the cost of insurance is about 24.8%. But the assumptions are explicit and unproven. The assumption that FMD, for example, will appear 5 out of every 100 years is higher than the actual probabilities based on recent history. However, the probability is likely elevated with the rise of incidence in the UK, EU and elsewhere, as well as the rising concern about agroterrorism. Likewise, the assumption of a drop of 75% is unproven. Since neither FMD nor BSE has occurred (at least since the 1950's) in the United States it is difficult to gauge exactly what the short run impacts would be. Nonetheless, with an annualized volatility of livestock prices of about 21% (Table 2) or about 12.14% ($0.21*(1/3)^{.5}$) for the 120 day period under discussion, a 75% drop in price implies a drop of about 6.18 standard deviations (Z = 0.75/.1214=6.18) an occurrence that would simply not happen under normal market conditions. Nonetheless, the belief that a contagious disease outbreak such as FMD or BSE will cause a precipitous decline in beef prices requires, as a matter of probability, supplementary consideration of such an event occurring.

Conclusions

This paper has examined the problem of providing revenue insurance for the livestock industry. To provide revenue insurance requires insuring a minimum of four separate sources of risk; productivity, selling prices, feed quality, and input prices. The characteristics of risk between the four categories differ significantly. Productivity is subject to pathogenic and ecological risk. Disease outbreaks, herd health, and population medicine are all factors of importance. The characteristic of risk differs from price risk, since disease outbreaks arrive periodically with randomness and with intensity and duration that are also random, if not controllable through extraordinary herd and veterinary management practices. Productivity losses are to a certain degree, reversible although reversibility does come at a cost. Feed quality risk is probably the least important since it is easily reversible, although again with some cost. Productivity losses due to feed quality are more probably settled through legal channels than insurance mechanisms.

In terms of pricing livestock insurance, this paper argued that three essential principles should be followed. First, the frequency of a disease outbreak measures the likelihood that in any given year an outbreak will occur. Given an occurrence the duration of the outbreak is critical. The duration measures the number of days that the herd is infected. The longer the duration the greater will be the damage and hence the premiums. Finally, the third principle is intensity. Intensity measures how susceptible the herd is to the disease. Low susceptibility will result in only moderate losses, but high susceptibility or intensity will result in large losses. A representation of the loss function and an example of premium setting using a gamma distribution in exponential form for generating randomness in duration, and a power function form for intensity was provided to illustrate the basic concepts.

This paper presented in more detail an approach to hedging net revenues when output price and feed costs are random. Taking the position that that proximate net revenue can be insured using available data on livestock and feed prices, a general net revenue insurance product was developed. The model requires the assumption of Brownian motion in cattle and feed (corn) costs, and through this assumption it was shown that net revenues are approximately normally distributed. Although net revenue can be insured using simple notions of conventional options pricing, the empirical component to the paper examined an array of possible products using Monte Carlo simulations. The products chosen included a put option on net revenue, a put option on cattle prices, a call option on input costs, an Asian option, an option on an average strike price, a lookback option and a barrier option. The point of presenting the variants to insuring net revenues was to illustrate that there are many alternative structures available to insuring proximate net revenues, each with its cost and benefit in terms of downside risk reduction.

Based on the conditions imposed it was shown that net revenue insurance, a put option, provided the greatest benefit to risk reduction. A revenue insurance based upon a put on cattle prices and a call on input cost was also shown to be effective as were the lookback and barrier options. Options on the average offered low-cost revenue protection but with slightly higher downside risk. However, in practice the notion of protecting average net revenues over a period of time may be attractive to many farmers. A model comprised of using only a put or only a call provided the least downside risk protection.

