The Costs and Benefits of Introducing Mandatory Hygiene Regulations[1]

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By K Cao and R Johnson[2]

In an idealised model the costs of capital and maintenance and the resulting flow of income benefits over a period of years enables the analyst to produce computations of present values and internal rates of return that summarise the whole investment process in a micro environment. In approaching an industry investment problem like mandatory hygiene regulations with benefits or costs to other entities involved, identifying the appropriate capital and maintenance costs and the industry and non-industry benefits is a giant task. In this paper, we report an attempt to identify the extra costs involved in the introduction of the regulations where industry recorded data is not available, and an attempt to identify industry and non-industry benefits from modelling market effects when countries impose restrictions on exports of NZ meat products. For the latter we employ the GTAP model and examine the saved costs to NZ when countries do not impose import restrictions on hygiene grounds. The problem involves consideration of private and public costs and benefits and the flow of costs and benefits when inadequate data is only available. Although our results are confined to average responses to the hygiene programme, they do give an indication of the overall necessity for embarking on such programmes in today's trading conditions.

Key words: HACCP/RMP, Benefit Cost Analysis, Meat, New Zealand

Introduction

Benefit-cost analysis has a charming simplicity when it comes to analysing complicated problems like forward investment programmes. The net present value (NPV) and the internal rate of return (IRR) summarise in a couple of simple statistics a complicated set of data collecting problems regarding the present status of an industry/economy and the future implications of proposed investment. It is the measurement problem that this paper addresses.

The requirements of overseas governments with respect to food safety resulted in an enhanced programme of meat hygiene regulations for the meat processing industry in the 1990s. In this period a number of countries agreed to institute a programme of meat inspection and product certification based on microbiological testing of meat

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[1] Paper prepared for the 2006 Conference of the New Zealand Agricultural and Resource Economics Society.

[2] Policy Analyst, Ministry of Agriculture and Forestry (kay.cao@maf.govt.nz) and Private Consultant (johnsonr1@paradise.net.nz), respectively. We would like to thank Anna Strutt for her expert advice with the GTAP simulation and Frank Scrimgeour and Chris Dake for their overall guidance. The views, findings, and conclusions are of the authors only and do not necessarily represent MAF's view on the subject.

products known as the Hazard Analysis Critical Control Point (HACCP). Failure to meet the import requirements of destination countries meant that New Zealand meat products could be banned or suspended from major markets for a considerable period of time. The programme involved considerable private enterprise investment in facilities and training to meet the new international requirements by 1999. It should be noted that international regulations for meat products have a long history and that this particular programme was an up-grading of standards from previously accepted levels.

The Animal Products Act 1999 marked the reform of the New Zealand law that regulates the production and processing of animal material and animal products. At the centre of this reform was the requirement for Risk Management Programs (RMP) which are based on the principles of HACCP. The meat industry is one of the first industries required to implement HACCP/RMP. Also, being a significant export-oriented industry, the meat industry provides an ideal case for the purpose of this study.

To estimate the cost of HACCP/RMP, a straight forward approach would be to survey the relevant companies for a breakdown of their capital and maintenance costs. Cao (2006) conducted a survey of meat plants regarding their HACCP/RMP implementation and showed that meat companies do not have details on the breakdown of costs related to HACCPRMP. In this paper we report the use of a quality-adjusted cost function to estimate changes in meat plant's variable cost of production due to HACCP/RMP compliance. For the saved costs (or benefits) of the programme, a GTAP model was used to estimate the losses in trade across the industry if a succession of countries closed their doors to NZ meat products due to HACCP/RMP non-compliance.

In the paper, we set out an idealised model of the benefit-cost framework of analysis and then proceed to the presentation of some estimates of the respective costs for entrepreneurs in the processing and meat export industry. This is followed by an analysis of the saved costs if markets are not lost from hygiene restrictions on some countries' imports. We briefly discuss how a social cost-benefit analysis might proceed from such a private cost viewpoint.

A Generalised Cost-Benefit Framework

In an ideal world of measurement it would be best practice if it were possible to obtain a clear time path of capital and maintenance costs associated with a new innovation or practice in an industry or company. This would enable initial capital costs to be placed in their correct time sequence and subsequent maintenance costs placed in some future time sequence. The advantage of this arrangement is that the analyst can proceed to a discounted cash flow analysis.

