End of Project Report

Quantification of Risks associated with plant disease: the case of Karnal bunt of wheat.

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SUMMARY

The aim of this study was to assess the economic impact of *Tilletia indica*, the cause of Karnal bunt of wheat (and triticale) in the EU. The methodologies used are relevant to estimating the costs of controlling other plant and animal diseases. The work was carried out as part of an EU funded research project.

To assess the likely impacts, an examination was made of the policies and arrangements that are in place in countries where Karnal bunt occurs. The cost components associated with a Karnal bunt outbreak and occurrence were identified, and the cost components were classified as: (i) direct costs; (ii) reaction costs, and (iii) control costs.

The direct costs are the yield and quality losses in crops affected with the disease. In addition to the specific direct costs associated with a Karnal bunt outbreak, there are also reaction costs which must be taken into consideration. These costs arise as a result of market reaction to the fact that Karnal bunt has been detected in a particular region. These reaction costs include indirect quality losses, loss of exports and seed industry costs. In addition to direct and reaction costs there are also control costs associated with an outbreak. These costs are associated with the efforts made to control and/or eradicate the pathogen. The specific control costs considered for this analysis include containment costs, eradication costs and surveillance and testing costs.

The main scenario assessed in this report is a "large" outbreak in a region in the UK initially affecting 50,000 ha of wheat. As a contrast, a "No Control Scenario" was also defined. In each case, the outbreak is detected in mid-harvest, with the pathogen being found in grain being delivered to a silo. This means that in the first year, the only impact is on the harvesting, processing and storage of the existing grain. In the control scenario, affected farmers will have to leave affected fields fallow or grassed-down for a minimum of 5 years, with a buffer zone of 3 km around the affected fields . Fields left bare fallow will have to have herbicides applied to control volunteer cereals and weeds. In the remainder of the affected region, only non-host crops could be grown, so that there would be no wheat grown for at least five years. Thus the costs differ between years both because of pathogen levels and because of official controls which will be imposed.

The results of the analysis indicate that a large outbreak affecting 50,000 ha of wheat would have significant economic costs for the affected region under the current contingency plan controls. The disruption to production, the inability to export wheat from the region and the wide range of control measures introduced would impose costs of €454 million on the region over a ten-year period. While there would be some economic consequences for those outside the affected region, and even some gain in economic welfare, these consequences are small compared to those within the region. In the first year, for example, the estimated cost to the region is equivalent to €159 per ha of wheat, while in the rest of the country and in the rest of the EU there would be net gains of €0.18 and €0.58 per ha, respectively. Since the overall costs to a region of an outbreak are likely to be substantial, considerable efforts are warranted to prevent such an outbreak occurring.

The direct yield and quality effects of the disease are generally small, and on their own may not justify substantial control measures being implemented or substantial efforts to exclude the disease from the EU. However, the reaction costs, where the market's response is reflected, can be substantial. This was also evident in the No-control scenario. In trying to minimise the direct and reaction costs, and especially in trying to prevent the spread of the pathogen to other parts of the EU, it can be economic to impose considerable control costs. Nevertheless, on the basis of these estimates of the costs associated with the scenario of a large regional outbreak, control costs constitute the overwhelming proportion of the economic costs borne by the industry within the affected region, and the extent of those controls needs to be carefully assessed. This is especially true in the context of the results of the No-control scenario. In this scenario it was estimated that if no controls were imposed to prevent the spread of KB in the EU following an outbreak, depending on the rate of spread of the pathogen, the total costs could be 10 times greater than that for the "large" outbreak scenario analysed.

Thus, the producers in the affected region can pay a high price for the controls that are put in place to prevent KB spreading elsewhere. The impacts of an outbreak of KB are likely to be felt unevenly

across the wheat industry and the wider economy. Even within the affected region, there can be large differences in outcomes for individuals. Farmers with KB on their farms will suffer considerable economic losses, particularly if crops and/or harvested grain are destroyed. Farmers within the affected region, but not having a crop affected by the pathogen, will also suffer economic losses, albeit to a lesser extent. Farmers outside the affected region will not incur significant costs, and may even gain from the outbreak, as long as it does not spread to their own region.

In addition, there are likely to be significant social consequences if there were to be an outbreak of Karnal bunt in the EU. There would be social disruption for the farmers, particularly (but not only) those with affected crops, as there are likely to be significant impacts on many aspects of their production, including which crop to grow, the seed that can be used, crop management practices, where and how the grain can be marketed, etc. There will also be social disruption for those involved in supplying inputs and processing the outputs of the grains industry. These social effects are likely to affect the broader community across the region, as multiplier effects occur and quarantine and other control measures are imposed. These impacts could extend beyond the agricultural sector in the event of a major outbreak.

The issue of compensation payments is not addressed in this economic analysis. However, without any compensation payments, the costs on the affected region are very high, while the costs in the rest of the EU are minimal. Any compensation payments from governments or the EU would alter the burden of those costs.

The results of this analysis are highly dependent on the precise scenarios analysed. Alternative outbreak and control scenarios, which can be readily analysed in the flexible model developed, would provide different economic outcomes from those illustrated here. In developing the most appropriate policy response to the threat of KB in the EU, analysis of different control strategies can indicate the most cost-effective policies.