Consideration was also given to methods for pricing catastrophic insurance in the event of a disease outbreak such as FMD or BSE. The model presented followed the conventional approach of incorporating a jump process into the standard Brownian motion price process. Based on an assumption that either of these diseases could occur 5 out of every 100 years, and that when such an occurrence arrived the price of livestock fell by 75% it was shown that the catastrophe premium increased the premium of a simple price-insured revenue insurance product by about 24%. In other words, even though the likelihood of an outbreak is low, the magnitude is sufficiently high to be of economic significance. However, the basis of the analyses was based on two unknown data points, namely the likelihood of occurrence and the magnitude of loss. Clearly the cost of catastrophe insurance will increase or decrease if either one of these variables increase or decrease, and a recommendation for further research is to empirically examine and enumerate the costs of catastrophe using historical precedence and perhaps more sophisticated insurance models. For example, space considerations restricted us from examining the effect of catastrophic jumps for most of the models we examined.

The paper presented a model that is mathematically feasible and that is consistent with certain insurance objectives. Since it is based upon futures prices, it is free from moral hazard and adverse selection since the sources of risk are exogenous. Nonetheless the model does present some qualitative shortcomings. The empirical model was based only upon the net revenue gain from feeder to finish, but in reality some producers may not like the risk exposure that this presents and might prefer insuring all of the productivity and the feed costs. This is a minor adjustment to the empirical model, and is easily captured in the mathematical model. Perhaps more critical is the naivety in which feed costs were expressed. In the theoretical and empirical model, it was assumed that the feed price risks were based on average daily gains and a single crop. In reality feed rations are more complex and may include prices on crops such as hay and forage that are not traded. The theoretical model can handle this added complexity, but the pricing formula becomes more complex. In addition it was assumed that the relevant price series was a futures contract, but some farmers may prefer insurance on the local cash price. This too creates theoretical and empirical problems since commodities bought or sold in the cash market are non-traded in the sense of risk-neutral or arbitrage free insurance pricing. Models of proximate net revenue insurance that include the cash market risk would have to include also the market price of risk, rather than the risk free rate, in the growth rate equations for pricing.

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List A Diseases	List B Diseases			
	Multiple species diseases	***Cattle diseases***	***Swine diseases***	***Avian diseases***
Foot and mouth disease	Anthrax	Bovine anaplasmosis	Atrophic rhinitis of swine	Avian chlamydiosis
Swine vesicular disease	Aujeszky s disease	Bovine babesiosis	Enterovirus encephalomyelitis	Avian infectious bronchitis
Peste des petits ruminants	Echinococcosis/hydatidosis	Bovine brucellosis	Porcine brucellosis	Avian infectious laryngotracheitis
Lumpy skin disease	Heartwater	Bovine cysticercosis	Porcine cysticercosis	Avian mycoplasmosis (M. gallisepticum)
Bluetongue	Leptospirosis	Bovine genital campylobacteriosis	Porcine reproductive and respiratory syndrome	Avian tuberculosis
African horse sickness	New world screwworm (Cochliomyia hominivorax)	Bovine spongiform encephalopathy	Transmissible gastroenteritis	Duck virus enteritis
Classical swine fever	Old world screwworm (Chrysomya bezziana)	Bovine tuberculosis		Duck virus hepatitis
Newcastle disease	Paratuberculosis	Dermatophilosis		Fowl cholera
Vesicular stomatitis	Q fever	Enzootic bovine leukosis		Fowl pox
Rinderpest	Rabies	Haemorrhagic septicaemia		Fowl typhoid
Contagious bovine pleuropneumonia	Trichinellosis	Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis		Infectious bursal disease (Gumboro disease)
Rift Valley fever		Malignant catarrhal fever		Marek s disease
Sheep pox and goat pox		Theileriosis		Pullorum disease
African swine fever		Trichomonosis		
Highly pathogenic avian influenza		Trypanosomosis (tsetse-borne)		

List A diseases: Transmissible diseases that have the potential for very serious and rapid spread, irrespective of national borders, that are of serious socio-economic or public health consequence and that are of major importance in the international trade of animals and animal products.
List B diseases: Transmissible diseases that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of animals and animal products.

