Chemical Residues In The Australian Beef Industry: Assessing The Economic Impacts Of The Chlorfluazuron Incident On Returns To Cattle Producers

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The chlorfluazuron incident is just one of a number of chemical residue incidents that have plagued the Australian beef industry since the late 19980s. The frequency and diversity of residue episodes in Australia have served to illustrate the potential of agricultural and veterinary chemicals to cause considerable disruption to Australia's meat trade, even when the chemicals do not pose a health risk to consumers. For example, the discovery of chlorfluazuron residues in Australian beef in 1994 resulted in an export ban being placed on beef containing chlorfluazuron residues. While it is believed that residues in Australian beef can result in significant losses to the Australian cattle industry, a detailed economic evaluation of the cost of a residue incident has not been undertaken. A major aim of this study is to develop an economic model that can be used to assess the economic impact of any chemical residue incident on any agricultural industry, with an emphasis on producer returns, and to illustrate the general applicability of the model by using it to assess the economic impact of the chlorfluazuron incident on returns to Australian beef cattle producers. This is done within a multiple-product, multiple-market framework, where the presence of chlorfluazuron residues in cattle is modelled as a shift in supply from one market segment to another.

1. Introduction

1.1 Background

Over the past decade, there has been considerable industry interest in strategies that can effectively and efficiently deal with chemical residues in meat in the Australian livestock industries (Residue Management Group (RMG) 1995). The presence of chemical residues can affect both domestic consumption and overseas trade of meat and meat products. Australian livestock industries are particularly vulnerable to the adverse affects of a chemical residue problem because of the importance of livestock commodity exports. For example, around 64 per cent of beef production and around 20 per cent of lamb production is exported (Australian Bureau of Agricultural and Resource Economics (ABARE) 1995). In an attempt to maintain uninterrupted access to export markets, Australian livestock products are randomly tested to ensure that they are free of contaminants.

As part of its quality assurance program, the Mid Coast Meat Company Pty Ltd at Macksville in NSW tests for organochlorine contaminants in beef using a regular gas chromatograph procedure. During July to September 1994, analysts at the Mid Coast Meat Company discovered an unusual 'spike' on a chromatograph print-out. While this spike was located close to where dichlorodiphenylethene (DDE)[1] residues in meat would have shown up on the print-outs, this new spike had not been encountered before and was unknown. Subsequent investigation revealed that the unidentified spike was caused by chlorfluazuron (CFZ) residues. CFZ is the active ingredient of an insecticide called Helix® which was used by the cotton industry to control the Heliothis caterpillar.

As a result of the discovery of CFZ residues in Australian beef, a considerable amount of time and resources have been devoted to determining those properties where cattle could have been exposed to CFZ, developing and implementing testing procedures for CFZ residues in beef, determining its biological nature and trying to minimise adverse domestic and international consumer reaction to CFZ residues in Australian beef. Since October 1994, a large number of Australian industry organisations and State and Federal government departments have been involved in the response to the CFZ incident.

1.2 Motivation for the Study

While an outbreak of an exotic disease in Australia, such as foot and mouth disease, would cause considerable economic loss to the Australian meat and livestock industries, the risk of Australia's meat trade being adversely affected by chemical residues is far greater than is the risk of an exotic disease outbreak. This is not only because of increased chemical usage by Australian agricultural industries, but also because consumers world-wide have become increasingly concerned about the presence of chemical residues, such as herbicides, pesticides, antibiotics and growth promotants in their food (Dunn, Tulepule and Toussaint 1994). These concerns have resulted in a number of importing countries increasing the scope and intensity of their residue testing programs, attempting to have the maximum residue limits for agricultural and veterinary chemicals lowered (and in some cases to prohibit their use) and placing increasing pressure on exporting countries to undertake their own residue testing program. Most

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1 D.D.T. is the common name for dichlorodiphenyltrichloroethane and it is the parent compound that was marketed. Dichlorodiphenyldichloroethane (D.D.D.) is the first degradation product of D.D.T. and involves the loss of chlorine. Dichlorodiphenylethene (D.D.E.) is the second or long term degradation of D.D.T. and again involves the loss of chlorine (H. Baker 1995 pers. comm.).

importantly, violative residue findings and/or the failure of the exporting countries to implement a testing program that satisfies the requirements of the importing country could result in either temporary or permanent exclusion from the market (RMG 1994).

The Australian government has long sought to manage the potential risk posed by the presence of agricultural and veterinary residues in foodstuffs through legislative chemical registration and usage control. However, it was only since the 1960s that the Australian government, and the Australian livestock industries, explicitly sought to meet the demands of export markets with regard to their limits on residue levels and their standards for environmental contaminants. The increase in domestic consumer concerns about, and international market requirement for, food safety and human health, resulted in Australian authorities introducing a number of initiatives directed towards ensuring a high standard of food quality (RMG 1994). These initiatives include:

- increased regulation of agricultural and veterinary chemicals;
- the development of a chemical clearance system by the Commonwealth Department of Health which led to a centralised toxicological evaluation process and consideration of Maximum Residue Limits (MRLs) by the National Health and Medical Research Council (NHMRC);
- the establishment of the National Food Authority (NFA);
- the development and adoption of the quality assurance and the clean food export programs;
- the establishment of the National Registration Authority for Agricultural and Veterinary Chemicals (NRA);
- industry funding of the National Residue Survey (NRS) and related marketing and research projects being undertaken by various statutory authorities;
- the introduction of a strict monitoring program to ensure that any beef that is produced using hormonal growth promotants is not exported to the European Union; and,
- the formation of the RMG to provide leadership and advice on chemical residue issues and to implement a national strategic plan aimed at ensuring Australia's meat and livestock industries maintain uninterrupted access to international markets.

However, despite the continuous development and implementation of residue control measures in Australia, there have been a number of residue incidents in Australian beef exports since the late 1980s that have resulted in significant economic losses to the Australian cattle industry (RMG 1994). For example, in 1987 organochlorine residues discovered in Australian beef exports in the United States almost resulted in Australian beef being refused entry into the United States. This situation was avoided by the intensive lot-testing and property clearance programs that were introduced in Australia at an estimated cost of around $50 million to the cattle industry. In addition to the organochlorine incident, sulphonamides were found in Australian veal that had been exported to the United States in 1990 and, in 1991, penicillin was found in Australian beef in Canada. Then, in 1993, organochlorines, organophosphates, synthetic pyrethroids, hormone growth promotants and antibacterials were detected in beef exports in various key export markets (RMG 1994). In 1994, CFZ residues in beef were identified (RMG 1995).

The frequency and diversity of residue episodes in Australia have served to illustrate the potential of agricultural and veterinary chemicals to cause considerable disruption to

Australia's meat trade, even when the chemicals do not pose a health risk to consumers. However, a detailed economic evaluation of the level and distribution of the cost of a residue incident has not been undertaken. This means that, while a considerable amount of industry and government funds are being spent annually in Australia on various measures aimed at reducing the likelihood and severity of future residue episodes, the benefits of these measures (in terms of reduced trade losses and residue 'clean-up' costs) are unknown. An estimation of the size and distribution of the cost of the CFZ episode would provide policy makers with a benchmark with which to evaluate net returns to the development and implementation of a national residue management plan and the control measures currently in place.

1.3 Aim of the Study

The major aims of this study are to:

- develop an economic model that can be used to assess the economic impact of any chemical residue incident on any agricultural industry, with an emphasis on producer returns; and

- illustrate the general applicability of the model by using it to assess the economic impact of CFZ residues in beef on returns to Australian beef cattle producers.

1.4 Scope of the Study

In recent years, substantial effort has been devoted to measuring the welfare effects of agricultural research within a partial-equilibrium framework that uses the concept of economic surplus (Alston, Norton and Pardey 1995). Procedures and formulae for measuring the size and distribution of returns to agricultural research, in terms of changes in economic surplus, have largely been derived from welfare economic theory and literature on modelling market displacements (Muth 1964; Gardner 1975; Just, Hueth and Schmitz 1982; Alston, Norton and Pardey 1995). The literature now contains a wealth of information on how to examine the impact of a research-induced technical change for a range of market situations (Lindner and Jarrett 1978; Rose 1980, Just, Hueth and Schmitz 1982; Freebairn, Davis and Edwards 1982 and 1983; Alston and Scobie 1983; Holloway 1989; Alston 1991; Alston, Norton and Pardey 1995). While much of the attention has focused on supply-shifting research, the widespread applicability of the economic surplus approach is evident from the number of studies in which it has been used (Griliches 1967; Peterson 1967; Peterson 1969; Davis, Oram and Ryan 1987; Brennan, Godyn and Johnston 1989; Lemieux and Wohlgenant 1989; Voon 1991; Voon and Edwards 1992; Hafi, Reynolds and Rose 1995).

Estimating a change in economic welfare using changes in producer surplus and consumer surplus provides a useful framework for analysing the impact of a chemical residue episode in the Australian beef industry. However, in the case of a residue incident, quality aspects are important and need to be incorporated into the analysis. A number of alternative methods have been suggested to conceptualise the issue of analysing the effects of quality-enhancing technology. Unnevehr (1986, 1990) suggests that one approach is to estimate implicit prices for the individual product attributes, while Voon (1991) and Voon and Edwards (1992) suggest that quality-enhancing research results in an upward shift in the demand curve.

In contrast, Alston, Norton and Pardey (1995) claim that depicting a research-induced change in quality as a shift in demand is useful in only a limited number of cases. They believe that quality-enhancing research results in a change in supply conditions rather than a change in demand conditions and, therefore, should be modelled as such. One approach suggested by Alston, Norton and Pardey (1995, p.244) is 'to use a multiproduct model ... and either to treat product characteristics as products (so that "quality" is continuously variable) or to treat different qualities of products as different products (discrete variations in "quality")'. They suggest that while the latter approach could be more restrictive, it is likely to be more practical. Because of the nature of the CFZ incident, the latter approach is used in this study.

