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A Rational Risk Policy for Regulating Plant Diseases and Pests

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Executive Summary

Diseases and pests pose risks to U.S. agriculture and forests, but regulations and quarantines to control these risks are costly. The U.S. Department of Agriculture issues rules to control these risks based on economic analyses that do not take adequate account of links between risks and policy outcomes. A benefit-cost analysis that fully incorporates both the risk of a disease outbreak and the effect of regulations and quarantines on such risk can yield quite different conclusions.

We apply methods that combine probabilistic risk assessments with economic analysis. We show that if USDA had incorporated risk into its benefit-cost analysis of Karnal bunt, a disease affecting wheat, it would have reached different conclusions about the impact of its actions. We estimate that suboptimal regulatory decisions in the case of Karnal bunt cost between $350 million and $390 million per year. We recommend that USDA incorporate risk assessments into its economic analyses of proposed regulations.

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1. <u>Introduction</u>

Foreign pests and diseases pose threats to U.S. agriculture that have long been used to justify stringent import regulations and broad domestic quarantine authorities. Since 1912 the U.S. Department of Agriculture (USDA) has had responsibility for implementing plant quarantines and authority to impose restrictions on the interstate movement of any article that may be infested with exotic pests or diseases (Palm 1999). But regulations and quarantines can impose substantial costs on producers and others who are directly affected and can adversely affect consumers and others through restrictions in supply (James and Anderson 1998).

Balancing the protection from pests and diseases with the costs of quarantines and regulations is a challenge to policy-makers because the substantial uncertainty surrounding threats from plant pests and diseases greatly complicates economic assessments (James and Anderson 1998). USDA has developed probabilistic risk assessments, but regulators have typically considered benefits and costs separately. USDA's economic analyses typically assume that specific control measures are sufficient to avert specific outcomes, such as a 10 percent drop in exports. Ignoring the underlying distribution of benefits and costs overstates the certainty of the analysis, and more importantly, can potentially suggest very different optimal regulatory actions.

A careful and reliable economic assessment is important. Ensuring that net economic effects are positive is an integral part of the Federal quarantine policy guidelines developed by the National Plant Board in 1931.[1] These guidelines state that: (1) the pest concerned must be of such nature as to offer actual or expected threat to substantial interests; (2) the proposed quarantine must represent a necessary or desirable measure for which no other substitute, involving less interference with normal activities, is available; (3) the objective of the quarantine, either for preventing introduction or for limiting spread, must be reasonable of expectation; (4) *the economic*

gains expected must outweigh the cost of administration and the interference of normal activities. (Sim 1998, emphasis added). In addition, the scope of federal regulations and quarantines addressing plant pests and diseases is very broad.[2] Seventeen federal quarantines covering most of the U.S. currently protect a variety of plants—from peach orchards in Pennsylvania threatened by the plum pox virus to Eastern hardwood forests at risk of gypsy moths infestations (table 1).

In this paper, we examine the costly quarantine established by USDA in 1996 to prevent the spread of Karnal bunt, a disease affecting wheat. During the early stages of establishing its regulatory strategy, USDA made extensive use of probabilistic risk assessments to determine the efficacy of various quarantine protocols. It paid less careful consideration, however, to the estimated benefits and costs of its proposed rule. In early press releases and *Federal Register* notices, the benefits were expressed largely in terms of the value of the U.S. wheat market believed to be at risk (e.g., 61 FR 12058, Docket No. 96-016-1). In addition, when the regulatory impact analysis for the final rule was published on May 6, 1997, the benefits and costs of the regulation were discussed without consideration of the distribution of potential outcomes. In particular, the analysis assumed that the regulation would avert at least a 10 percent drop in wheat exports and that the value of avoiding this drop in exports justified the regulations.

We use the example of Karnal bunt to show how regulatory analyses that do not incorporate an adequate risk assessment can lead to costly regulatory decisions. We argue that if risk had been incorporated directly into the benefit-cost analysis, different conclusions would have been reached about their expected impact. In the case of Karnal bunt, sub-optimal regulatory decisions cost consumers, taxpayers and producers between $350 million and $390 million per year.

The paper is organized as follows. In section 1, we present a brief history of Karnal bunt and the events leading to the establishment of the federal quarantine in 1996. In section 2, we develop a model of quarantine policy that relates the expected

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[1]The National Plant Board is an organization of state plant pest regulatory agencies created in 1925 to promote efficiency and uniformity in the promulgation and enforcement of plant quarantines and plant inspection policies (Sim 1998).

[2]For example, estimates of the costs of invasive species to the United States range from $1.1 billion annually (Office of Technology Assessment 1993) to $137 billion (Pimentel et al. 2000). See also Pinstrup-Anderson (1999) and Orke et al. (1996).

costs of quarantine actions to the expected benefits. In section 3, we utilize the probabilistic risk assessments undertaken in 1996 to assess how proposed regulatory actions mitigated the risks of Karnal bunt. In section 4, we consider the potential benefits and costs of the regulations. Section 5 examines the expected benefits and costs of regulations incorporating information on the distribution of potential outcomes given various regulatory actions. We present conclusions in the last section.

2. Regulatory History

Karnal bunt is a disease affecting wheat, rye, and triticale (a hybrid of wheat and rye) caused by the fungus *Tilletia indica* Mitra (Bonde et al.). Karnal bunt can cause production losses to wheat in the form of reduced yields due to the infestation of kernels and reduction in the quality of the wheat flour. Generally, wheat containing more than 3 percent bunted kernels is considered unsatisfactory for human consumption because of a fishy odor that makes wheat products unpalatable (Warham 1986), but it poses no risk to human health.

Karnal bunt was first reported in 1931 in the Indian State of Haryana in wheat-growing areas near the city of Karnal, from which the disease gets its name. In 1982, the United States discovered diseased wheat kernels in wheat imported from Mexico. Following confirmation of Karnal bunt in Mexico, USDA took action to prevent the importation of host plant material (including seed and grain) and any other articles that might spread the disease (Poe 1997). In October 1983, USDA added Mexico and other countries where Karnal bunt was known to occur to the list of countries in the Wheat Disease subpart of the Foreign Quarantine Notices (7 Code of Federal Regulations 319.59). Following the U.S. action against Mexico, the number of countries with phytosanitary trade restrictions involving Karnal bunt jumped from 4 to 22 (Beattie and Bickerstaff 1999).

A risk assessment of Karnal bunt completed by USDA in 1988 concluded that because of the close proximity of wheat growing areas of Arizona and California to infested areas in northwestern Mexico and the flow of prevailing winds, "transport of the Karnal bunt pathogen is extremely likely" (Schall 1988). A subsequent pest risk analysis conducted in 1991 concluded that Karnal bunt was a high risk pest, primarily

because "wheat from infested areas would probably be denied or restricted access in the export market"[3] (Schall 1991). Because of its potential adverse effects on exports, the analysis recommended that in the event of introduction of the Karnal bunt pathogen USDA should establish and maintain quarantines to restrict distribution.

On March 8, 1996, the Arizona Department of Agriculture detected Karnal bunt during a seed certification inspection.[4] On March 20, 1996, the U.S. Secretary of Agriculture signed a "Declaration of Extraordinary Emergency" authorizing emergency action under 7 U.S.C. 150dd to control Karnal bunt within the States of Arizona, New Mexico and Texas. The quarantine was extended to Imperial and Riverside counties in California on April 12, 1996. In an interim rule effective March 25, 1996 and published in the Federal Register on March 28, 1996, the Animal and Plant Health Inspection Service (APHIS) established the Karnal bunt regulations and quarantined all of Arizona and portions of New Mexico and Texas because of Karnal bunt. The regulations defined regulated articles and restricted the movement of these high-risk articles from the quarantined areas.