Table 1: OIE Classification of Diseases (source: http://www.oie.int/eng/maladies/en_classification.htm)

Statistic	corn_price	live cattle_price
Mean	272.33	65.61
Median	258.13	65.68
mean/median	1.06	1.00
Mode	219.00	66.98
Std Dev	76.99	3.24
Min	178.50	54.80
Max	548.00	73.64
Range	369.50	18.84
range/median	1.43	0.29
Skewness	1.54	-0.17
Coeff of Var	3.54	0.05
Log Changes		
Mean growth	-0.0006	0.0001
Volatility	0.0236	0.0133
Annualized Growth	-0.15	0.02
Annualized volatility	0.37	0.21

Table 2: Sample Statistics

	corn_price	live cattle_price
corn_price	1	
live cattle_price	-0.56353	1

Table 3: Correlations

Name	Base Case	Revenue Put	Live Cattle Put plus Corn Call	Live Cattle Put	Corn Call
Mean	234.30	234.30	234.30	234.30	234.30
Std Dev	80.81	49.82	48.79	62.09	66.68
Skewness	0.08	1.67	1.60	0.72	0.54
Kurtosis	3.16	5.74	5.71	3.93	3.38
Minimum	-67.92	199.39	195.51	31.53	60.60
Maximum	561.44	532.08	528.20	543.19	546.45
5th Perc.	103.04	199.39	195.51	147.73	137.09
95th Perc.	367.36	338.00	334.30	349.12	352.54
Insurance Cost	0.00	29.36	33.24	18.25	14.99

Table 5: Results for Net Revenue Insurance Simulations: Plain Vanilla Products

Name	Net Revenue	Net Revenue Put	Asian Put	Ave Strike Put	Down and In	Lookback Put on max
Mean	234.30	234.30	234.30	234.30	234.30	234.30
Std Dev	80.81	49.82	64.62	64.33	49.94	51.37
Skewness	0.08	1.67	0.59	0.60	1.66	1.10
Kurtosis	3.16	5.74	3.61	3.62	5.71	4.32
Minimum	-67.92	199.39	52.28	36.31	177.06	171.13
Maximum	561.44	532.08	544.62	544.18	532.22	551.80
5th Perc.	103.04	199.39	141.13	140.85	199.53	171.25
95th Perc.	367.36	338.00	350.54	350.18	338.14	332.71
Option Price	0.00	29.36	16.82	17.26	29.22	9.64