Exposure to CFZ represents a change in the quality, or type, of cattle produced. Following Brennan, Godyn and Johnson (1989), these 'quality' aspects of CFZ can be incorporated into the analysis by allowing for different cattle markets based on whether or not cattle have been exposed to CFZ. The existence of CFZ residues in some Australian cattle can then be represented *as a shift in the supply* of cattle between markets. The changes in producer and consumer welfare for each market can then be measured.

Taking into account the multimarket setting of the Australian beef industry and the quality-altering aspects of the residue incident, the aims of this study are achieved by:

- developing a multimarket, multiproduct supply-and-demand model of the Australian beef industry;
- identifying which producers had cattle that were exposed to CFZ residues and defining supply curves for those producers and other producers separately;
- measuring the size of the residue-induced supply shifts for cattle;
- allowing for substitution between CFZ-affected cattle and non-affected cattle inputs in beef production;
- estimating the producer losses or gains for each of the markets; and
- calculating the net total cost of the CFZ incident to Australian cattle producers.

1.5 Outline of the Study

The format of this study is as follows. In Section 2, a multiregional, multiproduct model is developed to assess the economic impact of the CFZ incident on returns to Australian cattle producers. This model is then implemented in Section 3. The conclusions of the study are presented in Section 4, along with the policy implications of the analysis and areas for further research.

2. The Model

2.1 Introduction

In this study, a partial-equilibrium framework involving a CFZ-induced supply shift is developed to assess the impact of the CFZ incident on returns to cattle producers. The 'CFZ-impact' model developed within this framework is based on a number of important characteristics of the Australian beef industry. First, beef is not a homogeneous product and can, to some extent, be 'tailored' to meet differing market requirements (Gaden 1993). While carcase specifications vary between Australia's individual key export markets, in general, carcases sold on the export market are heavier and have a higher fat content than carcases sold on the domestic market (Gaden 1993). Therefore, cattle grown for the export market and cattle grown for the domestic market represent different types of cattle and are not perfect substitutes. In this analysis, for the sake of simplicity, it is assumed that there is no substitutability in demand between domestic cattle and export cattle, although substitutability between CFZ-affected cattle and domestic cattle is allowed for.

Second, Australian beef is a tradeable commodity, with over 60 per cent of annual production exported. Moreover, Australia is the world's largest beef exporter (ABARE 1995).

Third, the CFZ incident was largely a regional problem, affecting only a relatively small proportion (1.2 per cent) of the total number of cattle slaughtered in Australia for the three years ending October 1997. Given the small number of Australian cattle exposed to CFZ, the incident is likely to have had no impact on the world price of beef and, hence, the price paid for Australian cattle destined for the export market, and only a small impact on the price paid for domestic cattle.

Fourth, the source of the CFZ problem was dealt with very quickly after the discovery of CFZ residues in beef in late 1994. Nevertheless, because of the chemical nature of CFZ, cattle were tested to have CFZ residues more than two years after the problem was first recognised. It is expected, however, that the CFZ problem will be completely resolved in 1997 (NSW Agriculture 1996). In this study it is, therefore, assumed that the duration of the CFZ problem is three years, from the end of October 1994 until the end of October 1997.

Fifth, the presence of CFZ residues in cattle represents, conceptually at least, a change in the quality of the affected cattle. In other words, CFZ-affected cattle can be viewed as being a different 'type' of cattle to cattle that were not CFZ-affected. The difference between affected and non-affected cattle is largely due to the different testing and processing procedures that have be undertaken according to the CFZ status of the cattle.

Edwards and Freebairn (1982) developed an analytical framework for estimating productivity increases in part of an industry that produces a tradeable commodity. While the Edwards and Freebairn model is useful in analysing the effects on welfare from an exogenous shock in a market where the commodity is homogeneous, in this study beef is treated as a heterogeneous commodity obtained from two types of cattle (domestic cattle and export cattle) in the pre-CFZ situation, and from three types of cattle (domestic cattle, export cattle and CFZ-affected cattle) during the CFZ incident. For the purpose of this analysis, the Edwards and Freebairn model, therefore, needs to be extended to incorporate the heterogeneous nature of cattle.

Following Brennan, Godyn and Johnston (1989), the different types of cattle are accounted for by allowing for different cattle markets, where a CFZ-induced quality change in cattle is represented as a shift in the supply of cattle from one market to another. In addition, because it is assumed that the aggregate quantity of beef demanded at the retail level is not affected by the CFZ incident (primarily because of the very small number of CFZ-affected cattle relative to total Australian cattle slaughterings), the aggregate derived demand for cattle is also assumed to be unaffected by the CFZ incident. Therefore, given the creation of a new beef input, namely, CFZ-affected cattle, changes in producer surplus are estimated taking account of the substitution effects through demand in the domestic cattle market.

In summary, the model developed here is a static, partial equilibrium model with all lagged adjustments being captured in the three-year time horizon. In line with the duration of the CFZ problem in Australia, the length of run for all the supply-and-demand curves is three years and, because the focus of this study is on the economic impact of the

CFZ incident on producer welfare, all the supply-and-demand curves are defined at the farm level. In addition, for each of the cattle markets, linear supply-and-demand curves and competitive pricing behaviour are assumed (Zhao, Griffith and Mullen 1996).

In the rest of this Section, procedures and formulae for measuring CFZ-induced changes in producer surplus for each of the three (market) segments of the model are presented in turn, and then the formulae for calculating the total change in producer surplus is presented.

2.2 Model Description

2.2.1 The Domestic Cattle Market

The Australian domestic market for cattle is illustrated in the top segment of Figure 2.1. As defined in the CFZ-impact model, cattle sold on the domestic market meet domestic market specifications and are CFZ-clean. After the use of Helix® by the Australian cotton industry some, but not all, of the domestic market cattle became CFZ-affected. Even though the number of CFZ-affected cattle is relatively small, it has still been sufficiently large to have had an impact on the price of domestic cattle. Therefore, the CFZ incident has not only impacted on the economic welfare of domestic cattle producers who had CFZ-affected cattle, but also on the welfare of domestic cattle producers whose cattle were not exposed to CFZ. To determine the distribution of the economic impact of the CFZ incident between producers with affected cattle and those whose cattle were CFZ-clean, it is necessary to distinguish between the 'Region' and the 'Rest-of-Australia' in this segment of the CFZ-impact model.

While the majority of the CFZ-affected cattle were sourced from the cotton growing regions of Northern NSW and Southern Queensland, not all cattle in these regions were CFZ-affected. In addition, cattle in other areas of Australia were also exposed to CFZ, because they had been fed CFZ-affected cotton trash and cotton trash pellets. To accommodate this, following Brennan, Godyn and Johnston (1989), the Region is defined as containing all producers that had cattle that became CFZ-affected, rather than as a geopolitical area. This is done by specifying separate supply and demand curves for the Region and for the Rest-of-Australia. The horizontal summation of the two supply curves gives the total Australian supply of domestic cattle. Similarly, the horizontal summation of the demand curves gives the total Australian demand for domestic cattle. However, for ease of exposition, the Regional and Rest-of-Australia demand curves for domestic cattle are not included in the model because there are no welfare areas measured off these curves.

In the domestic cattle segment of Figure 2.1, the supply curve for domestic cattle for the Region in the absence of the CFZ incident is S_a^d (panel *a*) and the supply of domestic cattle for the Rest-of-Australia is S_r^d (panel *b*). The horizontal summation of S_a^d and S_r^d is the aggregate supply curve for domestic cattle, S_0^d (panel *c*). D_0^d is the initial aggregate Australian demand curve for domestic cattle. Prior to the CFZ episode, the equilibrium price for domestic cattle was P_0^d and the equilibrium aggregate quantity was Q_0^d, which is the summation of regional production, Q_a^d, and production in the Rest-of-Australia, Q_{r0}^d.

As a 'first-round' effect, discovery of CFZ-affected cattle causes a leftward shift in the supply of cattle on the domestic cattle market, at both the Regional and national levels. The extent of the supply shift is determined by the definition of the Region. Because the Region is defined to include all those producers who had cattle that became CFZ-affected, after the discovery of CFZ residues, the shift in S_a^d is just sufficient for the Region to no longer supply cattle to the domestic beef market. In other words, the Region's supply curve becomes non-existent and the Region's production falls from Q_a^d to zero, as the supply of these cattle shifts from the domestic cattle market to the CFZ-affected cattle market (see Section 2.2.3). The supply curve of domestic cattle for the Rest-of-Australia is unaffected by the CFZ incident by definition, while the aggregate supply curve shifts from S_0^d to S_1^d, where S_1^d is equal to S_r^d. As a result of the shift in the supply of domestic cattle, the equilibrium price increases to P_1^d and the equilibrium aggregate quantity falls to Q_1^d. The increase in the price received for cattle in the Rest-of-Australia results in the quantity of domestic cattle produced in the Rest-of-Ausuralia increasing from Q_{r0}^d to Q_{r1}^d.