USDA saw the Federal quarantine and emergency actions as a "necessary, short-run measure taken to prevent the interstate spread of the disease to other wheat producing areas in the outbreak area, so that eradication could be eventually achieved" (62 Federal Register 24754-24755). USDA described its objectives as three-fold: (1) to protect U.S. wheat producers in Karnal-bunt free areas, (2) to protect U.S. export markets, and (3) to provide the best possible options for producers in quarantined areas who are affected by the Karnal bunt detections (USDA APHIS1997).

USDA initially required producers in New Mexico and Texas who had planted fields with infected seed to plow down their crop immediately. Because crop development was further along in Arizona and California, plowing down crops was not considered viable. Instead, a number of regulations were implemented that affected persons or entities that produced wheat in the regulated area and/or moved certain

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[3] An economic analysis conducted by USDA in 1994 indicated that annual crop losses due to Karnal bunt in Arizona, Texas, New Mexico and California would total between $406 thousand and $1 million per year and that annual losses in export markets could total over $57 million for Arizona and Texas alone (cited in Podleckis 1995).
[4] Checks of seed lots dating back to 1993 from the same area in Arizona revealed the presence of Karnal bunt teliospores at low levels (Nelson 1996).

articles associated with wheat out of a regulated area (table 2). These articles were subject to regulations to minimize the risk of spreading the pathogen to other uninfected areas.

USDA sampled all wheat fields within the regulated areas of Arizona, California, New Mexico and Texas at harvest for Karnal bunt teliospores. It tested any wheat shipped outside of the regulated area for Karnal bunt teliospores. It prohibited grain that tested positive for Karnal bunt from moving out of the regulated areas, but allowed it to be milled or fed to cattle within the regulated area. USDA required other contaminated articles to be cleaned and sanitized before movement out of the regulated area. To determine whether Karnal bunt was present in areas outside of the quarantined areas, a comprehensive national survey of wheat elevators was planned for the fall of 1996.

USDA prohibited commercial seed intended for planting or for breeding and seed development purposes from moving outside the regulated areas. Wheat seed could be planted within the quarantined areas, but only if tested negative for Karnal bunt teliospores and was treated prior to planting. Grain that tested negative could move outside of the regulated areas under limited permit. Grain had to be shipped in sealed railcars and the railcars had to be sanitized after the grain was delivered to its destination. Grain that was exported received a phytosanitary certificate from USDA certifying that the grain had been tested twice and found negative for Karnal bunt.[5]

Negative-testing grain was permitted to move to approved domestic flour mills. Due to the grinding process and intended use, the risk of spread of the disease through movement of the flour was viewed by USDA as negligible. In the milling process, however, a considerable amount of byproduct or millfeed is produced. The millfeed is typically sold as cattle feed which represents about 10 percent of the value of the milled wheat. Because of the risk that manure from the cattle could be deposited on wheat fields and thus potentially be a pathway for spread of Karnal bunt, USDA required that mills heat the millfeed to 130 degrees F for 30 minutes or steam-treat to 170 degrees F.

3. A Model of Quarantine Policy

To analyze costs and benefits of alternative policies, we use a model of disease control similar to one outlined in Rendleman and Spinelli (1999). Let W_D be welfare in the event of a disease outbreak and W_N be welfare in the event of no outbreak such that $W_N > W_D$. If an outbreak occurs with probability p, then the expected welfare, EW, can be written[6]:

$$EW = pW_D + (1 - p)W_N$$

(1)

Now consider a quarantine policy, f, that affects both the probability of an outbreak and welfare such that:

$$EW(f) = p(f)W_D(f) + (1 - p(f))W_N(f) - C(f)$$ (2)

where $C(f)$ is the cost of implementing the quarantine. An optimal regulatory policy maximizes (2) with respect to f such that:

$$\frac{dEW(f)}{df} = 0 \text{, or}$$ (3)

$$p'(f)W_D(f) + p(f)W_D'(f) - p'(f)W_N +$$
$$(1 - p(f))W_N'(f) - C'(f) = 0$$ (4)

Rearranging terms, an optimal quarantine policy f^*, the marginal change in benefits is equal to the marginal change in costs.

$$p'(W_D - W_N) = C' - [pW_D' + (1 - p)W_N']$$ (5)

The left hand terms reflects the net change in welfare due to the change in probability—the benefits of reducing the risk of outbreak. The right hand terms reflect the expected change in welfare due to the quarantine policy—the costs of implementing the quarantine.

The optimal quarantine policy can be shown in figure 1. A, B, C, D, E and F are quarantine policies with associated costs and benefits. Policies A, C, D and F lie on an

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[5]Grain originating from outside of the regulated areas received phytosanitary certificates certifying that the grain was from areas where "Karnal bunt was not known to occur."

[6] A more general form can be written $EW = \int_{-\infty}^{\infty} W(J)f(J)dJ$ where $f(q\vartheta)$ is the probability density function of the risk of outbreak. For the purposes of this analysis it is assumed that an outbreak will have a similar effect on welfare regardless of the intensity of outbreak. In the case of Karnal bunt, losses dues

efficient frontier of policy alternatives; that is, for a given cost, these policies result in the maximum possible benefits. Policies B and E are inferior policies. Policy C is the optimal quarantine policy, f^*, that satisfies equation (5). At this point, the marginal benefit of the quarantine policy is equal to its marginal cost.

4. Assessing the Probability of Outbreak

To estimate the effects of various quarantine protocols on the likelihood of outbreaks of Karnal bunt in areas outside the quarantined area, USDA relied on a number of probabilistic risk assessments conducted prior to discovery of Karnal bunt in Arizona (Schall 1988, 1991; Podleckis 1995) and in the first two months following the outbreak (Podleckis and Firko 1996a, 1996b, 1996c, 1996d). Probabilities of outbreak were estimated for a variety of potential pathways including millfeed, export elevators, seed originating in the quarantined area, railcars transporting grain from the quarantined area to domestic mills and export elevators, grain storage facilities, and combines and other harvesting machinery.

The risk assessments measured the risk of wheat outside the quarantined area becoming infected with Karnal bunt. The size of potential outbreaks was not estimated. For the purposes of this analysis the size of the outbreak is less important since the disease had relatively small effects on crop yields. Of larger concern was the possibility that countries would not import wheat from the United States if Karnal bunt were found outside of the quarantine area.

The risk assessment presented here is based on the USDA risk assessments. However, unlike the USDA analysis which focused on measuring risk of individual pathways, this risk assessment focuses on the overall level of risk of outbreak from any source.[7] The probability of an outbreak of Karnal bunt occurring outside the quarantined area, p^*, can be written as:

$$p^* = 1 - (1 - p_1)(1 - p_2)(1 - p_3)(1 - p_4)(1 - p_5) \text{ where} \tag{6}$$

p_1 probability of an outbreak of Karnal bunt outside the quarantined area from millfeed

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to export restrictions were tied to the presence of the disease, not necessarily to the intensity of the outbreak.