Table 6: Simulation Results for Exotic Net Revenue Insurance Products

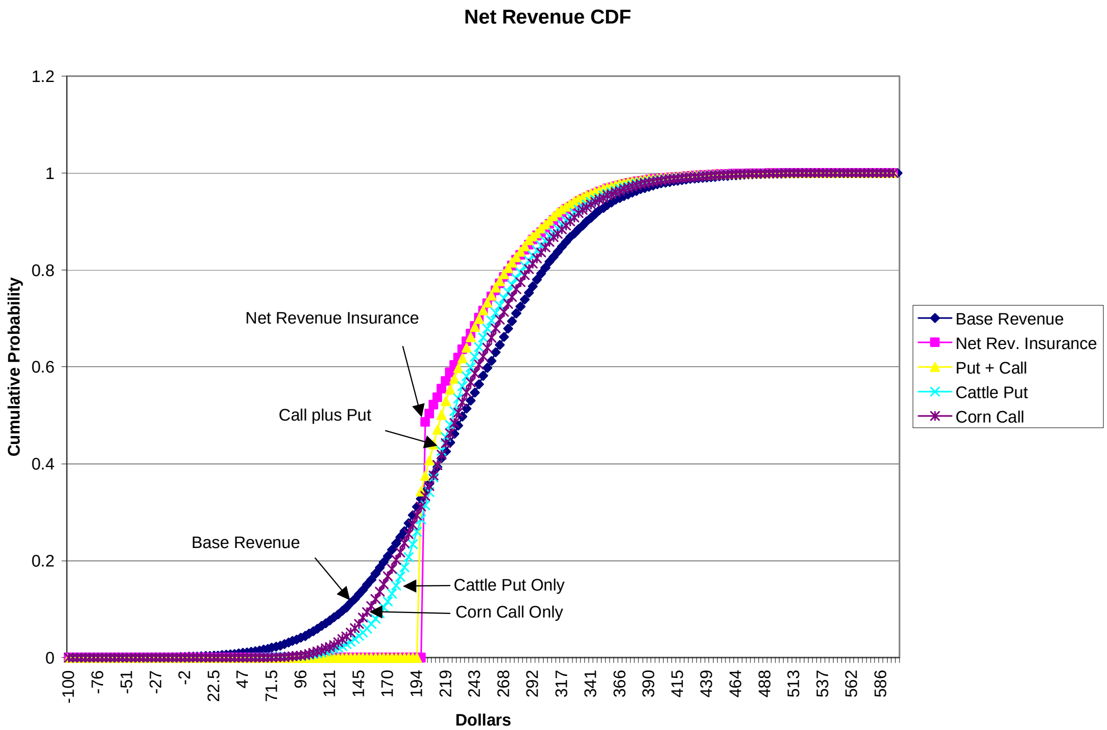

Figure 1: Cumulative Distribution Functions for Net Revenue Insurance

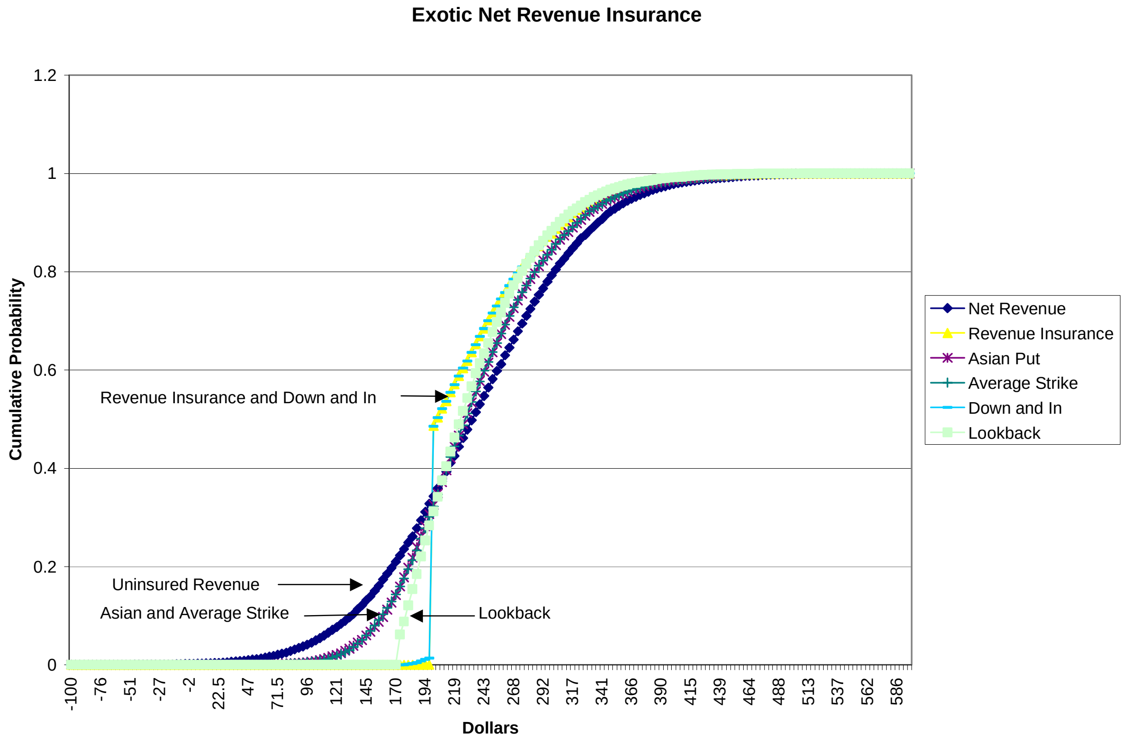

Figure 2: Cumulative Distribution Functions for Net Revenue Insurance