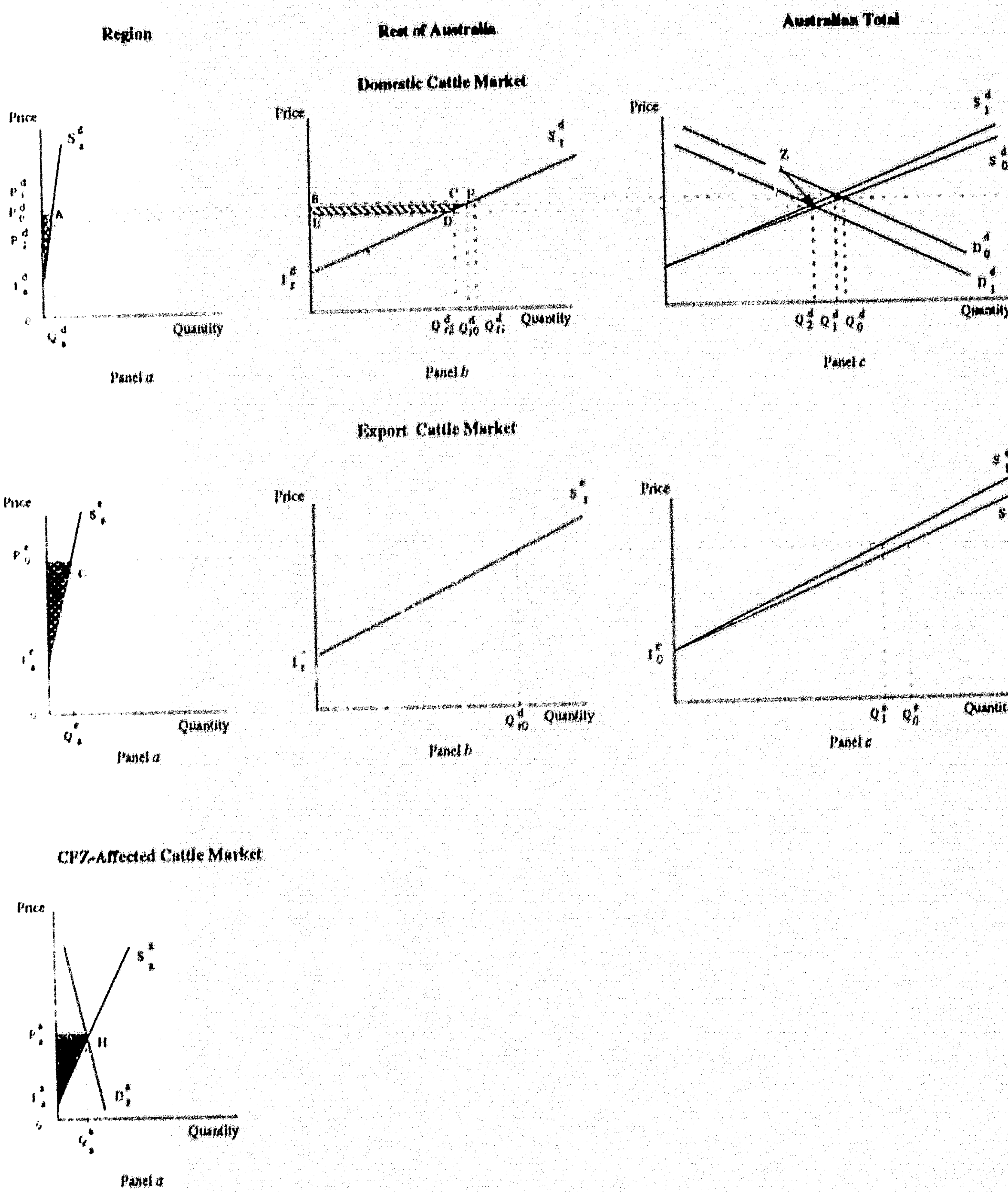
As a 'second-round' effect, because of the creation of a new type of cattle (i.e. CFZ-affected cattle which are related in consumption to CFZ-clean cattle), the demand for CFZ-affected cattle can be expected to result in a reduction in the demand for domestic cattle. The feedback in consumption causes the demand curve for domestic cattle to shift from D_0^d to D_1^d. The extent of this shift is determined by the number of cattle coming from either the domestic cattle market or the export cattle market onto the CFZ-affected cattle market. Because both domestic cattle and export cattle have been exposed to CFZ, the backward shift in the domestic demand curve can be expected to outweigh the backward shift in the aggregate domestic supply curve. As a result, the equilibrium price for domestic cattle falls from P_1^d to P_2^d and the equilibrium aggregate quantity falls to Q_2^d. The fall in the price received for domestic cattle results in a fall in the quantity of domestic cattle supplied by the Rest-of-Australia from Q_{r1}^d to Q_{r2}^d.

The effects on the economic welfare of domestic cattle producers are as follows:

- The welfare of domestic cattle producers in the Region is reduced as a result of the CFZ incident because of the contraction in the Region's supply of domestic cattle. In this case, because the Regional domestic cattle have been produced as CFZ-clean cattle, the economic loss to the Regional producers consists of two components. The first is the 'economic profit forgone'. It is represented by the area $P_0^dAI_a^d$ (panel *a*). The second is the decrease in the 'producers' resource base' from producing these cattle. It is equal to the area $P_0^dAQ_a^d0$ less the area $P_0^dAI_a^d$, less any costs that have been included in estimating the supply curve but that are not incurred because the cattle are not sold on the domestic cattle market (e.g., selling costs). Thus, Regional cattle producers lose the costs incurred in producing these cattle, plus the expected profit from their sale, by not being able to sell in the CFZ-clean market.

- Domestic cattle producers in the Rest-of-Australia are made worse off as a result of the CFZ incident because the equilibrium price for domestic cattle decreases as a result of the reduction in aggregate demand. The loss to these producers is equal to the area BFDE (panel *b*).

Figure 2.1: The effect of chlorfluazuron residues on returns to Australian cattle producers



2.2.2 The Export Cattle Market

The impact of the CFZ-incident on the welfare of producers of export cattle is illustrated in the middle segment of Figure 2.1. The export cattle market is not disaggregated horizontally to include the rest of the world because, while Australia is a large country beef exporter, the number of cattle affected by the CFZ incident was not large enough to effect the international price of beef. Therefore, the Region can be treated as a small 'country' beef exporter. As such, welfare changes in the export cattle market accrue solely to the Region. While there is also no need to include the Rest-of-Australia in this part of the analysis, because there is no spillover price effect from the Region to the Rest-of-Australia, the Rest-of-Australia is depicted in the middle segment of Figure 2.1 to illustrate the impact the CFZ incident has had on the total supply of Australian export cattle.

In the export cattle segment, the supply curve for export cattle from the Region in the absence of the CFZ incident is S^c_a (panel *a*). P^c_0 is farm level price paid for cattle suitable for the export market. It is a constant in the analysis. Prior to the CFZ-incident, production of export cattle in the Region is equal to Q^c_a.

The discovery of CFZ residues in export cattle causes a shift in the Region's supply of export cattle from the export cattle market to the CFZ-affected market. The Region's supply curve becomes non-existent and production of export cattle in the Region falls from Q^c_a to zero. However, the supply of export cattle in the Rest-of-Australia is not affected by the CFZ incident (by definition). The aggregate supply curve shifts from S^c_0 to S^c_1, where S^c_1 is equal to S^c_r. As a result, the aggregate quantity of export cattle supplied to the export market falls from Q^c_0 to Q^c_1. Because the change in the Region's supply of export cattle does not effect the world price for beef, the CFZ-induced economic surplus loss to export cattle producers, accrues solely to the export cattle producers that have CFZ-affected cattle.

As was the case with the Regional domestic cattle producers, the loss to Regional export cattle producers also consists of two segments. The first, the 'economic profit forgone', is represented by the area $P^c_0GI^c_a$ (Figure 2.1, middle segment, panel *a*), and the second, the decrease in the farmers' resource base from producing Regional export cattle, is equal to the area $P^c_0GQ^c_a0$ less the area $P^c_0AI^c_a$, less any costs included in estimating the supply curve that are not incurred because the cattle are not sold on the export cattle market (e.g., selling costs).

2.2.3 The CFZ-affected Cattle Market

Prior to the CFZ incident, no market for CFZ-affected cattle existed. After the discovery of CFZ residues in beef, a new type of cattle became available. Because of the international and domestic legal residue limits for CFZ, and because cattle in other countries were not affected by CFZ residues, the CFZ-affected cattle market segment can be depicted as a single commodity market in a closed economy.

The CFZ-affected cattle market is supplied by cattle coming from the Regional domestic cattle market and the Regional export cattle market. However, the supply and demand curves for the CFZ-affected cattle market cannot be defined by simply aggregating the individual Region supply and demand curves for the two types (or qualities) of cattle that existed prior to the CFZ-incident. This is because the CFZ-induced change in the quality of cattle resulted in a change in the supply conditions. After the discovery of CFZ residues in beef, the cattle producers in the Region no longer produced any domestic cattle or export cattle. What they produced instead was a different type (or quality) of cattle, that is, CFZ-affected cattle. In addition, because these cattle could be, and were, sold, there was also a demand curve for these cattle, with the equilibrium price and quantity being determined by the intersection of the (CFZ-affected cattle) market supply and demand curves.

The market for CFZ-affected cattle is depicted in the bottom segment of Figure 2.1. In this segment the total supply curve for CFZ-affected cattle is S^a_a, and the total demand curve is represented by D^a_a. P^a_a is the equilibrium price for CFZ-affected cattle and Q^a_a is the equilibrium quantity. The economic surplus accruing to the producers of CFZ-affected cattle is equal to the area $P^a_a J I^a_a$.

2.3 Change in Producer Welfare

Information on the economic welfare effects of the CFZ-induced quality change in cattle for each type of cattle producer is provided in the individual cattle market segments of the model. To obtain the total welfare effect on cattle producers, it is necessary to add the individual welfare changes. By aggregating the appropriate welfare measures, information on economic welfare changes to producers in the Region, to producers in the Rest-of-Australia and to total Australian producers can be obtained.

In economic surplus analysis, it is usual to equate a change in a producer's economic welfare with the change in producer surplus, where producer surplus is a measure of economic profits (i.e., the quasi-rents that accrue to inputs used in farming). In the case of the CFZ incident, however, the producer's economic welfare is affected not only by a change in the producer surplus, but also by a change in the producer's resource base. In each of the following sections, the formulae for calculating the total change in producer surplus will be presented first and then, where appropriate, mention will be made of the procedure required to calculate the change in the producer's resource base.