[7] A more detailed description of the risk assessment model is summarized in the appendix.

p_2 probability of an outbreak of Karnal bunt in host fields outside the quarantined area from grain in transit to mills or export elevators

p_3 probability of an outbreak of Karnal bunt outside the quarantined area from combines or other harvesting machinery

p_4 probability of an outbreak of Karnal bunt outside the quarantined area from railcars after grain is unloaded at mills or export elevators

p_5 probability of an outbreak of Karnal bunt outside the quarantined area from seed

In general, the probability of outbreak via a given pathway is positively related to the number of railcars or other conveyances transporting grain or seed outside of the quarantined areas. The number of railcars leaving the quarantined area is, in part, determined by the incidence of infested fields within the quarantined area. The higher the infestation of Karnal bunt within quarantined area means less negative-testing wheat available for export or domestic milling purposes and a lower probability of outbreak outside of the quarantined area.[8]

The overall level of risk tends to be influenced by the riskier pathways. Changes in the probability of outbreak in a given pathway may be large in absolute terms, but have little effect on the overall level of risk. By focusing on individual pathways, the risk reducing potential of the protocol may be overestimated. For example, in the initial analysis the controversial requirement to heat treat millfeed was justified by USDA on the basis of the relatively sharp reduction in the risk of outbreak from contaminated millfeed. Yet when we separate this out, the results indicate that while the millfeed treatment requirement reduced the mean risk of Karnal bunt outbreak from contaminated millfeed from 1 in 15,175 to 1 in 60 million, the effect of the protocol was negligible in reducing the overall level of risk (table 3). Likewise, restrictions on the movement of negative-testing seed also had a relative small effect on the overall risk of outbreak. One of the pathways with the highest probability of outbreak was p_4—the probability of outbreak of Karnal bunt in elevators that received grain that had been transported in contaminated railcars. The mean risk of outbreak from this pathway assuming that railcars were not required to be cleaned after delivery was 1 in 35. This

risk was significant since a contaminated elevator would potentially be identified when sampled in the national survey of wheat elevators.

The USDA analysis also ignored the level of ambient risk that had existed prior to the discovery of Karnal bunt in Arizona. Podleckis (1995) had estimated that the probability of outbreak in the United States from contaminated Mexican boxcars was as high as 2.59 x 10^{-3} (1 in 386). This ambient risk was higher than the risks of outbreak from contaminated railcars from the regulated areas, millfeed, or negative-testing seed, and potentially reduced the effect any such protocols might have in mitigating the overall risks of outbreak.

In our analysis, we considered eight quarantine options. The options were based on the following protocols: 1) the restriction on the movement of negative-testing seed outside of the quarantine area; 2) the requirement that railcars be cleaned after delivery of wheat from the quarantined area; and 3) the requirement to heat treat millfeed. We chose these protocols because they imposed large costs on the wheat industry in the southwest and, as a result, were controversial. Option 1 reflects the least restrictive option where the quarantine protocols were limited to restrictions on the movement of positive-testing grain. Grain and seed that twice tested negative for Karnal bunt teliospores would be free to move to export and domestic locations with no additional restrictions. Railcars need not be cleaned. Option 8 reflects protocols put in place by APHIS in March of 1996 following the discovery of Karnal bunt in Arizona. The other options reflect various combinations of the three protocols, plus the base case option.

The effects of the options on the risk of outbreak are presented in table 4. The probabilistic risk assessments provide estimates of the probability of outbreak with an estimated mean and distribution. The table presents two measures of central tendency (median and mean) and the 95th percentile value. Current APHIS policy uses the 95th percentile value in making regulatory decisions (Firko et al. 1996). Viscusi (1998) discusses the potential for a "conservatism" bias when the 95th percentile value is used for every component of the estimate. In the risk assessment presented here, the 95th percentile value was drawn from the joint distribution p^*, not from a combination of the 95th percentile values for the individual p_i.

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[8]This assumes that the probability of teliospores surviving shipment outside of the quarantined area is

Of the individual protocols, railcar cleaning had the largest effect on the overall level of risk of outbreak because of the relatively high risk of contamination through railcars. Restrictions on the movement of negative-testing seed and millfeed treatment requirements had minimal effects on the overall level of risk. Taken together, the three protocols reduced the level of risk by almost 99 percent relative to the base case level.

5. Estimated Benefits and Costs of the Federal Quarantine Program

While USDA conducted extensive risk assessments to estimate the effectiveness of various quarantine protocols in reducing the risk of outbreak, it ignored these assessments when estimating the costs and benefits of the quarantine. From the initial detection of Karnal bunt in Arizona and USDA's subsequent announcement of a declaration of extraordinary emergency, protection of U.S. export markets was articulated as a primary goal of USDA's regulatory efforts (Glickman 1996). The United States typically exports about 1.2 billion bushels of wheat annually, with an estimated value of about $3 to $4 billion. About half of U.S. wheat exports were to countries that at the time Karnal bunt was discovered in Arizona maintained restrictions against wheat imports from countries where Karnal bunt was known to occur. USDA argued that failure to implement the quarantine would jeopardize trade with those countries. Benefits of Federal quarantine, therefore, were regarded largely as the avoided losses in the export market.

It its Regulatory Impact Analysis published on May 6, 1997, USDA estimated that a 50-percent reduction in U.S. wheat exports would likely reduce U.S. wheat prices by 30 percent, and lower net sector income by $2.7 billion. This estimate takes into account the dampening effect on domestic wheat prices, as wheat for export is diverted into the domestic consumption market, animal feed outlets, and ending stocks.

The reduction in U.S. wheat exports, however, would likely be less than 50 percent. Not all countries that have restrictions against Karnal bunt would, in practice, strictly prohibit wheat imports from the United States. (Italy and Germany currently import wheat from countries where Karnal bunt is known to occur despite European Union regulations to the contrary). Second, while some markets would be captured by

uncorrelated with the incidence of infection within the quarantined area.

wheat from exporting countries that are free of Karnal bunt, U.S. wheat exports to countries that have no restrictions against Karnal bunt would likely increase. In the long run, the effects could be minimal depending on whether the market were to treat Karnal bunt as a quality issue and develop discounts for Karnal bunt.

In the impact analysis, USDA estimated that the impact of Karnal bunt on exports, because of substitution effects, would likely result in a 10-percent reduction in U.S. wheat exports. A decrease of 10-percent in exports would cause a 22-cent per bushel drop in the wheat prices and a drop in annual wheat sector income of $545 million. The effects of decreases in wheat exports of various percentages are presented in Table 5.

While the effect on prices and incomes would likely affect all producers of wheat, it is noteworthy to point out that the majority of benefits from Federal quarantine actions were received by producers outside of the regulated areas who produce over 95 percent of the wheat grown in the United States. Beattie and Bickerstaff (1999) have recently argued that the regulations were largely the result of rent-seeking behavior on the part of wheat producers outside of the regulated areas. It is certainly true that wheat producers outside the quarantine area were strong supporters of USDA quarantine actions[9].

The impact analysis failed to consider changes in consumer welfare. Based on the price and domestic demand levels in table 5 and an implied domestic demand elasticity of -0.7, consumer surplus effects were estimated. Subtracting consumer gains and any additional government price support payments due to low prices, annual net welfare effects ranged from $261 million for a 10 percent loss in exports to $976 million assuming a 50 percent reduction in exports.

Since the potential adverse effects of an outbreak of Karnal bunt on export markets may last longer than a year, we calculated the net present value of benefits

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[9]A number of agricultural commissioners from wheat producing states were concerned, however, that the quarantine actions themselves were having an adverse impact on trade (Sim 1998). Indeed, a number of wheat importing countries that had no prohibitions on Karnal bunt prior to the Declaration of Extraordinary Emergency, soon afterwards adapted the requirement that U.S. wheat contain an additional phytosanitary certificate certifying that the wheat was from an area where Karnal bunt was known not to occur.

assuming losses over a 10 year period using a 7 percent discount rate.[10] Based on the annual net welfare losses in table 5, the discounted welfare effects ranged from $2.1 billion to $7.8 billion. This should be viewed as a conservative assumption. In the long run, if export losses due to Karnal bunt remained large and prices depressed, many wheat producers would likely switch to alternative crops, mitigating sector losses. Because of the factors mentioned above, it is likely the long term losses associated with an outbreak would be less than $2 billion.[11]

In its regulatory impact analysis, USDA estimated that the costs of the Karnal bunt regulations in 1996 incurred by producers, handlers and other affected parties was $44 million (table 6). It was estimated that about 8 percent of the 1996 crop wheat produced in the regulated area tested positive for Karnal bunt. This wheat was largely diverted to feed use in the regulated area resulting in an estimated loss to producers and handlers of $4.2 million.