1. Introduction

The fungus *Tilletia indica*, the cause of Karnal bunt of wheat, can lead to serious economic losses. The pathogen is difficult to control because it is seed-borne and the spores are known to survive for many years. Karnal bunt (KB) has long been known to occur in India, Pakistan, Afghanistan, Iraq and Mexico. More recently, it has been detected in the USA in 1996 and in South Africa in 2000. As a result of concern regarding its possible entry into Europe through trade pathways, the pathogen was added to the EC Plant Health Directive list of quarantine organisms in 1997. Resulting form its entry on this list and the ensuing debate amongst scientists the project "Risks associated with *Tilletia indica*, the newly-listed EU quarantine pathogen, the cause of Karnal bunt of wheat" was funded under the European Commission's Fifth Framework Proposal (Project QLK5-1999-01554). The aim of the project was to produce an accurate assessment of risk to the EU based upon experimentation within specific scientific objectives. The results outlined in this report are based on workpackage 5 of the project which was included in the project to examine the socioeconomic impact of *T. indica* should it be introduced to Europe. The objectives of Workpackage 5 were (i) to determine the socio-economically important parameters for *T. indica* in countries where it occurs and (ii) to determine the potential socio-economic impact of *T. indica* in Europe.

While Brennan *et al.* (1992) showed that KB imposed significant costs on Mexico, the relevance of that analysis to other countries has been unclear. There has been recent debate as to whether *T. indica* poses a significant risk to wheat production and whether it therefore should be listed as a quarantine organism by any country or Regional Plant Protection Organisation. While many markets restrict imports from regions with KB, some authors contend that *T. indica* does not have significant effects on yield or quality and that the closure of export markets for countries where it occurs is inappropriate. For example, Beattie and Biggerstaff (1999) questioned whether the actions taken by the US authorities in response to the detection of KB in south-western USA in 1996 were appropriate. They argued that: (a) KB is not a serious plant disease; (b) the 1996 US regulatory action was taken in response to politically motivated economic interests outside the quarantine region; and (c) those actions were costly. More recently, Cardwell *et al.* (2003) also argued that KB continues to be a minor disease in both Asia and North America, and that, since KB spreads very slowly and causes little direct crop production loss, most of the economic cost is due to the quarantine status of the disease.

Clearly, there is a need to examine the likely economic costs involved in a disease outbreak before appropriate decisions about the level of risks faced can be addressed properly. Recent studies of potential impacts of KB (Glauber and Narrod, 2001; Stansbury *et al.,* 2002, Elliston *et al.,* 2004) have not addressed either the detailed costs involved or the economic consequences of the control strategies imposed.

The overall objective of this report is to define an approach to estimating the costs of the potential economic impacts of *T. indica* in the EU in an economic framework. A particular objective is to examine in detail the components of the economic costs of a possible outbreak of KB in the EU, and to assess the relative importance of the different elements of these costs.

The following section identifies the costs associated with a KB outbreak, as identified from countries in which the pathogen has occurred. Following this, the methodology used in this analysis is outlined. The cost components are defined and the economic framework for estimating the effects of an outbreak of KB is explained. The data on the cost components are then described, and the estimation procedures outlined. The scenario analysed in this paper is specified, and in the subsequent section the results of the analysis are presented. The results are followed by a discussion of their implications, and some conclusions are drawn.

2. Defining the Costs of Karnal Bunt

Examination of the policies and arrangements that are in place in those countries allows the cost components associated with a KB outbreak and its subsequent occurrence to be classified as: (i) direct costs; (ii) reaction costs; and (iii) control costs.

2.1 Direct Costs

KB causes only small yield losses (Brennan and Warham, 1990; Brennan *et al.,* 1992; Kehlenbeck *et al.*, 1997). Direct quality losses occur when *infected* wheat is considered unsuitable for food uses and as a result is down-graded to feed[4] wheat. There can be a considerable economic cost associated with the loss of value of food wheat (both bread and durum) when it is down-graded to feed wheat (Murray and Brennan, 1998).

2.2 Reaction Costs

"Reaction costs" (which include indirect quality losses, loss of exports and seed industry costs) arise as a result of some components of the market reacting to the fact that KB has been detected in a particular region. As well as the direct quality losses associated with the down-grading of infected wheat, there can also be indirect quality losses associated with the down-grading of unaffected grain. As these indirect quality losses are associated with *unaffected* grain they are reaction costs rather than direct costs.

The extent of the losses associated with an export ban following an outbreak of KB will depend initially on the level of exports from a region prior to the KB outbreak and also on the types of wheat produced within a region. The reaction of markets to grain from a KB-affected region will also have a significant effect on the costs associated with an outbreak. Smith (2001) found that 35 countries have specific restrictions on the importation of wheat from countries with KB.

Because the presence of KB can affect the quantities of bread wheat and feed wheat available to the market, the response of prices to shifts of possibly large amounts of wheat from the food category to the feed category is important. Prices for "clean" food-quality grain are likely to be affected as well as for feed grains. These price effects have not previously been accounted for in the analysis of the impact of Karnal bunt.

In the event of an outbreak of KB, any seed production within the affected area is also likely to suffer losses, e.g the inability to sell seed from the affected area (Murray and Brennan, 1998). The costs associated with implementing a quality assurance programme, if not already in operation, is a further reaction cost associated with a KB outbreak.

2.3 Control Costs

Control costs are associated with the efforts to control and/or eradicate an outbreak of KB (Brennan and Warham, 1990; Kehlenbeck *et al.,* 1997). In the event of an outbreak of KB, widespread testing and surveillance programmes would be undertaken, so that additional testing and surveillance costs would be incurred, as well as the cost of surveys to define the presence of the pathogen or to define the limits of its spread.

Containment and/or eradication costs would also be incurred in the event of an outbreak of KB. The losses associated with destroying the affected grain and/or standing crops can be substantial. Other control costs include the cost of fumigation of harvesting, transport and handling machinery and equipment. There may also be a need to treat mill by-products from the milling of infected grain, and possibly treatment of animal manure from animals fed KB-infected grain. Where restrictions are placed on the crops that farmers could grow within the quarantine zone, or if seed treatments are required for seed sown within it (Brennan and Warham, 1990), economic costs are incurred. There will also be costs of ensuring compliance with any regulations and policies introduced to control or eradicate KB.

The precise controls imposed can be readily modified in light of the contingency plan in place for a particular outbreak scenario analysed. The key cost components identified are summarised in Table 1.