2.3.1 The Region

Initial Situation

In the domestic cattle market segment of the model (Figure 2.1, top segment, panel *a*), the initial Regional price intercept is equal to I^d_a, the initial equilibrium price of domestic cattle is P^d_0, and the initial equilibrium quantity supplied by the Region is equal to Q^d_a. Thus, given linear supply and demand curves, the initial producer surplus accruing to domestic cattle producers in the Region, PS^d_{a0}, is equal to the area below the price line and above the supply curve, that is:

$$PS^d_{a0} = 0.5\,(P^d_0 - I^d_a)\,Q^d_a \qquad (2.1)$$

In the export cattle segment of the market (Figure 2.1, middle segment, panel *a*), the initial Regional price intercept is I^e_a, the initial equilibrium price for export cattle is P^e_0 and the initial equilibrium quantity supplied by the Region is Q^e_a. The pre-CFZ producer surplus accruing to export cattle producers in the Region, PS^e_{a0}, is equal to:

$$PS^e_{a0} = 0.5\,(P^e_0 - I^e_a)\,Q^e_a \qquad (2.2)$$

In the CFZ-affected cattle market segment (Figure 2.1, bottom segment, panel *a*), there is no supply of CFZ-affected cattle prior to the CFZ incident, so production and producer surplus, PS^a_{a0}, is equal to zero, that is:

$$PS^a_{a0} = 0 \tag{2.3}$$

During the CFZ Incident

In the domestic cattle market segment, by definition, there is no supply of domestic cattle from the Region during the CFZ incident, so the producer surplus accruing to Regional producers of domestic cattle during the CFZ episode, PS^d_{a1}, is equal to zero, that is:

$$PS^d_{a1} = 0 \tag{2.4}$$

In addition, becau[illegible] Regional producers used resources to produce domestic cattle, which by defini[illegible] ey can no longer sell on the domestic cattle market, this use of resources represents a reduction in their resource base (RB^d_{a1}). It is equal to:

$$RB^d_{a1} = (P^d_0 Q^d_a) - PS^d_{a0} - (NC^d_{a0} Q^d_a) \tag{2.5}$$

where NC^d_{a0} is equal to costs related to supplying cattle to the domestic market that are not incu red because the cattle are not sold on that market.

In the export cattle market segment, there is no Regional supply of export cattle during the CFZ i ident, so the producer surplus accruing to Regional producers in the export cattle market during the CFZ episode, PS^e_{a1}, is equal to zero, that is:

$$PS^e_{a1} = 0 \tag{2.6}$$

In addition, because the Regional producers used resources to produce export cattle, which by definition, they can no longer sell on the export cattle market, this use of resources represents a reduction in their resource base (RB^e_{a1}). It is equal to:

$$RB^e_{a1} = (P^e_0 Q^e_a) - PS^e_{a0} - (NC^e_{a0} Q^e_a) \tag{2.7}$$

where NC^e_{a0} is equal to costs related to supplying cattle to the export market that are not incurred because the cattle are not sold on that market.

In the CFZ-affected cattle segment, during the CFZ incident, the supply price intercept for CFZ-affected cattle is I^a_a, the equilibrium price is P^a_a and the equilibrium quantity is Q^a_a. The economic surplus accruing to producers of CFZ-affected cattle during the CFZ episode, PS^a_{a1}, is equal to:

$$PS^a_{a1} = 0.5\,(P^a_a - I^a_a)\,Q^a_a \tag{2.8}$$

Change in Economic Welfare to Producers in the Region

The total change in producer welfare for the Region (ΔEW^t_a) is equal to the change in producer surplus in the domestic cattle segment plus the change in producer surplus in the export segment plus the change in the CFZ-affected cattle segment less the reduction in the Regional domestic cattle producers' resource base less costs not incurred, that is:

$$\Delta EW^{t}_{a} = [PS^{d}_{a1} - PS^{d}_{a0} - RB^{d}_{a1}] + [PS^{c}_{a1} - PS^{c}_{a0} - RB^{c}_{a1}] + [PS^{a}_{a1} - PS^{a}_{a0}] \quad (2.9)$$

therefore,

$$\begin{aligned} \Delta EW^{t}_{a} = & \{0 - [0.5\,(P^{d}_{0} - I^{d}_{a})\,Q^{d}_{a}] - [(P^{d}_{0}\,Q^{d}_{a}) - PS^{d}_{a0} - (NC^{d}_{a0}\,Q^{d}_{a})]\} + \\ & \{0 - [0.5\,(P^{c}_{0} - I^{c}_{a})\,Q^{c}_{a}] - [(P^{c}_{0}\,Q^{c}_{a}) - PS^{c}_{a0} - (NC^{c}_{a0}\,Q^{c}_{a})]\} + \\ & \{[0.5\,(P^{a}_{a} - I^{a}_{a})\,Q^{a}_{a}] - 0\} \end{aligned} \quad (2.10)$$

2.3.2 The Rest-of-Australia

The Initial Situation

The domestic cattle market is the only market segment where the CFZ incident has impacted on the economic welfare of cattle producers outside the Region (Figure 2.1, top segment, panel *b*). In the domestic market segment, prior to the CFZ incident, the supply price intercept for domestic cattle in the Rest-of-Australia is equal to I^{d}_{r}, the initial equilibrium price is P^{d}_{0}, and the initial equilibrium quantity supplied by the Rest-of-Australia is equal to Q^{d}_{r0}. Thus, the initial producer surplus accruing to domestic cattle producers in the Rest-of-Australia is equal to:

$$PS^{d}_{r0} = 0.5\,(P^{d}_{0} - I^{d}_{r})\,Q^{d}_{r0} \quad (2.11)$$

During the CFZ Incident

In the domestic cattle market segment, the supply price intercept for the Rest-of-Australia remains constant at I^{d}_{r}, the equilibrium price decreases from P^{d}_{0} to P^{d}_{2}, and the initial equilibrium quantity of domestic supplied in the Rest-of-Australia decreases from Q^{d}_{r0} to Q^{d}_{r2}. Thus, as a result of the CFZ incident, producer surplus accruing to domestic cattle producers in the Rest-of-Australia is equal to:

$$PS^{d}_{r1} = 0.5\,(P^{d}_{2} - I^{d}_{r})\,Q^{d}_{r2} \quad (2.12)$$

Change in Producers Surplus in the Rest-of-Australia

The change in producer surplus for the Rest-of-Australia (ΔPS^{t}_{r}) is equal to the producer surplus during the CFZ incident (PS^{d}_{r1}) minus the producer surplus before the CFZ incident (PS^{d}_{r0}), that is:

$$\Delta PS^{t}_{r} = PS^{d}_{r1} - PS^{d}_{r0} \quad (2.13)$$

therefore,

$$\begin{aligned} \Delta PS^{t}_{r} &= \{[0.5\,(P^{d}_{2} - I^{d}_{r})\,Q^{d}_{r2}] - [0.5\,(P^{d}_{0} - I^{d}_{r})\,Q^{d}_{r0}]\} \\ &= Z\,(Q^{d}_{r0} + Q^{d}_{r2}) / 2 \end{aligned} \quad (2.14)$$

where Z is the actual change in the CFZ-induced price for domestic cattle and is equal to:

$$Z = [(Q_a^a - Q_a^d)\,[(P_0^d - I_r^d) / Q_{r0}^d]\,[(P_0^d / Q_0^d)\,1/\eta^d]] / [[(P_0^d - I_r^d) / Q_{r0}^d] + [(P_0^d / Q_0^d)\,1/\eta^d]] \qquad (2.15)$$

where η^d is the Australian price elasticity of demand for domestic cattle, and the proof for Z is presented in Box 2.1.

Box 2.1 Calculation of the change in the price of domestic cattle

From Figure 2.2,

$$\text{tangent } \alpha = Z / X$$
$$\text{tangent } \beta = Z / (A - X)$$

therefore,

$$Z = X \text{ tangent } \alpha$$

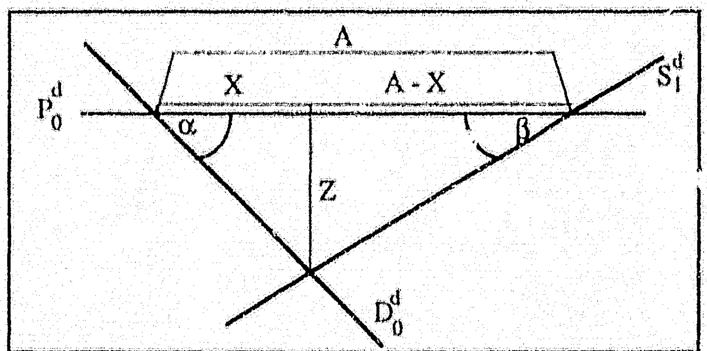
and,

$$Z = (A - X) \text{ tangent } \beta$$

therefore,

$$X \text{ tangent } \alpha = (A - X) \text{ tangent } \beta$$
$$X = A \text{ tangent } \beta / (\text{tangent } \alpha + \text{tangent } \beta)$$
$$Z = X \text{ tangent } \alpha$$
$$Z = A \text{ tangent } \beta \text{ tangent } \alpha / (\text{tangent } \alpha + \text{tangent } \beta)$$