Regulatory requirements to treat millfeed caused many domestic mills to drop contracts with producers and handlers of grain from the quarantined areas, resulting in a decline in prices for negative-testing wheat within the regulated areas. In the absence of the regulatory requirement on millfeed, domestic wheat millers would have likely purchased negative-testing grain from the infected areas. Although some millers were reluctant, the high quality of the durum wheat produced within this area would have helped counter their reluctance to the purchase of uninfected grain. However, the requirement that millfeed be treated and railcars sanitized increased the costs of milling wheat from the regulated area and prompted cancellation of many contracts with grain producers and handlers. USDA's estimate of loss in value due to producers and handlers of negative-testing wheat was $28 million per year.

Under the 1996 quarantine and emergency actions, wheat seed produced in the regulated areas was prohibited from sale outside of the regulated areas. Wheat seed

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[10]The Federal Office of Management and Budget recommends this rate for benefit-cost analyses. See OMB Circular A-94.

[11]We assume that the probability of outbreak is independently distributed for each crop year. This is reasonable given the relatively low probability of outbreak under the options considered and the fact that the likelihood of infection is highly dependent on optimal temperature and moisture conditions (Podleckis and Firko 1997). Assuming independence, we can calculate the costs of the quarantine for the crop year versus a discounted stream of costs and benefits that result from an outbreak in that year.

intended for planting within the regulated areas had to be sampled and tested for Karnal bunt, and for seed originating in a regulated area, treated prior to planting. These restrictions were estimated to have a significant impact on the seed industry, largely due to the high value that is commanded by wheat sold for seed relative to grain. USDA estimated that 1.5 million bushels of wheat seed sustained a loss in value of $5 to 6 million. Seed developers, who earn returns on their investment in research and development of wheat varieties, also claim potential long-term losses in royalties; by receiving plant variety protection (or patent rights), seed developers then obtain royalties on future sales of wheat that are developed and sold for propagative purposes. Other economic losses suffered by the seed industry, but are difficult to quantify, include additional handling, storage, and finance costs on seed that could no longer be sold outside the regulated areas and costs to relocate wheat breeding operations outside of the regulated areas.

In a report submitted as an exhibit in a lawsuit brought by the Arizona Wheat Growers Association against USDA, Beattie (1996) argued that the quarantine had adverse effects on wheat seed development. He estimates that the loss in productivity due to the quarantine likely cost producers and consumers between $177 and $357 million on a net present value basis.

The USDA impact analysis also enumerated losses to other parties such as wheat straw producers, custom harvesters, and producers who were required to destroy their crops prior to harvest because of the regulations. These losses were estimated to total approximately $5 to 6 million in 1996.

6. Estimated Expected Costs and Benefits

In the Regulatory Impact Analysis accompanying the final Karnal bunt regulations on compensation, USDA concluded that:

> ...our quarantine measures were appropriate and justifiable when compared with the magnitude of the benefits achieved. Even a 10-percent reduction in wheat exports would have a significant effect on wheat sector income. It is estimated that a 10-percent decline in wheat

exports would cause a decline in wheat sector of over $500 million. (62
FR 24765)

But can these conclusions be justified if one examines the <u>expected</u> costs and benefits of
the regulations?

Benefit-cost analysis for alternative quarantine options can be completed under
the assumptions given above (table 7). For the base case (option 1), the costs of
diverting positive-tested wheat to feed markets and destroying any crops planted with
contaminated seed is $5.4 million ($4.2 million plus $1.2 million). The probability of an
outbreak outside the quarantine area was reduced from certainty with no protocol to
0.0567. For a 10-percent diversion of exports with present value of costs $2,098
million, the expected loss due to an outbreak of Karnal bunt outside of the quarantined
area is $119 million (0.0567 *$ 2,098 million), and the welfare gain from utilizing the
base case option is $1,979 million dollars (i.e., $2,098 million—$119 million)**.** Each of
the other options also shows a large expected benefit/cost ratio when considered
individually. However, from figure (2), options 1, 2, 5, and 8 were the most efficient
policies in providing the most benefits for a given level of outlays.

Table 8 presents the marginal benefits and costs of options 2, 5 and 8 assuming
various levels of export market effects due an outbreak of Karnal bunt. Under the base
case option, a minimal quarantine is put into place that regulate positive-testing grain,
but the marginal benefits are large relative to the costs. Likewise, the addition of option
2--railcar cleaning--provides from $115 to $427 million in additional benefits for
additional costs less than $1 million. The addition of protocols restricting the movement
of negative-testing seed (option 5) imposed direct costs of additional $6 million, while
the reduction in expected welfare loss was only $3 million assuming a 10 percent loss in
exports over 10 years and when evaluated at the mean probability estimates. If export
losses were as high as 50 percent annually over 10 years, the expected marginal benefit
rises to $11 million. The seed protocol is likewise marginally cost effective when
evaluated using the more conservative 95th percentile value for the risk of outbreak.

Even under the most conservative assumptions (i.e., 50-percent loss in exports
over 10 years evaluated at the 95th percentile of risk of outbreak), USDA's quarantine
policy (option 8) was sub-optimal to other options available. The additional costs due to

the millfeed requirement cost producers $28 million compared to a marginal benefit of only $0.1 to $1.3 million. When one includes the potential loss in productivity due to the seed protocol, estimated by Beattie as $177 to $357 million, USDA's quarantine policy may have cost producers and consumers as much as $391 million ($28 million + $6 million + $357 million) while providing additional benefits of only $3.1 to $40.3 million. Thus, the net costs of USDA's quarantine policy are likely to be between $351 million and $388 million per year.

7. <u>Discussion</u>

The costs of USDA=s efforts to control Karnal bunt are less than originally expected because USDA=s policies have become less stringent. USDA has deregulated many of the original areas placed under quarantine. In 1998, USDA relaxed the quarantine to allow commercial seed to move outside of the regulated area. In 1997, USDA changed the standard for defining regulated areas based on the presence of bunted kernels rather than Karnal bunt teliospores. These changes have allowed much of the original regulated area to return to more normal marketings. Losses in recent years have been small and confined to positive-testing grain. While the number of countries requiring phytocertificates on U.S. wheat has increased to 54 countries, importing countries have generally accepted the changes.

The cost of the quarantine has been controversial since it was established in March 1996. To increase cooperation, USDA agreed to pay producers, grain handlers and other affected parties compensation for losses suffered due to the federal quarantine action. Compensation payments have totaled more than $40 million since 1996.

A larger issue has been the regulatory status of Karnal bunt as a plant disease. Even at the time Karnal bunt was discovered in Arizona in 1996, many scientific bodies (e.g., American Phytopathological Society) considered Karnal bunt to be a minor plant pest that could be controlled much like other wheat pests, i.e., without the use of quarantine measures. In 1997, USDA convened an international symposium on Karnal bunt with the intent of convincing other nations to deregulate Karnal bunt. To date, no countries have agreed to change their phytosanitary restrictions on wheat imports containing Karnal bunt.