[4] "Feed" wheat is wheat that is only suitable for animal feed and is traded on the feed grains market.

Table 1: Cost Components for an Outbreak of Karnal Bunt

Direct Costs
Yield losses
Down-grading affected milling wheat to feed
Reaction Costs
Down-grading unaffected milling wheat to feed
Price and export effects
Seed industry costs
Quality assurance costs
Control Costs
Survey and identification costs
Administrative - Compliance costs
Cropping restrictions
Yield reduction from resistant variety
Additional fungicide costs
Value of standing crop destroyed
Costs of destroying growing crop
Value of affected grain destroyed
Costs of destroying affected grain
Treatment of mill by-products
Grain processing costs (heat treatment)
Livestock industry costs
Machinery cleaning costs
Facility cleaning costs

3. Economic Analysis of Changes in Quality of Wheat Production

3.1 Conceptual Framework

One of the key effects of KB is the effect on the marketability of wheat in the affected region, so that affected wheat can no longer be sold as milling wheat. Thus, some wheat is down-graded from milling to feed quality, which is equivalent to a shift of the supply curve for each wheat type (Brennan, Godyn and Johnston, 1989). The economic effects of such a change are measured as changes in the "Producer surplus" (PS) and the "Consumer surplus" (CS), which are measures of the economic welfare of each of the two industry groups[5].

3.2 Changes in Economic Welfare with Karnal Bunt

When calculating the impact of such supply shifts, it is not appropriate to rely on a direct adaptation of the neat algebraic analysis of shifts in supply curves developed for analysis of research impacts (as in Alston *et al.,* 1995). This is because if all wheat produced in the affected area is down-graded to feed wheat, the supply curve for milling wheat in the region effectively ceases to exist. Hence, rather than calculating the area between two supply curves (with and without KB), it is necessary to calculate the producer surplus without KB directly, since all PS may be lost in the milling wheat market in the affected region (see Appendix I for more detail).

[5] Alston *et al.* (1995, pp. 43*ff*) provide a brief review of the definition and limitations of the concepts of producer and consumer surplus measures.

3.3 Transmission of Price Effects through Spillovers

The shifts in supply in the affected region as a result of KB are likely to impact on the world price for the relevant types of wheat. The extent of those price effects depends on the extent of the supply shifts and the own-price elasticities of supply and demand in the wheat market (Edwards and Freebairn, 1984), and if substantial proportions of the production of the EU are likely to be affected, significant price effects could be felt outside the affected areas.

In this analysis, the world markets for each crop are disaggregated into two major component regions, namely the EU and the Rest of the World (ROW). Following Stansbury *et al.* (2002), the EU is further sub-divided into regions, as follows: (i) The affected region in which the outbreak is detected; (ii) The rest of the country in which the outbreak occurs; and (iii) The rest of the EU. Appendix 2 outlines this approach in more detail.

The following assumptions are made for the analysis of the impact of price effects:

(a) All countries other than the EU are grouped into the Rest of the World;
(b) All supply and demand curves are linear;
(c) All shifts in supply within the component markets are defined as parallel shifts;
(d) Aggregate supply curves, as for the affected country, the EU as a whole and the World market, are horizontal additions of shifts in the component markets (and thus can have "kinks" in them – see Edwards and Freebairn, 1982); and
(e) Similarly, producer and consumer surplus are estimated in the component regions, and the aggregate surpluses, as for the affected country, the EU as a whole and the World market, are determined as the sum of surpluses in the component markets.

The analysis was carried out for the three classes of wheat: (i) Bread wheat; (ii) Durum wheat; and (iii) Feed wheat. Bread and durum wheat affected with KB were assumed to be down-graded to feed, so that the bread and durum wheat supply curves shifted to the left, while the down-graded wheat induced a shift in the feed wheat supply curve to the right.

The economic welfare analysis undertaken through shifts in supply and demand curves incorporates all of the components of disease impact, reaction and control costs that affect the quantity of wheat available within each class of wheat. Thus, the welfare effects include the economic impacts of: (a) yield losses; (b) destruction of growing crops; (c) destruction of harvested grain; (d) down-grading from food to feed wheat; (e) export bans; and (f) price effects. Some of these components [(a) to (d)] can be estimated directly, and simply estimating the total welfare effects would involve some double-counting. As a consequence, the residual of the total welfare effects, after the direct estimates have been deducted, is the "price and export effects" shown in the results tables below.

3.4 Price Effects in Affected Region's Feed Wheat Market

The ban on exports of grain from the affected region mean that the feed wheat market is isolated from the world market, and must determine its own price to clear the market. Thus, while the Rest of the Country, Rest of EU and Rest of the World sectors operate as if the affected region's supply were removed from the market, the affected region itself behaves like a closed market for feed wheat (as illustrated in Appendix 1). To address the case where a small feed wheat market is overwhelmed by huge quantities of down-graded wheat so that prices could become negative to clear the market, prices for feed wheat have a lower limit of zero in the analysis.

3.5 Qualifications of Empirical Results

In the empirical analysis, the following simplifying assumptions are made for the analysis of the impact of price effects: (a) Elasticities of demand and supply are the same throughout the EU; (b) The cross-price elasticity of demand between milling and feed wheat is zero; (c) There are no second-round impacts on demand or supply of other commodities as a result of a change in surplus, and therefore income; and (d) Demand is assumed to remain static in the face of KB outbreak, because there are no human health issues relating to the use of wheat associated with KB.

As the focus of this report is on the EU, all other countries are grouped together as Rest of the World in the analysis. The results of this study should not imply any particular impact for countries other than the EU.

3.6 Evaluation Model

The analysis was carried out using a spreadsheet model based on that used in the DREAM (Dynamic Research Evaluation Model) evaluation model (Alston *et al.,* 1995, Appendix A5.1.2). However, since DREAM was not able to accommodate horizontal shifts in supply, the analysis had to be adapted to accommodate the shifts in supply that are associated with a re-classification of wheat from milling to feed quality[6].