Figure 2.2 Determining the value of Z



Now, from Figure 2.2 (which is taken from Figure 2.1 (panel *c*))

$$\text{tangent } \beta = \text{slope } S_1^d = \text{slope } S_r^d = (P_0^d - I_r^d) / Q_{r0}^d$$
$$\text{tangent } \alpha = \text{slope } D_0^d = \text{slope } D_1^d = (P_0^d / Q_0^d)\,1/\eta^d$$

therefore,

$$Z = \{(Q_a^a - Q_a^d)\,[(P_0^d - I_r^d) / Q_{r0}^d]\,[P_0^d / Q_0^d\,1/\eta^d]\} / \{[(P_0^d - I_r^d) / Q_{r0}^d] + [(P_0^d / Q_0^d)\,1/\eta^d]\}$$

2.3.3 The Impact of the CFZ Incident on All Australian Cattle Producers

The total change in economic welfare (ΔEW_t^t) can be measured by adding up the CFZ-induced changes in the welfare areas measured off the Marshallian supply-and-demand curves in all of the affected markets. Hence, the total economic impact of the CFZ incident on all Australian cattle producers is equal to the change in economic welfare for the Region plus the change in producer surplus for the Rest-of-Australia, that is:

$$\Delta EW_t^t = \Delta EW_a^t + \Delta PS_r^t \qquad (2.16)$$

therefore,

$$\begin{aligned}\Delta EW_t^t = & \{0 - [0.5\,(P_0^d - I_a^d)\,Q_a^d] - [(P_0^d\,Q_a^d) - PS_{a0}^d - (NC_{a0}^d\,Q_a^d)]\} + \\ & \{0 - [0.5\,(P_0^c - I_a^c)\,Q_a^c] - [(P_0^c\,Q_a^c) - PS_{a0}^c - (NC_{a0}^c\,Q_a^c)]\} + \\ & \{[0.5\,(P_a^a - I_a^a)\,Q_a^a] - 0\} + \{Z\,(Q_{r0}^d + Q_{r2}^d)/2\} \qquad (2.17)\end{aligned}$$

2.4 Key Assumption in the Model

The most critical assumption made in applying the above model to estimate the change in cattle producer welfare from the discovery of CFZ residues in cattle is that the supply and demand curves for cattle in each market are linear. Linear supply-and-demand curves are frequently used in economic surplus studies because they enable simple algebra to be used to calculate surplus change. However, various authors have criticised the use of linear supply curves with point elasticities at the equilibrium of less than one because they imply a negative price intercept (Kim, Schaible, Hamilton and Barney 1987; Godyn, Brennan and Johnston 1987; Voon and Edwards 1991b). Indeed, given that the supply curve is the same as the rising part of the marginal cost curve above the minimum average variable cost (see, for example, Just, Hueth and Schmitz 1982, pp. 48-52), the implication that positive quantities would be supplied at negative prices is unrealistic. A number of alternative methods have been suggested to overcome the problem of a negative intercept when the supply of a commodity is inelastic. First, it can be assumed that a supply curve that is inelastic at the initial equilibrium point is kinked so it has a positive price intercept (Hertford and Schmitz 1977; Rose 1980). While Hertford and Schmitz (1977) suggested that the supply curve should be kinked at the new price, Rose (1980) suggested kinking the supply curve at the original quantity. Regardless of where the arbitrary kink is in the supply curve, this method is a departure from the linear model.

Second, a constant-elasticity model, in which supply-and-demand curves of constant elasticity are assumed, could be developed so, regardless of its elasticity, the supply curve passes through the origin. While this modelling approach overcomes the problem of a negative price intercept, the constant-elasticity model, like the linear model when supply is inelastic, has some implausible implications when extrapolating back to the origin (Alston, Norton and Pardey 1995).

A third alternative is to assume a non-linear function form that is concave from above and has a positive price intercept. This model, suggested by Lynam and Jones (1984) and later used by Pachico, Lynam and Jones (1987), has the immediate appeal of greater realism than either the linear or the constant-elasticity models.

On the surface, each of these approaches appear to be viable alternatives to a linear model. However, while these approaches do overcome the problem of a negative price intercept when the supply curve is inelastic, there are some other problems that either remain unsolved or that are a product of these approaches. For example, one hazard associated with an inelastic supply curve is that the welfare change can be overestimated if the proportionate vertical shift in supply is calculated from the proportionate horizontal shift using the expression $K = J/\varepsilon$, where K equals the vertical supply shift, J equals the horizontal supply shift and ε equals the elasticity of supply (Alston, Norton and Pardey 1995). Also, with regard to using a constant elasticity supply curve, a proportional or pivotal supply shift is typically assumed. However, assumptions made about the nature of the supply shift are significantly more important, in terms of their impact on the estimated change in the level of welfare, than are assumptions about the functional form of the supply curve. Finally, while the approach suggested by Lynam and Jones (1984) is flexible with regard to the nature of the supply shift, this approach requires a non-linear algorithm for its solution. Alston and Wohlgenant (1990) suggest the extra effort required to solve price and quantity changes may not be warranted.

The pertinent question is whether the use of linear supply curves in the CFZ-impact model (Figure 2.1) provides an adequate approximation for the purpose of assessing the impact of the CFZ incident on returns to Australian cattle producers. Starting from the principle that cattle producers strive to maximise profits in a competitive market environment, the supply curve for each type (or quality) of cattle would be equivalent to the marginal cost curve for the respective cattle type, above the respective average variable cost curve. Therefore, the assumption that the supply curve (in each of the market segments in the model) would have a positive price intercept is valid, regardless of the supply elasticity. However, there is no *a priori* reason to assume that a supply curve is a straight line joining the positive price intercept and the known equilibrium price and quantity. How realistically linear supply equations represent the true economic relationship will depend on the relationship in question. While in most economic studies the true functional form is unknown, what is known in this case is, given that the supply curves in this analysis are inelastic, the true economic relationship would indeed not be linear if the intersection with the price axis is positive.

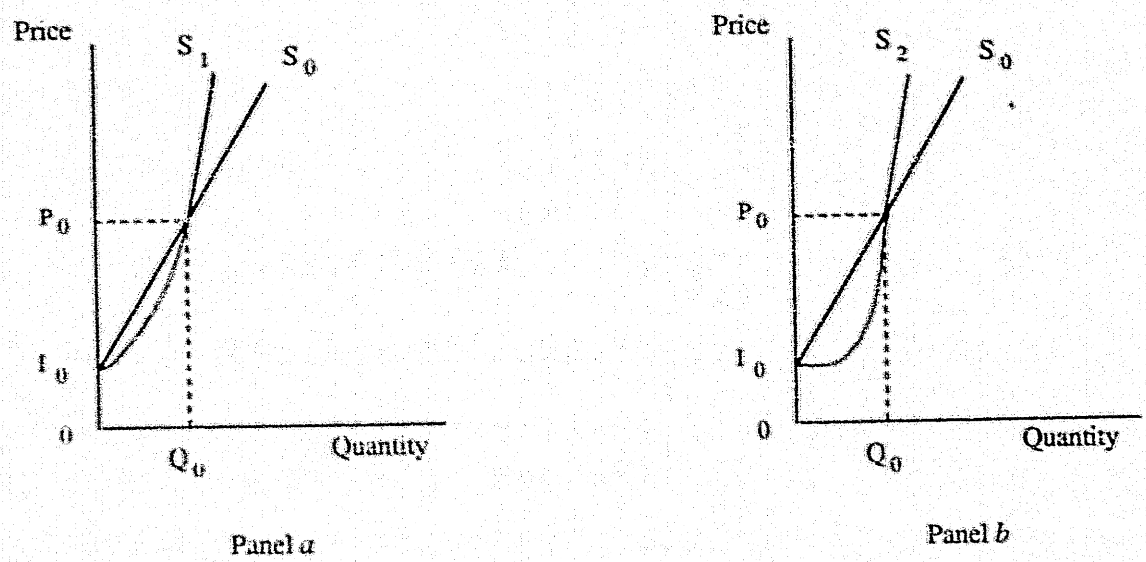
In the CFZ-impact model, the implications, in terms of welfare measurements, of mis-specifying the supply curve will vary according to the market segment being considered. This is because the impact of the CFZ incident in the individual market segments varied. For example, the CFZ incident resulted in only a relatively small proportionate shift in the supply of cattle in the total domestic market (Figure 2.1, top segment, panel *c*), but a large proportionate shift in the supply of cattle at the Regional level (panel *a* in all three segments of Figure 2.1).

In the case of the total Australian domestic cattle market (Figure 2.1, top segment, panel *c*), the shift in the supply from S_0^d to S_1^d, combined with the shift in the demand curve from D_0^d to D_1^d, is used to calculate the change in the price of domestic cattle. Now, the horizontal shift in both curves is small relative to the total market, and the use of inelastic supply curves would result in an unrealistically large vertical supply shift. Given the preceding discussion, linear supply and demand curves and elastic supply are assumed. In addition, a parallel shift in demand is assumed. These assumptions provide an adequate approximation of the CFZ-induced change in the price of domestic cattle.

The impact of the CFZ-incident on producers in the Rest-of-Australia are calculated using the estimated CFZ-induced change in the price of domestic cattle and off the supply curve S_r^d (Figure 2.1, top segment, panel *b*). Clearly, in this case, specification of the supply curve has very little impact on the change in welfare. This is because the specification of the supply curve does not affect the rectangle BCDE, only the triangle CFD. As the triangle is very small compared with the rectangle, it follows that total welfare change is relatively insensitive to the assumptions made about the elasticity of supply or about the functional form of the supply curve. Therefore, in this case, the use of a linear, elastic supply curve provides a reasonable approximation of the CFZ-induced welfare change to domestic cattle producers who were not affected by the CFZ incident.