8. Conclusions

Since the late 1980s, USDA has conducted probabilistic risk assessments of regulations and quarantines proposed to control pests and diseases but it has not fully integrated these assessments with its economic analysis. In the case of Karnal bunt, the risk assessment and analysis suffered from several deficiencies. First, USDA tended to focus on risk mitigation for individual pathways, seemingly without regard to the effect on the overall level of risk. As a result, the effects of individual quarantine protocols appear to have been overstated. Second, in its benefit-cost analyses, USDA ignored the effects of the quarantine policies on consumers and so overestimated the benefits of the quarantine. Third, its analysis did not look at the expected marginal benefits and costs of various quarantine alternatives. Had USDA considered the expected marginal effects in its decisions, it is likely that at least two of the more controversial and costly protocol—seed restrictions and the millfeed requirement—would have received closer scrutiny and possibly been rejected as viable options.

As a result, it is likely that USDA=s quarantine policies cost producers, consumers and taxpayers more than $30 million more than had an optimal quarantine policy been implemented. If losses to producers and consumers due to restrictions on seed development are considered, the net costs of sub-optimal policies were likely to be between $350 million and $390 million per year.

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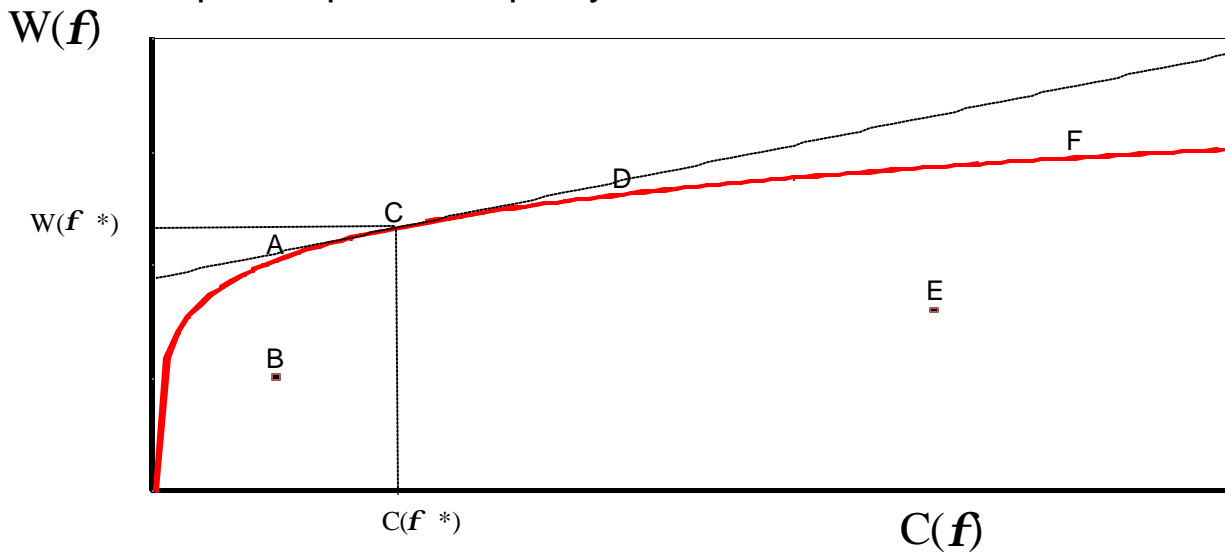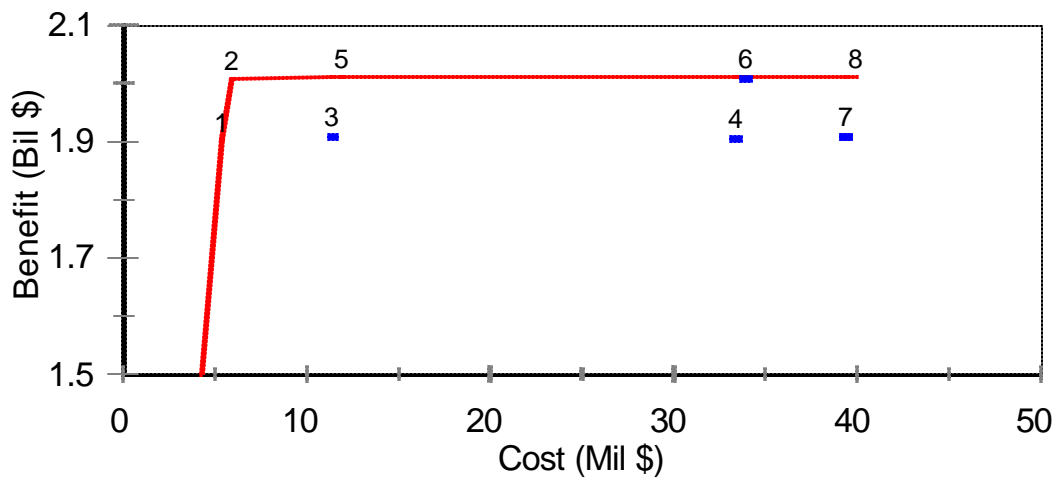*Figure 1*
Optimal quarantine policy

W(**f**)

W(**f** *)

C(**f** *)

C(**f**)

A B C D E F

Figure 2
Karnal Bunt Quarantine Alternatives

Benefit (Bil $)

2.1
1.9
1.7
1.5

0   10   20   30   40   50

Cost (Mil $)

1 2 3 4 5 6 7 8

Appendix: Karnal Bunt Risk Assessment Procedure

In this analysis we tried to be true to the original analysis (Podleckis and Firko 1996a, 1996c) upon which regulatory assumptions were based. Below we describe how the approach used in this paper differs from the original model.

The probability of at least one outbreak of Karnal bunt occurring outside the quarantined area is modeled through a series of multiplicative steps. This probability is modeled as a function of the quarantine protocols and the number of railcars or other conveyances transporting grain or seed outside of the quarantined areas. Further the number of infected railcars of grain shipped out of the quarantined area is modeled as a function of the amount of wheat testing positive for Karnal bunt either in fields, railcars or elevators in the quarantined area.

The exact pathways by which contamination can occur is detailed in figure 3. This analysis departs from the original analysis however in calculating some of the probabilities. In the original model (P8), the probability that grain going to storage was infected with Karnal bunt, was considered an additive function of the probability that the harvested grain was infected/contaminated with Karnal bunt (P3), the probability that the grain was contaminated by equipment (P6), and the probability that local conveyances were contaminated (P7). Technically this is not correct. The system of protocols must be considered together when assessing the probability of a positive find. This analysis departs from the original analysis by computing this probability as P8 = [1-(1-P3)(1-P6)(1-P7)]. Similarly in the original analysis the probability of a shipment having Karnal bunt, (P12) is modeled as an additive function of the probability that the grain going to storage had Karnal bunt (P8) and the probability that grain picked up Karnal bunt in local storage (P11). In this analysis this probability was changed to P12 = [1-(1-P8)(1-P11)].

Monte Carlo simulation is used to compute the probability of at least one outbreak of Karnal bunt outside the quarantine area. In each iteration of the model, this value is determined by the multiplicative contribution of a series of steps raised to the frequency in which either railroad cars were shipped or combines moved out of the quarantine area.

Typically these steps include the probability that a shipment had Karnal bunt P12, the probability that the Karnal bunt was in the shipment and detected (P13), the probability that viable Karnal bunt survived the shipment (P15), the probability that Karnal bunt reached a suitable host (P16) and the probability that Karnal bunt was able to become established (P17).