4. Empirical Analysis

4.1 Outbreak Scenario

The costs of a KB outbreak will depend on a number of factors, including: (a) the size of the outbreak; (b) the country and region in which the outbreak occurs; (c) the time of detection of the outbreak; (d) the mix of milling, durum and feed wheat in the affected region; and (e) the control regime adopted.

In this analysis, the scenario analysed is a "large" outbreak in the UK affecting 50,000 ha of wheat, in which the outbreak is detected in mid-harvest, with the pathogen being found in grain being delivered to a silo. The control regime analysed is the draft UK contingency plan for *T.indica* as at April 2004. In the first year, because the outbreak is only detected at harvest, the only impact is on the harvesting, processing and storage of the existing grain. In subsequent years, farmers with affected fields will have to either manage them as bare fallow or grass them down for 5 years. Official controls will be placed on the affected fields as well as in a 3-km radius buffer zone around the affected fields in which only non-host crops will be permitted. However, in the first year the assumption for this analysis is that the only controls are those that would be imposed on detection at mid-harvest. The key elements of the scenario of a "large" outbreak in the UK are listed here:

- A 0.1% yield loss in affected crops;
- 20% of crops in the region are affected in year 1;
- As 50,000 ha of crop are affected in Year 1 and those crops represent 20% of the region's wheat, the total wheat area in the affected region is 250,000 ha;
- A region in the UK with 250,000 ha of wheat is approximated by a circle with a radius of 70 km. A buffer zone is established around this region, extending the boundaries by a further 3 km, so the entire region including buffer zone has a radius of 73 km from its centre;
- On initial detection, all unharvested crops identified as affected will be destroyed, amounting to 20% of the total affected crops;
- For the already harvested crops, 10% of affected grain is destroyed directly;
- All of the remaining affected grain is subjected to heat treatment to kill *T. indica* spores and is then used as feed;
- No wheat from the affected region/buffer zone is milled;
- An export ban is imposed on all wheat from the affected region, whether directly affected or not;
- All bread and durum wheat produced in the region is downgraded to feed wheat, even where no *T. indica* spores are detected;
- In subsequent years, fields on which KB was detected in Year 1 must be kept as bare fallow or be grassed-down for the following five years, after which non-host crops can be grown in those fields;
- Within the affected region/buffer zone, no wheat can be grown for the following nine years, so that within the entire region all land other than the fields in which KB was detected can grow only non-host crops;
- The affected region has the same mix of bread, durum and feed wheat as the whole of the UK (that is, 31.1% bread, 0.1% durum and 68.8% feed wheat);
- The affected region has the same average yields for wheat as the whole of the UK;
- The affected region has the same proportion of national wheat consumption as it has of national wheat production.

4.2 Supply and Demand Elasticities

The extent of price changes is determined by the interaction of supply and demand elasticities. Synthesised elasticity estimates were used to cover the likely responses and range of elasticities. In

[6] A copy of the spreadsheet model, based on Excel®, is available from the authors.

the short-run, after an outbreak of KB is detected at harvest, supply is fixed, with no possibility of supply response, so that the supply elasticity in the first year is zero (Table 2). However, the impacts of an outbreak of KB will be felt for several years afterwards, with planting restrictions and trade implications. After Year 1, the medium-term elasticity of supply is likely to be low, estimated at 0.5 for both milling and feed wheat.

Table 2: Demand and Supply Price Elasticities Used in Analysis

	Short term (Year 1)	Medium term (Years 2-5)
Elasticities		
Elasticity of supply - Milling	0.00	0.50
Elasticity of demand - Milling	-0.60	-0.60
Elasticity of supply - Feed	0.00	0.50
Elasticity of demand - Feed	-3.00	-3.00
Elasticity of supply - Durum	0.00	0.50
Elasticity of demand - Durum	-0.60	-0.60

The demand elasticities for milling wheat and durum wheat are likely to be low (less than 1.0) because there are few substitutes for wheat in food production and –0.6 was the assumed rate for the analysis. However, in feed, there is high substitutability between feed ingredients (Brennan, Singh and Singh, 2002). For example, Singh and Brennan (1998) found that medium-term own-price demand elasticities for cereals for feed were between -2.6 and -3.9 in Australia. On this basis, the demand elasticities for feed wheat chosen for this analysis were assumed to be –3.0 for all regions.

4.3 Data Used

For area, yield and production data, the five-year average to 2001 was used for the analysis (see Brennan *et al.,* 2004, for further information on data sources). Estimates were made of the likely breakdown within the category "common wheat" between milling and feed wheat. The break-down of exports into wheat types was estimated for each country (S. Thornhill, Personal communication). From those calculations, an average of 43% of milling wheat produced in each EU country is exported, and an average of 15% of feed wheat is exported.

The expected yield losses in affected crops of 0.1% assumed for the analysis were derived from Brennan and Warham (1990). The price data used in the analysis were obtained from different national sources (see Brennan *et al.,* 2004, for further information on data sources). The average price for each wheat type in the UK was: (a) Bread wheat €135 /t; (b) Feed wheat €114 /t; and Durum wheat €155 /t.

The costs associated with cropping restrictions were defined by the difference between the gross margin for wheat and the best alternative gross margin for the alternative crops that could be grown under cropping restrictions. The data used for the analysis are available in Brennan *et al.* (2004).

4.4 Results from Analysis of a "Large" Outbreak Detected at Harvest

4.4.1 Costs in Year 1

The components of the costs in the first year resulting from an outbreak at harvest are outlined in Appendix 3. With 50,000 ha of affected crop and expected average disease-free yields of 7.63 t/ha, the value of the 0.1% yield loss is estimated as €46, 000. Outside the region, there are no yield losses.