The welfare implications of mis-specifying the supply curves are greatest at the Regional level. These implications are illustrated graphically in Figure 2.3. In both panel *a* and panel *b* of Figure 2.3, two short-run Regional supply curves are depicted. The first supply curve, S_0, is represented as a straight line joining the positive price intercept and the known equilibrium price and quantity. It is an approximation of the 'true', unknown supply curve. The second supply curves, S_1 in panel *a* or S_2 in panel *b*, are non-linear curves that are inelastic at the equilibrium point, either one of which could be the 'true' unknown supply curve. The supply curve, S_1, is consistent with the situation where the factor endowments in a particular region or country are dissimilar. In this case, producers of the commodity would be expected to have dissimilar marginal and

Figure 2.3: Possible specification bias due to assumption regarding linear supply curve



opportunity costs, implying that supply curve would be *relatively* steep at the price intercept and, because S_1 is a short-run supply curve, it is inelastic at the equilibrium point. As can be seen, in this situation, if S_1 is indeed the true supply curve then the linear supply curve, S_0, provides a reasonable approximation of the true supply curve and the producer surplus area measured off S_0 (i.e. $PS_0 = 0.5\ (P_0 - I_0)\ Q_0$), provides a reasonable approximation of the true producer surplus area measured off S_1 (PS_1). Therefore, it is assumed that:

$$PS_1 \approx 0.5\ (P_0 - I_0)\ Q_0 \qquad (2.18)$$

If, however, the factor endowments in the country or region were similar, implying that a large number of the farms had similar cost structures, then the 'true' short-run supply curve could be expected to be relatively flat at the price intercept and then become steeply-sloping at the equilibrium quantity. S_2 is consistent with this scenario. In this case, S_0 does not provide a reasonable approximation of the true supply curve and, given that the 'true' supply curve is highly inelastic, the producer surplus area measured off S_0 would be almost half the true welfare area measured off S_2 (PS_2). In this case, a more accurate approximation of the producer surplus area is:

$$\begin{aligned} PS_2 &\approx 2\ [0.5\ (P_0 - I_0)\ Q_0] \\ &\approx (P_0 - I_0)\ Q_0 \qquad (2.19) \end{aligned}$$

The supply curves S_1 and S_2 represent two extreme situations and, therefore, neither are likely to be the *true* functional form. However, while the assumption of linear supply curves in this model may result in some specification bias, changes in producer surplus measured off linear supply curves in the CFZ-impact model do provide a reasonable approximation of the minimum impact the CFZ incident is likely to have on producer surplus accruing to domestic, export and CFZ-affected cattle producers in the Region (i.e., it provides a reasonable approximation of a 'lower bound' estimate of the impact on producer profits). In addition, the maximum impact on producer surplus accruing to cattle producers in the Region can be approximated by doubling the minimum Regional impact (i.e. an 'upper bound' estimate). (Although, with regard to domestic and export cattle producers in the Region, assumptions regarding the specification of the supply curve do not impact on the total change in economic surplus, only the distribution of this change between what is classified as producer surplus and what is classified as the producers' resource base.)

3. Empirical analysis

3.1 Data Requirements

The data requirements for this analysis include the base sale prices, quantities and supply price intercepts for each of the cattle types. The total number of CFZ-affected cattle, and the proportion of these cattle that were originally destined for sale on the domestic market or on the export market, is also required. The base prices, quantities and the supply price intercepts for each of the cattle types are presented in Table 3.1.

The total number of cattle slaughtered in Australia for the three years ending October 1997 was obtained from D. Barrett (1996, pers. comm.). The proportion of Australian beef that is exported was calculated from information provided by D. Barrett (1996, pers. comm.) and from information contained in the ABARE publication, *Australian*

Commodities. Estimates of the number of domestic cattle and export cattle slaughtered for the three years ending October 1997 were derived from these figures.

To determine the number of CFZ-affected cattle slaughtered in the two years ending October 1996, information on the number of fat samples collected at abattoir for CFZ testing, and the associated testing rates were obtained from the CFZ on-plant testing figures supplied by AQIS (AQIS 1996). This information, combined with the fact that the average cattle lot size in NSW is three head (B. Gaden 1996, pers. comm.), made it possible to estimate the number of CFZ-affected cattle that were slaughtered between October 1994 and October 1996. An estimate of the number of CFZ-affected cattle that is likely to be slaughtered during the year ending October 1997 is based on the approximate number of cattle that were still CFZ-affected as at the 15 October 1995 (NSW Agriculture 1996) and on the proportion of Australian cattle numbers slaughtered for the three years ending 1996/97, obtained from information in the ABARE publication, *Australian Commodities*. The break-up of the total number of CFZ-affected cattle into those that were originally grown for sale on the domestic cattle market (20 per cent) and those that were originally destined for sale on the export cattle market (80 per cent) was provided by E. Joshua (1996, pers. comm.).

Table 3.1 Base price, quantity and supply intercept data for the three years ending October 1997

	Domestic cattle	Export cattle
Price ($A/head)		
Domestic cattle market	384.13	
Export cattle market		578.08
CFZ cattle market	304.69	
Quantity (million head)		
Domestic cattle market		
Region	0.06	
ROA	8.92	
Export cattle market		14.45
CFZ cattle market	0.06	0.23
Supply intercept ($A/head)		
Domestic cattle market		
Region	313.38	
ROA	326.23	
Export cattle market		478.57
CFZ cattle market	72.20	

Source: Davies and Llewellyn 1994; ABARE 1996; AQIS 1996; D. Barrett 1996, pers. comm.; E. Joshua 1996, pers. comm.; NSW Agriculture 1996; P. Knopke 1997, pers. comm.; Wesfarmers 1997 pers. comm.; and authors calculations

The number of cattle sold on the CFZ-market is equal to the total number of CFZ-affected cattle less the number that were found at the abattoir to have residue levels above the MRL. Cattle producers were not compensated for condemned animals (AQIS 1996). It is assumed that all the cattle sold on the CFZ-affected cattle market are processed for sale on the domestic market only. Given that, up to 28 October 1996, around 15 per cent of fat samples from CFZ-affected cattle were found to contain residues above the LOR, and processors, exporters (or insurance companies) would risk losing around $70 000 for each container of processed beef in which a violative sample is detected (R. Crouch 1995, pers. comm.), this assumption seems reasonable.

The equilibrium sale price ($/head) of domestic and export cattle was extrapolated from the 1994 average $/head sale price for different types of cattle contained in the NSW Agriculture publication, *Beef enterprise; budgets for NSW* (see Table 3.2 and Table 3.3) and the c/kg saleyard price for cattle for the three years ending June 1996/97, contained in the ABARE publication, *Australian Commodities*. The equilibrium sale price for domestic cattle is estimated to be $384.13 per head and the equilibrium sale price for export cattle is estimated to be $578.08 (Table 3.1).

On average, the sale price of CFZ-affected cattle is 35 per cent less than the price paid for CFZ-clean animals (D. Byrnes 1995, pers. comm.). However, CFZ-affected cattle that were destined for the export market have been subjected to a greater price discount than cattle that were destined for the domestic market. This is because the price of CFZ-affected 'export' cattle is discounted not only because of the CFZ status of the animals but also because these cattle do not meet domestic market specifications. In calculating the average sale price for CFZ-affected cattle, the sale price of CFZ-affected cattle sourced from the domestic cattle market is assumed to be 30 per cent below the price paid for domestic cattle and the sale price of CFZ-affected cattle sourced from the export market is assumed to be 40 percent below the price paid for export cattle. Also taken into account is the fact that, CFZ-affected cattle that are tested at the abattoir to have residue levels between the LOR and the MRL are subjected to at least a further 50 per cent price discount and, cattle with residue levels above the MRL receive a 100 per cent price discount (i.e., farmers are not paid for these cattle) (Wesfarmers 1997, pers. comm.). Based on this information, the sale price for CFZ-affected cattle is estimated to be $304.69 (Table 3.1).

The supply curve for an agricultural commodity consists of two components. These are marginal non-land costs and marginal rents to land (from alternative enterprises) (Rose 1980). Therefore, because the supply curve is not a marginal curve exclusive of rents, calculation of the supply price intercepts for each of the cattle types must include both the minimum 'direct' marginal cost of cattle production and the marginal land rents.

The minimum 'direct' marginal cost of supplying any agricultural commodity is equal to the variable cost of production. In addition, because market prices are used in this analysis, the appropriate marginal cost of production should also include the cost of selling that commodity (Brennan, Godyn and Johnston 1989). Information on the variable costs, including marketing costs, for various cattle types are contained in the NSW Agricultural publication, *Beef enterprises, budgets for NSW* (Davies and Llewellyn 1994). This information was used to calculate the 1994 estimate of the average total variable cost of supplying domestic cattle ($127.71) and export cattle ($253.54), presented in Tables 2.2 and 2.3, respectively. An index of prices paid by farmers was applied to these figures to obtain the average total variable cost of supplying each of the broad cattle types for the three years ending October 1997. The index of prices paid by farmers was obtained from P. Knopke (pers. comm. 1997). Based on this information, the average variable cost of supplying domestic cattle was estimated to be $133.46 and the average variable cost of supplying export cattle was estimated to be $264.95.