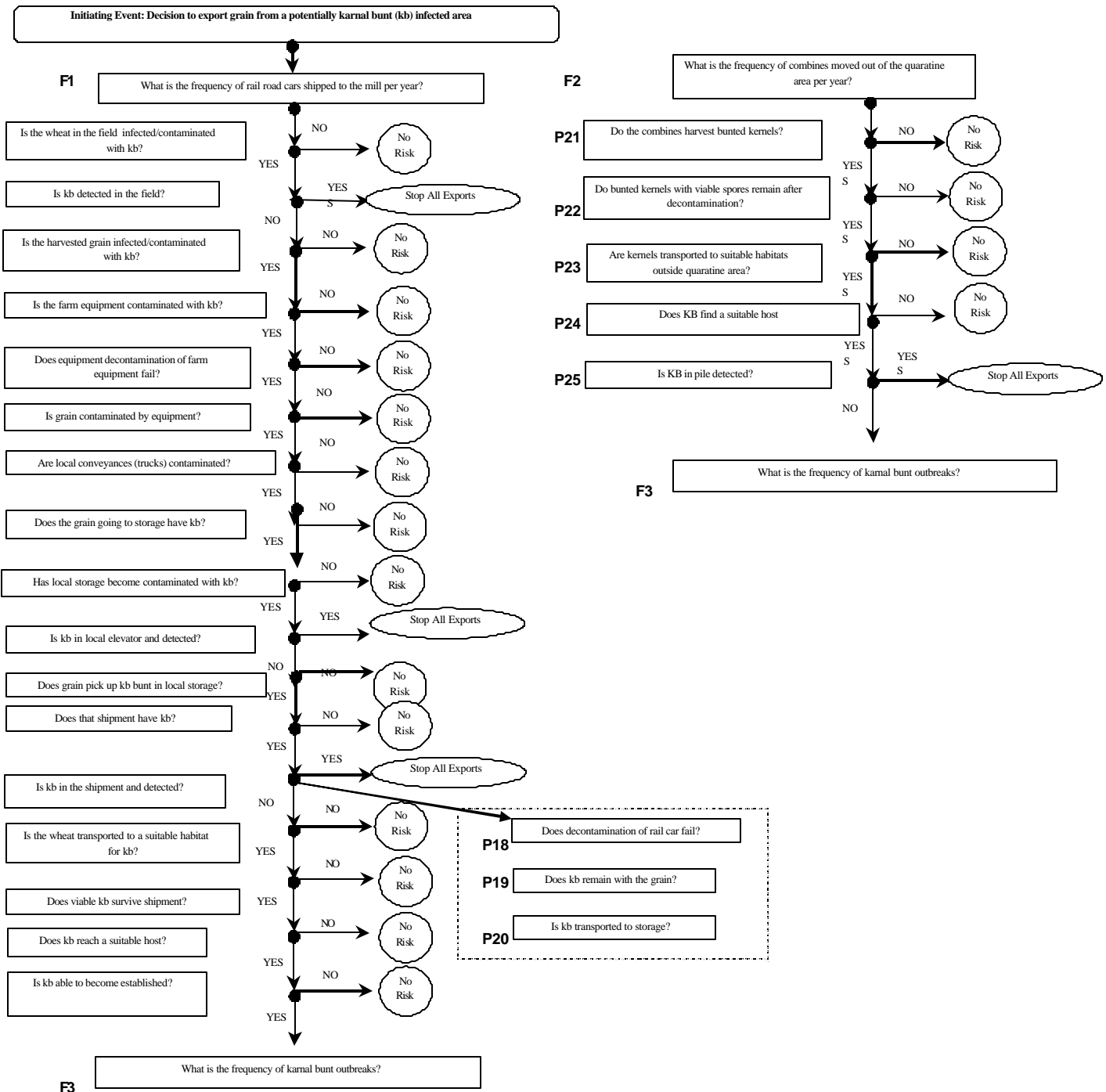For each scenario, the following formula is used to calculate the probability of an outbreak:

F3= 1-(1-P12*P13*P14*P15*P16*P17)^F1

In most scenarios (F1) is the frequency of railroad cars shipped to the mill. When combine movement is being considered (F1) is replaced by (F2) which is the frequency of combines moved out of the quarantine area. F3 is the frequency of Karnal bunt outbreaks.

Probabilities were estimated for a variety of potential pathways including millfeed, export elevators, seed originating in the quarantined area, railcars transporting grain from the quarantined area to domestic mills and export elevators, grain storage facilities, and combines and other harvesting machinery. From the scenarios originally used by Podleckis and Firko (1996a), it was determined that there were nine different scenarios that would lead to the probability that at least one outbreak of Karnal bunt would occur outside the regulated area. These scenarios included:

1) Grain to the mill, Risk of KB Outbreak in Mill State, Millfeed Treated

2) Grain to Mill, Risk of KB Outbreak in Mill State, Millfeed Treated

3) Grain to Mill, Risk of KB Outbreak in Transited States, Millfeed Treated

4) Grain to Export Elevator, Risk of KB Outbreak in transited States, Millfeed treated

5) Combine/harvest equipment moved out of quarantine area risk of KB outbreak in states receiving equipment

6) Grain to Mill, Risk of KB Outbreak in Secondary State (State Receiving rail Car after grain is unloaded at Mill)

7) Grain to mill, risk of KB contamination in storage facility in secondary state

8) Grain to Export Elevator, KB contamination in storage facility in secondary state

9) Risk of outbreak via seed harvested and planted in Arizona

To capture the effect of various combinations of options eight potential combinations of options were developed as seen in table A1. Monte Carlo analysis was performed using the @Risk Software. Each option was run for 10,000 iterations and the random seed numbers generated were fixed at 2. The specific values used for the probabilities in the model are summarized in Table A2. The values include an unspecified mix of the variability and uncertainty that can occur under each event.

Initiating Event: Decision to export grain from a potentially karnal bunt (kb) infected area

F1 What is the frequency of rail road cars shipped to the mill per year?

Is the wheat in the field infected/contaminated with kb? — NO → No Risk — YES

Is kb detected in the field? — YES → Stop All Exports — NO

Is the harvested grain infected/contaminated with kb? — NO → No Risk — YES

Is the farm equipment contaminated with kb? — NO → No Risk — YES

Does equipment decontamination of farm equipment fail? — NO → No Risk — YES

Is grain contaminated by equipment? — NO → No Risk — YES

Are local conveyances (trucks) contaminated? — NO → No Risk — YES

Does the grain going to storage have kb? — NO → No Risk — YES

Has local storage become contaminated with kb? — NO → No Risk — YES

Is kb in local elevator and detected? — YES → Stop All Exports — NO

Does grain pick up kb bunt in local storage? — NO → No Risk — YES

Does that shipment have kb? — NO → No Risk — YES

Is kb in the shipment and detected? — YES → Stop All Exports — NO

Is the wheat transported to a suitable habitat for kb? — NO → No Risk — YES

Does viable kb survive shipment? — NO → No Risk — YES

Does kb reach a suitable host? — NO → No Risk — YES

Is kb able to become established? — NO → No Risk — YES

F3 What is the frequency of karnal bunt outbreaks?

F2 What is the frequency of combines moved out of the quaratine area per year?

P21 Do the combines harvest bunted kernels? — NO → No Risk — YES

P22 Do bunted kernels with viable spores remain after decontamination? — NO → No Risk — YES

P23 Are kernels transported to suitable habitats outside quarantine area? — NO → No Risk — YES

P24 Does KB find a suitable host — NO → No Risk — YES

P25 Is KB in pile detected? — YES → Stop All Exports — NO

What is the frequency of karnal bunt outbreaks?

F3

P18 Does decontamination of rail car fail?

P19 Does kb remain with the grain?

P20 Is kb transported to storage?