Using the market framework, the net effects of shifts in quality between market sectors and the reduction in production because of crop destruction, disease-based yield losses and export bans are all integrated into the one analysis. To ensure that there was no double-counting in estimating the components of the losses in welfare, some components were estimated separately and the “price and export effects” were determined as the balancing item (see Brennan *et al.,* 2004, for further details).

The economic losses for farmers when milling and durum wheat is down-graded to feed wheat depend on the quantity of each type of wheat down-graded and the price premium for milling and durum wheats over feed wheat. Given the prices determined above, the 502,000 tonnes of milling wheat and 1,000 tonnes of durum wheat down-graded in Year 1 have a loss in value of €11.86 million. Of that grain, only 14% was affected with KB, so the majority (€10.21 million) of those losses are reaction costs rather than direct costs. The costs of the price and export ban effects, in addition to the quality down-grading, are estimated at €13.47 million in the first year.

The costs to the seed industry from the inability to sell seed from the affected region area are estimated at €200,000. Quality assurance costs are assumed to be negligible in this scenario based on the assumption that UK grain producers already operate a quality assurance programme and those costs are already captured in the analysis.

The total costs within the region for collecting grain samples, laboratory analysis to extract teliospores, molecular identification of the teliospores and spore monitoring in the first year are estimated as €0.30 million. The costs of surveying and analysis in the remainder of the EU to ensure freedom from the pathogen are estimated at a further €0.18 million. The administrative activity in the event of a KB outbreak will cost an estimated €200,000 for the affected region, and a further €80,000 in the rest of the EU and €10,000 in the rest of the world.

Because the outbreak was detected at harvest, there were no additional management costs in Year 1 for the growing crops, and no costs in Year 1 associated with restrictions in the area that could be planted to wheat. In the year the outbreak is detected, 20% of affected crops were assumed to be destroyed before harvesting, with a total cost of €9.57 million. Similarly, in the year the outbreak is detected, 10% of harvested affected grain is assumed to be destroyed, with the value of the wheat destroyed and the cost of the destruction process estimated at €4.71 million in that year.

No affected grain is milled in Year 1, but an estimated 274,000 tonnes of affected grain are subjected to heat treatment in Year 1, costing a total of €2.74 million. Because no affected grain is fed to livestock, there are no manure destruction costs in Year 1.

The costs of removing spores from all machinery, equipment and facilities coming into contact with affected grain were approximately €27,000 each year. Given the need to plant pathogen-free seed, seed producers in the affected region incur losses of €0.20 million per year. The seed normally produced in that region will need to be sourced elsewhere in the country, so that there will be equivalent gains in the rest of the affected country. On the basis that all UK production is subject to quality assurance in relation to KB, there are no specific costs associated with it, since they would be included in the market reaction to the presence of the pathogen.

Within the affected region, the total economic costs in Year 1 for an outbreak of KB detected at harvest are €43.135 million (Appendix 3). Of that total, direct costs are only €1.70 million, reaction costs are €23.88 million and control costs are €17.55 million. At the same time, there are welfare gains of €9.14 million in other parts of the EU in Year 1, as a result of the price effects resulting from the export embargo and controls imposed in the affected region.

4.4.2 Costs in Years 2 to 10

In the subsequent years, the costs resulting from an outbreak varied from those in Year 1 because different control measures and responses could be implemented. Since the contingency plan is to ensure that no wheat can be grown for at least five years, there will be no wheat crops in the region affected by *T. indica* in Year 2 and beyond. While the control regimes remain in place, the total costs of surveying, laboratory analysis and monitoring remain the same each year, as also do the costs associated with administration and compliance, amounting to €0.5 million per year.

In Years 2 to 6 after the outbreak, under the control regime analysed, farmers will be prevented from growing any wheat crop on land that had affected crops in Year 1, and will be required to keep the fields as bare fallow or grassed down. Thus, the whole income will be lost from fallow fields, and there will be additional costs in maintaining bare fallow. The income losses and extra fallow costs amount to €25.7 million per year in those fields. For Years 7 to 10, those fields can grow non-host crops. Further, farmers in the region are prevented from growing wheat, even on land with no affected crop in Year 1. The income loss from having to grow lower-return non-host crops rather than wheat in those fields amounts to €38.2 million per year. In total, crop restrictions impose costs of €63.9 million per year for Years 2 to 6, falling to €46.9 million per year for Years 7 to 10. Under the control regime analysed, the other control costs were zero throughout the period, because of the embargo on wheat production in the affected region and buffer zone.

The pattern of costs in the affected region over the ten years after the outbreak is shown in Table 4. While direct costs are €1.7 million in Year 1, they decline to zero. Similarly, reaction costs are €23.9 million in Year 1, and fall to zero in subsequent years. Control costs (including income loss from cropping restrictions) rise rapidly to reach €64.4 million for Years 2 to 6, then decline to €47.4 million for subsequent years. Control costs comprise all of the costs involved for the remainder of the period of the wheat production embargo.

Table 3: Components of Costs in Affected Region, Large Outbreak, Years 1 to 10

		Direct Costs	***Reaction Costs***	***Control Costs***	***Total Costs***
Year 1	*(€ m)*	1.7	23.9	17.5	**43.1**
Year 2	*(€ m)*	0.0	0.0	64.4	**64.4**
Year 3	*(€ m)*	0.0	0.0	64.4	**64.4**
Year 4	*(€ m)*	0.0	0.0	64.4	**64.4**
Year 5	*(€ m)*	0.0	0.0	64.4	**64.4**
Year 6	*(€ m)*	0.0	0.0	64.4	**64.4**
Year 7	*(€ m)*	0.0	0.0	47.4	**47.4**
Year 8	*(€ m)*	0.0	0.0	47.4	**47.4**
Year 9	*(€ m)*	0.0	0.0	47.4	**47.4**
Year 10	*(€ m)*	0.0	0.0	47.4	**47.4**
Present Value[a]	***(€ m)***	**1.7**	**23.9**	**428.1**	**453.7**
Present value per ha	***(€/ha)***	**6**	**88**	**1,576**	**1,670**