The average variable cost of supplying CFZ-affected cattle is assumed to be equal to feeding and veterinary costs incurred after the cattle became CFZ-affected, the average cost of testing affected cattle for CFZ residues at the abattoir and selling costs. In the base analysis, it is assumed that CFZ-affected cattle were withheld from sale for an average of six months to allow the residue levels to fall. The additional feed and health costs for domestic cattle were $5.08 per month in 1994 (Table 3.2) and the additional feed and health costs for export cattle were $5.47 per month in 1994 (Table 3.3) (Davies and Llewellyn 1994). The index of prices paid by farmers was applied to these figures to obtain the additional monthly cost of feed each of the broad cattle types for the three years ending October 1997. The average per head cost of testing CFZ-affected cattle is estimated to be $5.70. The cost of selling CFZ-affected cattle is estimated to be $32.69, and is a weighted average of the cost of selling domestic cattle and the cost of selling

Table 3.2: Estimation of average variable costs and DSE a ratings for domestic cattle

	Young cattle	Local trade/ feeders	Inland weaners - stores	Far Northcoast weaners 1	Far Northcoast weaners 2	Friesan steers	Yearling	Local/trade feeders Southcoast	Average
Enterprise unit	100 cows	100 cows	100 cows	100 cows	100 cows	100 steers	100 cows	100 cows	100 animals
Number of cattle sold	79	109	83	59.6	80.6	93	83	89	85
Average sale price- $/head	497.62	415.55	386.22	282.10	395.25	500	548.67	457.61	**440.85**
Variable costs									
Replacements	2700.00	13500.00	2500.00	840.00	1080.00	6200.00	2700.00	2500.00	4002.50
Health and vet costs	973.00	771.00	771.00	977.00	1370.00	950.00	1005.00	1242.00	1007.38
Eartags @ $2.00	46.00	34.00	42.00	36.00	44.00	0.00	40.00	36.00	34.75
Fodder crops	0.00	0.00	0.00	0.00	0.00	9550.00 b	0.00	0.00	1193.75
Hay & grain or silage	0.00	0.00	2400.00	0.00	0.00	2400.00	0.00	0.00	600.00
Pasture maintenance	2400.00	4920.00	0.00	0.00	4830.00	2640.00	6600.00	4980.00	3296.25
livestock selling costs	2459.00	2862.00	2094.00	1417.00	2281.00	3368.00	3534.00	3079.00	2636.75
Total variable cost - $	8578.00	22087.00	7807.00	3270.00	9605.00	25108.00	13879.00	11837.00	12771.38
Average variable cost- $/head	85.78	220.87	78.07	32.70	96.05	251.08	138.79	118.37	**127.71**
Gross margin - $/head	307.34	232.08	242.49	135.43	222.52	213.92	316.61	288.90	**244.91**
Average health & feed cost - $/head/month	2.81	4.74	2.64	0.81	5.17	12.95	6.34	5.19	**5.08**
Average selling cost - $/head	24.59	28.62	20.94	14.17	22.81	33.68	35.34	30.79	**26.37**
DSE rating	16.38	13.10	12.89	9.67	12.89	7.00	17.62	13.26	**12.85**

a Dry sheep equivalent
b Feed costs to weaning (first 10 weeks) plus supplementary feed costs (10 to 14 weeks)
Source: Davies and Llewellyn 1994

Table 3.3: Estimation of average varia costs and DSE a ratings for export cattle

	Heavy feeder steers	Growing out steers 8 months	Growing out steers 12 months	EC Cattle	Supergrass steers	Average
Enterprise unit	100 cows	100 steers	100 steers	100 cows	100 cows	100 animals
Number of cattle sold	83	98	98	84	83	89
Average sale price- $/head	539.42	632.24	682.00	688.13	668.24	**643.13**
Variable costs						
Replacements	3000.00	34500.00	33500.00	2700.00	3000.00	15340.00
Health and vet costs	1005.00	390.00	390.00	1087.00	1085.00	791.40
Eartags @ $2.00	40.00	0.00	0.00	40.00	* 40.00	24.00
Fodder crops	0.00	1440.00	1440.00	2500.00	2400.00	1556.00
Hay & grain or silage	0.00	0.00	0.00	0.00	5000.00	1000.00
Pasture maintenance	0.00	1980.00	2640.00	8460.00	3000.00	3216.00
livestock selling costs	2705.00	4002.00	4173.00	3175.00	3079.00	3426.80
Total variable cost - $	6750.00	42312.00	42143.00	17962.00	17604.00	25354.20
Average variable cost- $/head	67.50	423.12	421.43	179.62	176.04	**253.54**
Gross margin - $/head	380.22	196.48	246.93	398.41	378.60	**320.13**
Average health & feed cost - $/head/month	0.84	3.18	3.73	10.04	9.57	**5.47**
Average selling cost - $/head	27.05	40.02	41.73	31.75	30.79	**34.27**
DSE rating	16.18	7.20	8.48	22.57	21.86	**15.26**

a Dry sheep equivalent

Source: Davies and Llewellyn 1994

export cattle. The total average variable cost of supplying CFZ-affected cattle to the market is estimated to be $72.20.

Based on the notion that the production of one commodity is a function of the price of other commodities, opportunity costs reflect the marginal rent to land from alternative enterprises (Rose 1980). The opportunity cost of any resource is the return to that resource from its most profitable alternative use. The major alternative enterprise to growing beef cattle in Australia is wool production (E. Joshua 1996, pers. comm.). Therefore, the gross margin for wool production provides an estimate of the opportunity cost of beef cattle production.

The gross margin for wool in the cotton growing areas of Northern NSW and Southern Queensland is $14 per wether, which is an approximate gross margin per head for 23 micron wethers, the main type of wool grown in these areas (E. Joshua 1996, pers. comm., Crean 1996). For the Rest-of-Australia, the gross margin for wool is assumed to be $15 per wether, which is an approximate gross margin per head for 19, 21 and 23 micron wethers. The conversion factor required to translate the $ per wether gross margins into a $ per head cattle equivalent is the DSE rating. Based on information provided by Davies and Llewellyn (1994), the average DSE rating for Regional domestic cattle is calculated to be 12.85 (Table 3.2), while the average DSE rating for Regional export cattle is calculated to be 15 26 (Table 3.3). Following from this, the opportunity cost of supplying domestic cattle in the Region is estimated to be $179.92 per head, while the opportunity cost of supplying export cattle in the Region is estimated to be $213.61 per head and the opportunity cost of supplying domestic cattle in the Rest-of-Australia is $192.77 per head.

While the gross margin for wool production provides an estimate of the opportunity cost of beef production in general, there is no 'true' alternative enterprise for CFZ-affected cattle. This is because producers have not made a conscious decision to produce CFZ-affected cattle in the same way that they would decide to produce wool or wheat or non-affected cattle. Therefore, there is no opportunity cost associated with CFZ-affected cattle.

Using the data on the variable cost and the opportunity cost of beef production for each cattle type, the supply intercept for the domestic cattle market is estimated to be $313.38 for the Region and $326.23 for the Rest-of-Australia (Table 3.1). For the export cattle market, the Regional supply intercept is estimated to be $478.57, while the supply intercept for the CFZ-affected cattle market is $72.20 (Table 3.1).

Clearly, the data used in this analysis are imperfect. However, the incomplete data set is offset, to some extent, by the fact that the analysis that follows can be repeated using alternative estimates of key parameters.

3.2 Calculated Changes in Economic Welfare to Producers

The calculated changes in economic welfare, presented in Table 3.4, show the estimated economic loss to Australian cattle producers at the regional and national levels. The estimates of the welfare change provided in the top part of this table are based on the lower bound estimate for the change in producer surplus to CFZ-affected cattle producers. The total economic cost to Regional cattle producers is estimated to be $90.07 million. This comprises a $20.73 million loss to Regional domestic cattle producers, a $102.99 million loss to Regional export cattle producers and a $33.65 million gain to CFZ cattle producers. The loss to producers in the Rest-of-Australia, due to the CFZ-induced fall in the price of domestic cattle, accrues solely to domestic cattle producers and is estimated to equal $10.95 million. The addition of the individual changes in welfare provides an estimate of the loss to all Australian cattle producers, which is $101.02 million.

In the bottom part of Table 3.4, the estimates of the welfare change to Australian cattle producers are based on the upper bound estimate for the change in producer surplus to CFZ-affected cattle producers. To estimate the upper bound loss, the producer surplus accruing to Regional domestic, export and CFZ-affected cattle producers have all been doubled, although the total change in economic welfare accruing to Regional producers of domestic cattle and export cattle remains constant. The loss to producers in the Rest-of-Australia also remains unchanged at $10.95 million. However, the economic gain to the CFZ-affected cattle producers doubles ($67.30 million). Therefore, the loss to Regional producers is now estimated to be $56.43 million, while the total loss to Australian cattle producers is estimated to be $67.37 million.

Table 3.4 Estimates of changes in economic welfare for Australian cattle producers ($Am)

Change in economic welfare	Domestic cattle market	Export cattle market	CFZ cattle market	Total
Lower bound estimate				
Region				
Producer surplus	-2.05	-11.53	33.65	
Resource base	-18.68	-91.46	na	
Total	-20.73	-102.99	33.65	-90.07
Rest-of-Australia	-10.95	0.00	na	-10.95
Australia	-31.68	-102.99	33.65	-101.02
Fall in equilibrium price ($A/head)	1.22	0.00	na	na
Upper bound estimate				
Region				
Producer surplus	-4.10	-23.07	67.30	
Resource base	-16.60	-79.92	na	
Total	-20.73	-102.99	67.30	-56.43
Rest-of-Australia	-10.95	0.00	na	-10.95
Australia	-31.68	-102.99	67.30	-67.37
Fall in equilibrium price ($A/head)	1.22	0.00	na	na

na not applicable.