Figure 3: Scenario analysis

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Table A:1 Option Used and Changes to Scenarios Included

	Base case Option 1	Rail Option 2	Seed Option 3	Mill Option 4	Rail/Seed Option 5	Rail/Mill Option 6	Seed/Mill Option 7	Rail/Seed/ Mill Option 8
Millfeed	2*	2	2	1	2	1	1	1
Transit/ elevator	3 & 4	3 & 4	3 & 4	3 & 4	3 & 4	3 & 4	3 & 4	3 & 4
Combine	5	5	5	5	5	5	5	5
Rail road car	6, P15=1 7, P14=1 8, P13=1	normal	6, P15=1 7, P14=1 8, P13=1	6, P15=1 7, P14=1 8, P13=1	normal	normal	6, P15=1 7, P14=1 8, P13=1	normal
Seed	9	9	-	9	-	9	-	-

* note numbers represent scenarios included under each option; P13, P14, P15 defined in figure;

Table A2: Parameters Used

F1 a b c	**Frequency of rail cars shipped per year** Frequency of rail road cars shipped to the mill per year (45% of F1) Frequency of rail road cars exported per year (55% of F1) Frequency of rail road cars shipped to seed per year (10% of F1)	Triangle Triangle Triangle Triangle	4500 2025 2475 450	5530 2488.5 3041.5 553	6500 2925 3575 650
F2	**Frequency if combines shipped per year**	Triangle	50	100	200
P1 a b	**Probability that wheat in field infected/contaminated with KB**	Beta Beta	1.2 4	10 20	
P2 a b	**Probability that KB not detected in field**	Lognormal Beta	0.01 2	0.025 20	
P3	**Probability that harvested grain infected/contaminated with KB**	P1xP2			
P4 a b	**Probability that farm equipment is contaminated with KB**	Lognormal Beta	0.05 4	0.05 20	
P5	**Probability that decontamination of farm equipment fails**	Lognormal	0.01	0.025	
P6	**Probability that grain is contaminated by equipment**	P4xp5			
P7 a b	**Probability that local conveyances (trucks) get contaminated**	Lognormal Beta	0.001 4	0.0025 20	
P8	**Probability that grain going to storage has KB**	1-(1-p3)(1-p6)(1-p7)			
P9 a b	**Probability that local storage gets contaminated with KB**	Lognormal Lognormal	0.01 0.0001	0.025 0.0001	
P10 a b	**Probability that KB Is in local elevator and not detected**	Lognormal Constant	0.01 1	0.025	
P11	**Probability that grain picks up KB in local storage**	P9xp10			
P12	**Probability that shipment has KB**	1-(1-p8)(1-p11)			
P13 a b	**Probability that KB in shipment is not detected**	Lognormal Constant	0.01 1	0.025	
P14 a b	**Probability that grain Is transported to a suitable habitat**	Beta Constant	2 1	4	
P15 a b c d	**Probability that KB survives shipment (viable KB)**	Beta Lognormal Beta Constant	4 0.01 5 1	2 0.01 15	
P16 a b c d e	**Probability that KB reaches a suitable host**	Lognormal Beta Lognormal Beta Constant	0.001 1.75 0.0001 4 1	0.001 25 0.0001 2	
P17 a b c	**Probability that KB is able to become established**	Lognormal Beta Lognormal	0.001 1.75 0.0001	0.001 25 0.0001	
P18	**Probability that decontamination of rail car fails - Scenario 8, 9**	Lognormal	0.01	0.01	
P19	**Probability that KB remains with grain - Scenario 8, 9**	Beta	4	2	
P20	**Probability that KB is transferred to storage facility - Scenario 8, 9**	Beta	4	2	
P21	**Probability that combines harvest bunted kernels**	Lognormal	0.1	0.1	
P22	**Probability that bunted kernels with viable spores remain after decontamination**	Lognormal	0.01	0.01	
P23	**Probability that kernels are transported to suitable habitats outside quarantine area**	Beta	2	4	
P24	**Probability that decontamination of rail cars fails**	Lognormal	0.01	0.01	
P25	**Probability that KB in pile is not detected**	Beta	1.2	20	

Table 1–Federal Domestic Quarantines

Plant Pest	Year Initiated 1/	Crops Potentially Affected	Regulated Area
Pink bollworm	1967	cotton, kenaf, okra	AZ, AR, CA, NM, OK, TX
Witchweed	1970	corn, sorghum, sugarcane, rice	NC, SC
Golden nematode	1972	potatoes	NY
Japanese beetle	1979	ornamentals, tree fruits, row crops, turf	AL, CT, DE, DC, GA, IL, IN, KY, ME, MD, MA, MI, MN, MO, NH, NJ, NY, NC, OH, PA, RI, SC, TN, VT, VA, WV, WI
Sugarcane diseases	1983	sugarcane	HI, PR
Mexican fruit fly	1983	tree fruits	CA, TX
European larch canker	1984	Larch trees	ME
Citrus canker	1985	citrus fruit	FL
Black stem rust	1989	wheat and small grains	48 conterminous states and DC
Mediterranean fruit fly	1991	fruit, vegetables	CA, FL
Pine shoot beetle	1992	pine trees	IL, IN, MD, MI, NY, OH, PA, WV, WI
Imported fire ant	1992	impedes harvest and cultivation	AL, AR, CA, FL, GA LA, MS, NM, NC, OK, PR, SC, TN, TX
Gypsy moth	1993	hardwood forests	CT, DE, DC, IN, ME, MD, MA, MI, NH, NJ, NY, NC, OH, PA, RI, VT, VA, WV, WI
Oriental fruit fly	1993	fruits, vegetables	CA
Karnal bunt	1996	wheat, rye, triticale	AZ, CA, TX, NM
Asian longhorn beetle	1997	hardwoods	IL, NY
Plum pox	2000	stone fruit	PA

1/ Reflects year that current regulatory policy was implemented.

Table 2-- Impact of Karnal Bunt Quarantine Actions

Action	Regulated Article	Affected Entities	Numbers Affected	Types of Impacts due to KB and Quarantine Actions
Plow-down & Seed Plot destruction	• Fields planted with infected seed at pre-boot stage	• Certain producers in Texas and New Mexico	• 4100 acres • 73 producers	• Loss in value of wheat crop destroyed
Cleaning/ Disinfection	• Tools and Farm Equipment	• Wheat producers in RA	• 145 growers	• cost of cleaning
	• Harvesters	• Farmer owned and custom combines	• 389 combines	• cost of cleaning
	• Grain Trucks	• Grain haulers from field to grain elevators	• 976 trucks	• cost of cleaning
	• Grain storage and loadout facilities	• Grain handling firms	• 17 elevators	• cost of cleaning
	• Harvesters	• Combine harvester owners	• 36 to 40 combines	• Excess wear and tear on equipment
	• Harvesters	• Combines involved in pre-harvest sampling	• 5 to 10 combines	• Down-time on harvesters due to field testing
	• Harvesters	• Custom combine companies	• 5 companies	• Loss of income due to termination of contracts outside the RA
	• Railcars	• Grain handling firms	• 10,880 cars (511 for positive grain)	• cost of cleaning

RA - Regulated Area

Table 2 - Continued Impact of Karnal Bunt Quarantine Actions

Action	Regulated Article	Affected Entities	Numbers Affected	Types of Impacts due to KB and Quarantine Actions
Restriction on Use or Marketings	• KB-positive milling wheat	• Producers • Grain handling firms	• 145 growers • 6 handlers	• Loss in value of KB-positive wheat
	• KB-negative milling wheat	• Producers in RA • Handlers in RA	• 664 producers • 26.7 million bushels	• Loss in value of KB-negative wheat in RA
	• Millfeed	• Millers, millfeed processors	• 108 mills • 45,644 tons	• Millers reluctance to mill KB-negative wheat from RA
	• Movement restrictions on wheat seed	Seed producers, researchers, and companies	• 15 producers • 9 research firms • 20 seed marketers	• Loss in premiums • Loss in market value • Loss in royalties
	• Straw, Manure, Millfeed	• Straw producers and Handlers -Users of Straw • Livestock producers using wheat or straw produced in the RA • Flour millers • Millfeed processors/users	• 25 growers • 3 contractors • 1 straw user, making of straw mats for erosion • control • 7 millers in 5 States 2 millfeed processors	• Loss in income • Increased cost of production
	• Moratorium on wheat production on KB-positive fields	• Producers with KB-positive properties	• 109 growers • 13,674 acres	Loss in income from wheat
	• Soil on root crops grown on infected properties	• Vegetable producers on KB-positive properties	• Unknown number	• Increased cost of production
	• • Used seed sacks • Seed-conditioning equipment Byproducts of seed	• Seed research and marketing companies	• 9 research firms • 20 seed marketers	• Increased cost of production

Source: Karnal Bunt Regulatory Flexibility Analysis and Regulatory Impact Analysis published in the Federal Register, May 6, 1997.