a Discounted to present values with a discount rate of 5% per annum

4.4.3 Total Economic Costs

In the affected region, the present value of the costs of a 10-year strategy to control and eradicate *T. indica* from the EU, following an initial outbreak affecting 50,000 ha of wheat in the UK, is estimated at €454 million (Table 3). Less than 1% of total costs outlined in Table 3 for the affected region are the direct costs resulting from the disease itself. A further 5% of the costs are the result of the market reactions to the disease, and 94% of the total costs are the economic costs of controls established to contain and eradicate the disease. On average, the costs of *T. indica* are equivalent to an annual average of €167 per hectare over the ten years following the outbreak.

4.5 Analysis of a "No-Control" Scenario

To assess the appropriateness of the control regime based on the draft UK contingency plan, an analysis was also made of a "no-control" scenario. In this scenario, the assumptions made are listed here:

- 20% of crops in the region are affected in Year 1, rising to 100% of crops with KB spores by Year 5;
- One year in two is favourable to the disease, so that the expected proportion of crops with KB is 20% in Year 2, 30% in Year 3, 40% in Year 4 and 50% in Year 5 and subsequent years;
- No affected wheat is milled, but unaffected wheat is milled;
- An export ban applies to all wheat from the region;

- No seed is produced in the affected region;
- Resistant varieties and additional fungicides are not used.

On the basis of these assumptions, the No-control scenario (Table 4) leads to lower costs in the affected region. Thus, total costs in the affected region are €7.88 million in Year 1, the majority of which are Reaction costs. Subsequently, the costs initially decline to €6.25 million, then increase to €9.80 million by Year 5 and subsequent years. Over 10 years, the average costs per hectare of wheat in the affected region is €28 per hectare. Given that no wheat is exported, the farming systems and the processing industries based on those industries in the affected region are likely to change significantly. The probability that the spores would spread to other regions without strict controls is very high, so that the affected region would be expected to expand over time to envelop all the UK, and ultimately to spread to other EU countries without any forms of control. If this situation were to occur, the "affected region" would then include all of the EU, and the if annual costs per hectare of €28 were applied to all of the EU, then the costs would be approximately 10 times greater than the costs estimated above for the "large outbreak" scenario.

Table 4: Components of Costs in Affected Region, No-Control Scenario, Years 1 to 10

		Direct Costs	***Reaction Costs***	***Control Costs***	***Total Costs***
Year 1	*(€ m)*	0.5	7.1	0.3	**7.9**
Year 2	*(€ m)*	0.5	5.5	0.3	**6.2**
Year 3	*(€ m)*	1.1	5.8	0.3	**7.2**
Year 4	*(€ m)*	1.9	6.2	0.3	**8.4**
Year 5	*(€ m)*	3.0	6.5	0.3	**9.8**
Year 6	*(€ m)*	3.0	6.5	0.3	**9.8**
Year 7	*(€ m)*	3.0	6.5	0.3	**9.8**
Year 8	*(€ m)*	3.0	6.5	0.3	**9.8**
Year 9	*(€ m)*	3.0	6.5	0.3	**9.8**
Year 10	*(€ m)*	3.0	6.5	0.3	**9.8**
Present Value[a]	***(€ m)***	**16.7**	**51.5**	**2.3**	**70.6**
Present value per ha	***(€/ha)***	**67**	**206**	**9**	**282**

a Discounted to present values with an discount rate of 5% per annum

5. Implications and Conclusions

The results of analysis indicate that a large outbreak affecting 50,000 ha of wheat would have significant economic costs for the affected region under the current contingency plan controls. The disruption to production, the inability to export wheat from the region and the wide range of control measures introduced would impose costs of €454 million on the region over a ten-year period. While there would be some economic consequences for those outside the affected region, and even some gain in economic welfare, these consequences are small compared to those within the region. In the first year, for example, the estimated cost to the region is equivalent to €159 per ha of wheat, while in the rest of the country and in the rest of the EU there would be net gains of €0.18 and €0.58 per ha, respectively. Since the overall costs to a region of an outbreak are likely to be substantial, considerable efforts are warranted to prevent such an outbreak occurring.

The direct yield and quality effects of the disease are generally small, and on their own may not justify substantial control measures being implemented or substantial efforts to exclude the disease from the EU. However, the reaction costs, where the market's response to the outbreak and the presence of the pathogen is reflected, can be substantial. This was also evident in the No-control scenario. In trying to minimise the direct and reaction costs, and especially in trying to prevent the spread of the pathogen to other parts of the EU, it can be economic to impose considerable control costs. Nevertheless, on the basis of these estimates of the costs associated with the scenario of a large regional outbreak, control costs constitute the overwhelming majority of the economic costs borne by the industry within the affected region, and the extent of those controls needs to be carefully assessed. This is especially true in the context of the results of the No-control scenario. In this scenario it was estimated that if no controls were imposed to prevent the spread of KB in the EU following an outbreak, depending on the rate of spread of the pathogen, the total costs could be 10 times greater than that for the "large" outbreak scenario analysed.

Thus, the producers in the affected region can pay a high price for the controls that are put in place to prevent KB spreading elsewhere. The impacts of an outbreak of KB are likely to be felt unevenly across the wheat industry and the wider economy. Even within the affected region, there can be large differences in outcomes for individuals. Farmers with KB on their farms will suffer considerable economic losses, particularly if crops and/or harvested grain are destroyed. Farmers within the affected region, but not having a crop affected by the pathogen, will also suffer economic losses, albeit to a lesser extent. Farmers outside the affected region will not incur significant costs, and may even gain from the outbreak, as long as it does not spread to their own region.