Sensitivity analysis can be used to determine how sensitive the results are to the base values. While, in principle, sensitivity analysis could be undertaken for every base value used in the analysis, here it is restricted to a lower supply price intercept for CFZ-affected cattle and the possibility that some CFZ affected cattle, that were abattoir tested CFZ-clean, are exported. The sensitivity of these two cases on the CFZ-induced changes in producer welfare (lower bound estimates only) are presented in Table 3.5

In calculating the base variable cost of supplying CFZ-affected cattle, it was assumed that CFZ-affected cattle were withheld from sale for an average of six months. The base variable cost for CFZ-affected cattle, therefore, includes the extra cost of feeding and maintaining these cattle for an additional six months while producers waited for the residue levels in the affected cattle to fall. However, because of the widespread drought during 1994 and 1995 in NSW and Queensland, producers who had CFZ affected cattle could have decided to sell those cattle rather than to hold on to them for the six month period. This may have then resulted in higher numbers of cattle returning positive on-plant test results and a consequent fall in the price paid for CFZ-affected cattle. If it is assumed that no voluntary withholding period for CFZ-affected cattle exists and that the proportion of CFZ-affected cattle with positive test results increases from 15 per cent to

20 per cent, resulting in a 40 per cent (rather than 35 per cent) price discount for CFZ-affected cattle, then the supply price intercept for affected cattle would be $38.39 (instead of $72.20) and the average price paid for CFZ-affected cattle would be $266.48 (instead of $304.69). In this case, the welfare losses to Regional cattle producers ($90.71 million) and to the cattle industry as a whole ($101.66 million) are marginally above the welfare losses that were calculated based on the assumption that all CFZ-affected cattle were withheld from sale for an average of six months (see Table 3.5).

Table 3.5 Sensitivity of welfare estimates to a change in the base values ($A m)

Change in economic welfare	Domestic cattle market	Export cattle market	CFZ cattle market	Total
Base values				
Region				
Producer surplus	-2.05	-11.53	33.65	
Resource base	-18.68	-91.46	na	
Total	-20.73	-102.99	33.65	-90.07
Rest-of-Australia	-10.95	0.00	na	-10.95
Australia	-31.68	-102.99	33.65	-101.02
Fall in equilibrium price ($A/head)	1.22	0.00	na	na
No withholding period				
Region				
Producer surplus	-2.05	-11.53	33.01	
Resource base	-18.68	-91.46	na	
Total	-20.73	-102.99	33.01	-90.71
Rest-of-Australia	-10.95	0.00	na	-10.95
Australia	-31.68	-102.99	33.01	-101.66
Fall in equilibrium price ($A/head)	1.22	0.00	na	na
Increase in exports				
Region				
Producer surplus	-2.05	-11.53	33.65	
Resource base	-18.68	-91.46	na	
Total	-20.73	-102.99	33.65	-90.07
Rest-of-Australia	-1.64	0.00	na	-1.64
Australia	-22.37	-102.99	33.65	-91.71
Fall in equilibrium price ($A/head)	0.18	0.00	na	na

na not applicable.

In the base model, it is assumed that no CFZ-affected cattle are sold on the export market, even though 85 per cent of samples tested at abattoirs between October 1994 and October 1996 were found to be CFZ clean. If this assumption is relaxed and it is assumed that only 15 per cent of CFZ-affected 'export' cattle are sold in Australia, then the estimated fall in the domestic cattle price is $0.18 per head and the estimated welfare loss to cattle producers outside the Region is $1.64 million, rather than $1.22 per head and $10.95 million, respectively (see Table 3.5). The estimated welfare value for Regional cattle producers is not affected by altering the assumption regarding how much beef from CFZ-affected animals (subsequently tested clean at the abattoir) can be exported.

4. Conclusions, Policy Implications and Areas for Further Research

4.1 Conclusions

In late October 1994, an unidentified chemical residue in beef, detected by analysts at the Mid Coast Meat Company during routine quality assurance testing, was confirmed as CFZ. Even though the toxicity level of CFZ is extremely low for humans, residue levels in beef were found to be significantly above the legal limits set in Australia and overseas. This caused considerable concern in the beef and livestock industries because it is illegal to process beef for human consumption with CFZ residues above the MRL, and detection of violative CFZ residues levels in Australian beef could have seriously threatened Australia's beef trade. As a result, on 25 October 1994, residue control measures were put in place by AQIS to minimise the chance of Australian beef containing residues above the foreign market tolerance levels being exported, or beef with residues above the Australian MRL being sold on the domestic market. While the CFZ incident resulted in only a minimal disruption to exports of Australian beef, because of the implementation of satisfactory testing and control practices in Australia, it still resulted in increased costs to cattle producers who had CFZ-affected cattle, as well as a reduction in the price they received for these cattle.

A major objective of this study was to develop and implement an economic model that could be used to assess the impact of the CFZ incident on the Australian beef cattle industry, with an emphasis on producer returns. The results of the analysis show that, despite the relatively small scope of the incident (in terms of the number of cattle affected and the minimal disruption to the export market), the total cost to Australian cattle producers is estimated to be around $101 million for the three years ending October 1997. Not surprisingly, producers whose cattle have been exposed to CFZ bear the brunt of this cost.

The analysis also showed that, if the assumption regarding the six month voluntary withholding period for CFZ-affected cattle was relaxed, and the CFZ-residue detection rate increased from 15 per cent to 20 per cent, the estimated cost to Regional producers would have increased marginally. Also, if it is assumed that only 15 per cent of the CFZ-affected cattle that were originally destined for the export market are sold domestically, and the other 85 per cent are sold on the export market after been tested to be CFZ-clean, then the CFZ-induced fall in the price of domestic cattle would be $0.18 per head, and the loss to cattle producers outside the Region would be $1.64 million, rather than $1.22 per head and $10.95 million, respectively.

4.2 Policy Implications

In line with the rapid expansion of chemical use in modern agricultural systems, consumers world-wide have become increasingly concerned about food safety and human health issues. In fact, food safety has emerged as a major issue in food production in Australia and overseas in recent years (RMG 1994). This has led to a number of importing countries, including Australia, increasing the scope and intensity of their residue control and detection programs to ensure all imported agricultural commodities are free from chemical contaminants. Pressure has also been placed on exporting countries to implement residue control programs.

Since the 1960s, the Australian government has sought to meet international and domestic consumer demands regarding food safety and environmental issues. However, despite the continuous development and introduction of residue control measures in Australia, a range of chemical residues have been detected in Australian meat exports since the late 1980s. These residue incidents have resulted in the Australian government implementing a number of additional initiatives directed towards ensuring a high standard of food quality and environmental safety. For example, the NRA was established in 1993 and, after a spate of residue incidents in beef during 1993, the RMG was formed in January 1994.

The threat that violative levels of chemical residues in agricultural exports pose to Australia's export trade was highlighted when Australia faced the prospect of not been allowed to export beef to the United States following a cluster of detections of organochlorine residues in Australian beef in 1987. However, while it was generally believed that a chemical residue incident in Australian meat would cause significant economic loss to the Australian meat and livestock industries, a detailed economic analysis of the cost of a residue incident had not been undertaken. This study goes at least some way to filling this information gap. The results of this analysis provide decision-makers with information against which to weigh the costs of chemical residue preventative and control measures, especially as producer levies are increasingly being used to fund these measures (B. Schick 1995, pers. comm.). For example, beef producers were levied around $900 000 to fund the organochlorine program in 1994. In addition, the AMLC, which is funded by levies from livestock producers, provided $190 000 to cover the RMG coordinator, and $205 000 to cover the auditing costs associated with the hormonal growth promotants program. The CCA has also funded an additional $150 000 for residue testing through the NRS and contributed $40 000 to a feasibility study on a preferred national database for chemical residues (RMG 1994).

While the results of this study have value in themselves, in that they show how costly even a relatively localised residue incident with minimum trade disruption can be, perhaps of greater value to decision makers has been the development of an economic model which can not only make such an assessment possible, but is generally applicable to other industries and a variety of residue (or exotic disease) scenarios. Therefore, if there was concern that the risk of, say, an endosulfan incident occurring is high, then implementation of the model using 'best-bet' estimates of key parameters would provide policy makers with information on the likely economic impact of such an incident. Sensitivity analysis could then be used to determine just how robust the results are to alternative values of the key coefficients. These results, combined with information on the likelihood of such an incident occurring, could be used by government and industry personnel to measure the benefits of implementing a residue control plan designed to minimise the chances of an endosulfan incident occurring.

In addition, because this model can be solved using a computer spreadsheet, once the preferred base values for a particular residue incident scenario have been determined, it is a reasonably simple matter for policy makers to answer a number of policy related questions. For example, by altering the proportion of residue-affected product that can be sold on the export market, this model can be used to show the effect that differing residue limits between the domestic and international markets have on producer incomes. Also, by altering variables relating to the marginal cost of supplying residue-affected animal, the model could also be used to determine whether or not a producer would be better off withholding residue-affected animals for sale.

In sum, the increased consumer concern over some of the negative impacts of agricultural and veterinary chemical use, the significant technical advances made in residue detection equipment, and the strong stance being taken by importing countries with regard to chemical residues in agricultural products, has all placed pressure on the Australian governments and agricultural industries to improve their residue control and response capabilities. Information on the economic impact of residue incidents is an important factor with which to weigh the cost of any improvements. Clearly, the multi-product, multi-regional model developed in this study is a useful research tool that is suited to policy analysis.

4.3 Areas for Further Research

In this paper, attention has not been given to the vertical distribution of the welfare effects of a residue incident. This would be an obvious extension to the present analysis, as it would enable the economic impact on other key players in agricultural industries, such as meat processors in the CFZ incident, to be assessed.

The CFZ-impact model was developed within a partial-equilibrium framework. In this case, welfare measures taken off the *ceteris paribus* demand-and-supply curves for each of the cattle types are correct because the CFZ incident did not impact on the price of related commodities through substitution in either supply or demand. There could be, however, situations where a chemical residue incident affecting one commodity, say wheat, has a significant impact on the price of a related commodity, say barley. This may be complicated further if there is feedback from the barley market into supply in the wheat market. If general equilibrium issues are likely to be important in the area of chemical residues, it could be beneficial to develop a 'residue-impact' model within a general-equilibrium framework.

Another avenue for research might be the development of a fully-documented spreadsheet which could be used to solve the model developed in this study. The development of a 'user-friendly' spreadsheet model would enable Government and industry personnel to use the spreadsheet with confidence. They would then be able to produce a range of outcomes corresponding to a range of values for key parameters, as the need arises.

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