Table 3–The Effects of Various Protocols on the Risk of Karnal Bunt Outbreak

Protocol	Probability of an outbreak 1/	
	For that pathway	Overall
Railcar cleaning:		
- with	6.43×10^{-4}	2.14×10^{-3}
- without	5.18×10^{-2}	5.67×10^{-2}
Restrictions on the movement of negative-testing seed: - with	0	5.53×10^{-2}
- without	1.40×10^{-3}	5.67×10^{-2}
Millfeed treatment:		
- with	1.66×10^{-8}	5.66×10^{-2}
- without	6.59×10^{-5}	5.67×10^{-2}

1/ Evaluated at mean.

Table 4–Probability of an Outbreak of Karnal Bunt Under Alternative Quarantine Options

Quarantine Option	Probability of outbreak 1/		
	Median	Mean	95th percentile
Option 1--Base case 2/	2.92E-02 (---)	5.67E-02 (---)	1.93E-01 (---)
Option 2--Railcar cleaning	1.11E-03 (0.038)	2.14E-03 (0.038)	7.43E-03 (0.038)
Option 3–Restrictions on seed movement	2.78E-02 (0.951)	5.53E-02 (0.976)	1.92E-01 (0.994)
Option 4–Millfeed treatment	2.91E-02 (0.997)	5.66E-02 (0.999)	1.93E-01 (1.000)
Option 5–Railcar cleaning; restrictions on seed movement	2.32E-04 (0.008)	7.08E-04 (0.013)	2.45E-03 (0.013)
Option 6–Railcar cleaning; millfeed treatment	1.05E-03 (0.036)	2.07E-03 (0.037)	7.35E-03 (0.038)
Option 7–Restrictions on seed movement; millfeed treatment	2.77E-02 (0.949)	5.53E-02 (0.975)	1.92E-01 (0.994)
Option 8–Railcar cleaning; restrictions on seed movement; millfeed treatment 3/	1.91E-04 (0.007)	6.40E-04 (0.011)	2.29E-03 (0.012)

1/ Expressed in scientific notation; e.g., 2.92E-02 = 2.92 x 10^{-2} = .0292.

2/ Includes prohibition of movement of positive testing grain and seed from quarantined area; all negative testing grain and seed moved in sealed hopper cars; all combines disinfected before leaving quarantined area.

3/ Represents regulatory policies implemented by USDA in 1996.

( ) denote level of risk relative to base case

Table 5–Estimated Net Welfare Effects of Reduced Exports Due To An Outbreak of Karnal Bunt Outside of the Regulated Area 1/

Item	Unit	Reduction in Exports			
		0%	10%	25%	50%
Exports	mil. bu.	1,200	1,080	900	600
Total use	mil. bu.	2,462	2,394	2,295	2,138
Price	$/bu	3.85	3.63	3.29	2.68
Value of production	mil. dol.	9,543	8,998	8,146	6,637
Government payments 2/	mil. dol	1,815	1,815	1,815	1,943
Gross income	mil. dol.	11,358	10,813	9,961	8,580
Variable expenses	mil. dol.	4,823	4,823	4,823	4,823
Net cash income	mil. dol.	6,536	5,990	5,138	3,758
Welfare effects:					
Producer losses	mil. dol.	---	- 545	- 1,397	- 2,778
Consumer gains	mil. dol.	---	284	747	1,674
Change in government payments	mil. dol.	---	0	0	128
Net welfare	mil. dol.	---	- 261	- 650	- 976
Over 10 years 3/	mil. dol.	---	- 2,098	- 5,214	- 7,830

1/ Estimates based on 1997/98 marketing year.
2/ Includes AMTA payments ($1,815 million) plus loan deficiency payments.
3/ Discounted at 7 percent annually.
Adapted from: Karnal Bunt Regulatory Flexibility Analysis and Regulatory Impact Analysis (Federal Register, 62:24755, May 6, 1997)

Table 6–Estimated Costs Due to Karnal Bunt Regulations, 1996 Crop Year

Item	Estimated Costs (mil. dollars)
Plowdown of NM and TX fields planted with infected seed	1.2
KB-positive grain diverted to animal feed market	4.2
Cleaning and disinfecting railcars	0.6
Loss in value of seed	6.0
KB-negative grain that experience loss in value	28.0
Other 1/	4.1
Total	44.1
Losses to consumers and producers due to productivity losses in seed breeding 2/	117.0 - 357.0

Adopted from: Karnal Bunt Regulatory Flexibility Analysis and Regulatory Impact Analysis (Federal Register, 62:24755, May 6, 1997)

1/ Includes losses related to cleaning and disinfecting combine harvesters, sanitizing storage facilities, and loss in value of straw.

2/ Beattie (1996).

Table 7– Expected Costs and Benefits of Alternative Quarantine Actions Assuming As 10-percent Loss in Annual Exports (million dollars)

Quarantine Option	Expected Net Present Value of Benefits	Expected Costs	Net
Option 1--Base case 1/	1,978.8	5.4	1,973.4
Option 2--Railcar cleaning	2,093.2	6.0	2,087.3
Option 3–Restrictions on seed movement	1,981.7	11.4	1,970.3
Option 4–Millfeed treatment	1,979.0	33.4	1,945.6
Option 5–Railcar cleaning; restrictions on seed movement	2,096.2	12.0	2,084.3
Option 6–Railcar cleaning; millfeed treatment	2,093.4	34.0	2,059.4
Option 7–Restrictions on seed movement; millfeed treatment	1,981.7	39.4	1,942.3
Option 8–Railcar cleaning; restrictions on seed movement; millfeed treatment 2/	2,096.4	40.0	2,056.4

1/ Includes prohibition of movement of positive testing grain and seed from quarantined area; all negative testing grain and seed moved in sealed hopper cars; all combines disinfected before leaving quarantined area.

2/ Represents regulatory policies implemented by USDA in 1996.

Table 8–Marginal Costs and Benefits of Alternative Quarantine Options (million dollars)

Quarantine option	Marginal cost	Marginal benefit assuming that an outbreak of Karnal bunt outside of the regulated area will cause annual wheat export losses of:		
		10 %	25 %	50 %
Probability of outbreak evaluated at the mean:				
Option 2--Railcar cleaning	0.6	114.5	284.5	427.2
Option 5–Railcar cleaning; restrictions on seed movement	6.0	3.0	7.5	11.2
Option 8–Railcar cleaning; restrictions on seed movement; millfeed treatment	28.0	0.1	0.4	0.5
Probability of outbreak evaluated at the 95th percentile:				
Option 2--Railcar cleaning	0.6	389.3	967.5	1,453.1
Option 5–Railcar cleaning; restrictions on seed movement	6.0	10.4	26.0	39.0
Option 8–Railcar cleaning; restrictions on seed movement; millfeed treatment	28.0	0.31	0.8	1.3