The issue of compensation payments is not addressed in this economic analysis. However, without any compensation payments, the costs on the affected region are very high, while the costs in the rest of the EU are minimal. Any compensation payments from governments or the EU would alter the burden of those costs.

The results of this analysis are highly dependent on the precise scenarios analysed. Alternative outbreak and control scenarios, which can be readily analysed in the flexible model developed, would provide different economic outcomes from those illustrated here. In developing the most appropriate policy response to the threat of KB in the EU, analysis of different control strategies can indicate the most cost-effective policies.

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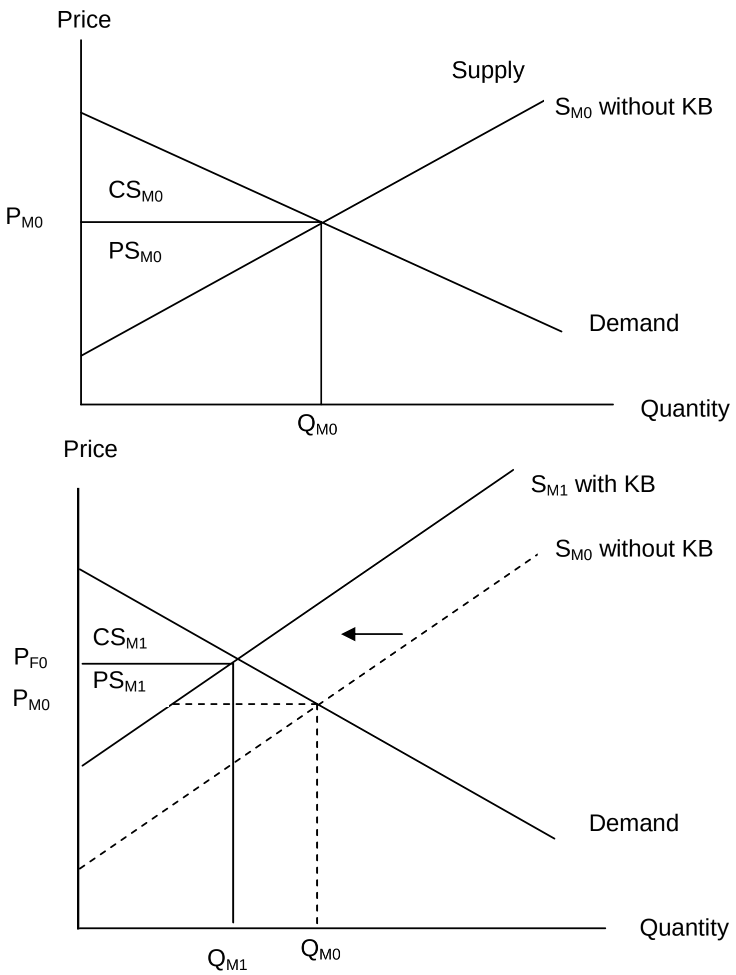
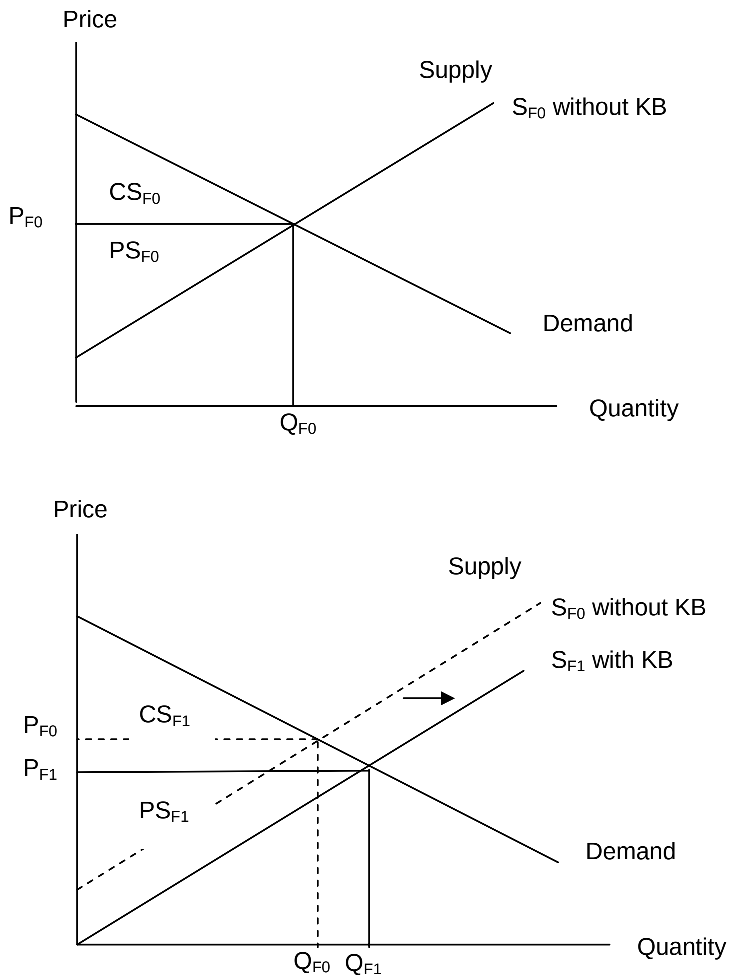
Appendix 1: Change in Producer and Consumer Surplus for When Wheat Downgrading from Milling to Feed Wheat

Comment [e1]: If my ideas about reducing the methodological content are accepted, both Appendices 1 and 2 could go

1a: Milling Wheat Market

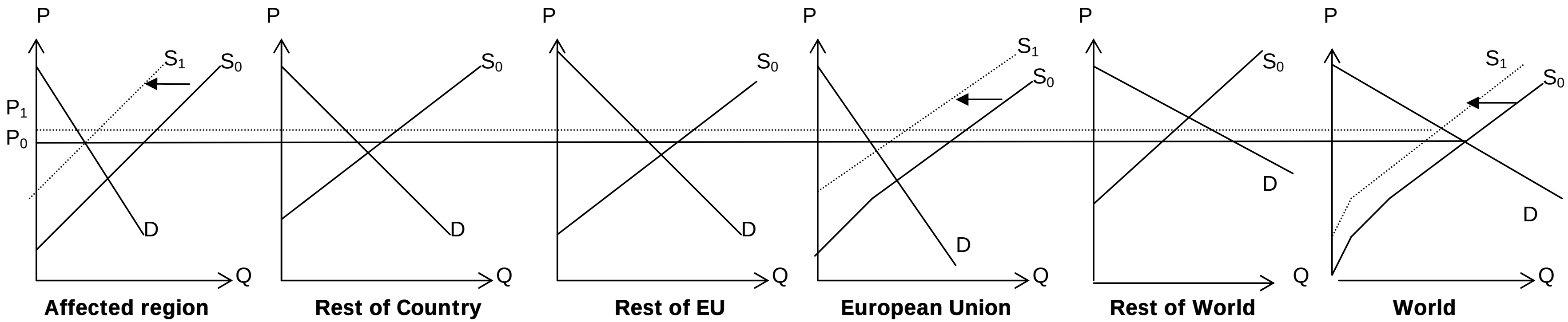


1b: Feed Wheat Market

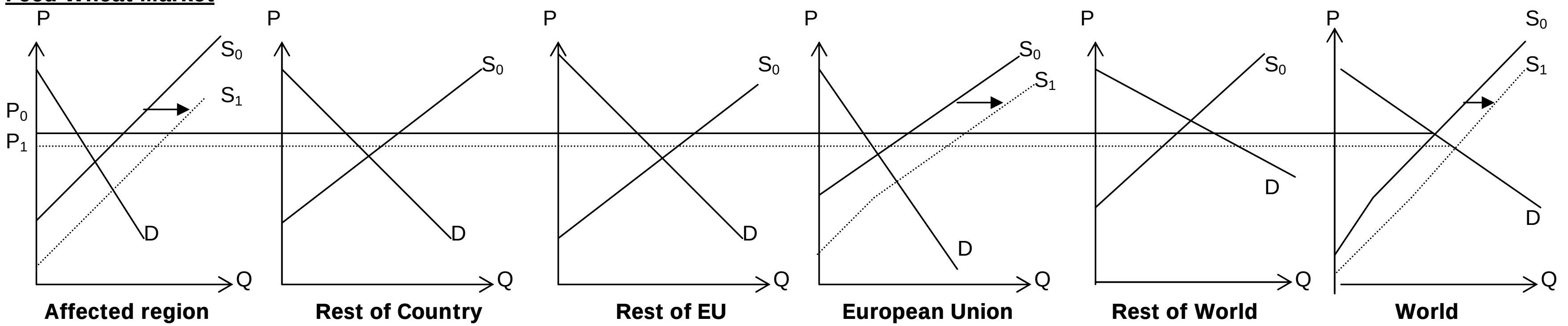


Appendix 2: Framework Used to Determine Price and Welfare Effects

Milling Wheat Market



Feed Wheat Market



Appendix 3: Economic Costs of Karnal Bunt: Large Outbreak, Year 1

		Region	*Rest of Country*	*Rest of EU*	*Rest of World*	*World*	*Country (UK)*	*EU*
Direct Costs								
Yield losses	(€'000)	46	0	0	0	46	46	46
Down-grading affected milling wheat to feed	(€'000)	1,655	0	0	0	1,655	1,655	1,655
- Total Direct Costs	*(€'000)*	**1,701**	**0**	**0**	**0**	**1,701**	**1,701**	**1,701**
Reaction Costs								
Down-grading unaffected milling wheat to feed	(€'000)	10,206	0	0	0	10,206	10,206	10,206
Price and export effects	(€'000)	13,472	-279	-8,921	9,115	13,387	13,193	4,272
Seed industry costs	*(€'000)*	200	-200	0	0	0	0	0
Quality assurance costs	*(€'000)*	0	0	0	0	0	0	0
- Total Reaction Costs	*(€'000)*	**23,878**	**-479**	**-8,921**	**9,115**	**23,593**	**23,399**	**14,478**
Control Costs								
Survey and identification costs	*(€'000)*	297	112	69	0	478	409	478
Administrative - Compliance costs	*(€'000)*	200	60	20	10	290	260	280
Income loss from cropping restrictions	*(€'000)*	0	0	0	0	0	0	0
Yield reduction from resistant variety	*(€'000)*	0	0	0	0	0	0	0
Additional fungicide costs	*(€'000)*	0	0	0	0	0	0	0
Value of standing crop destroyed	(€'000)	9,118	0	0	0	9,118	9,118	9,118
Costs of destroying growing crop	*(€'000)*	450	0	0	0	450	450	450
Value of affected grain destroyed	(€'000)	3,647	0	0	0	3,647	3,647	3,647
Costs of destroying affected grain	*(€'000)*	1,066	0	0	0	1,066	1,066	1,066
Treatment of mill by-products	*(€'000)*	0	0	0	0	0	0	0
Grain processing costs (heat treatment)	*(€'000)*	2,742	0	0	0	2,742	2,742	2,742
Livestock industry costs	*(€'000)*	0	0	0	0	0	0	0
Machinery cleaning costs	*(€'000)*	19	0	0	0	19	19	19
Facility cleaning costs	*(€'000)*	8	0	0	0	8	8	8
- Total Control Costs	*(€'000)*	**17,548**	**172**	**89**	**10**	**17,819**	**17,720**	**17,809**
Gross Economic Costs	*(€'000)*	**43,127**	**-307**	**-8,832**	**9,125**	**43,113**	**42,820**	**33,988**