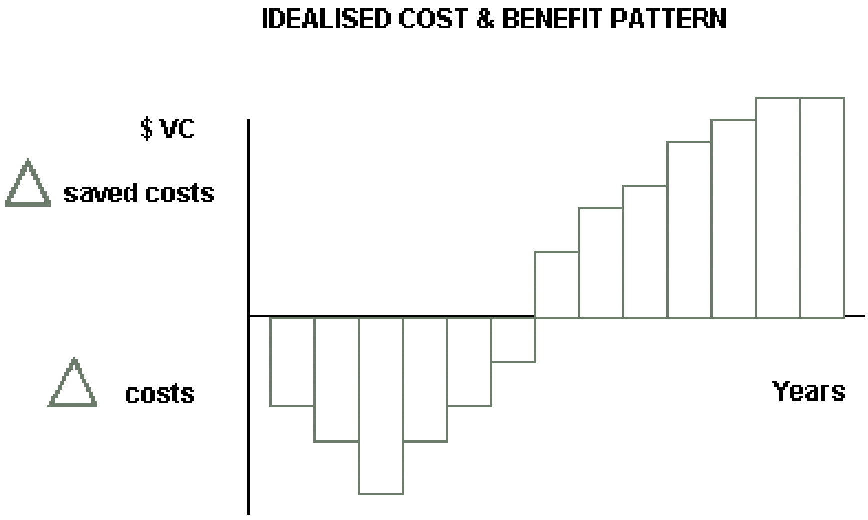
Likewise, a clear time path of the saved costs or benefits from the time of the investment to some future date allows the analyst to proceed.

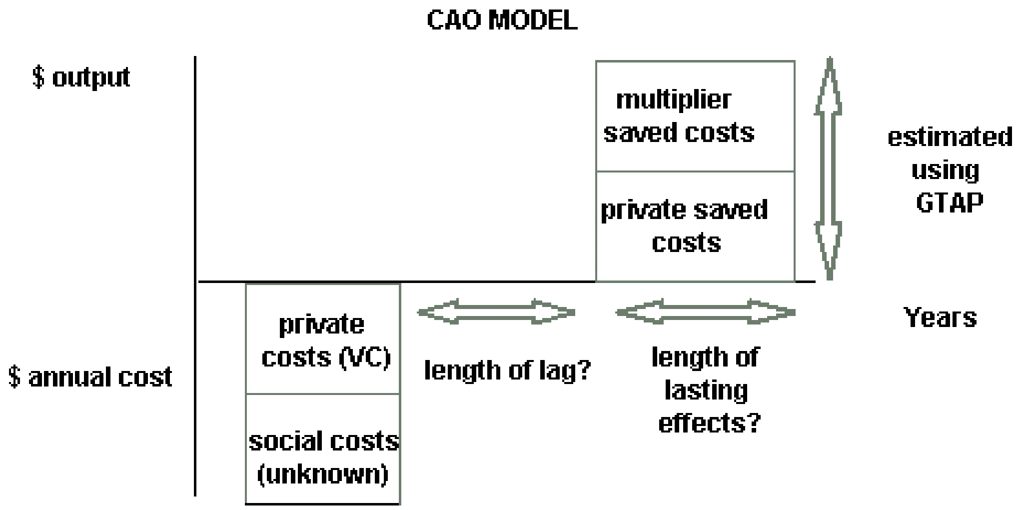
For an industry study in a profit framework, the discounted cash flow analysis provides the best estimate of the *private* rate of return.

In the case of a government investment, it is desirable to understand the broader social costs and benefits of an investment. A social cost-benefit analysis might include both a private rate of return and a social rate of return. The combined NPV and IRR will be a measure of the social rate of return.

The following diagrams illustrate the general (ideal) cost-benefit case and the case of HACCP/RMP cost-benefit analysis.

Figure 1





In the following sections, we first present the private costs and benefits, ie costs and benefits to the meat industry due to HACCP/RMP implementation. We then consider the social net benefit of the programme by examining government costs (ie HACCP/RMP administration costs) and the wider benefits to society including preventing a trade loss for quality reasons and reduction in foodborne illnesses. In the latter case we recognise that hygiene matters are dealt with on a government-to-government basis and that government has social costs of its own in implementing such a programme. In the case of wider trade benefits, the GTAP type of model estimates the multiplier effects of a given trade change on other industries beside the meat processing and export industry.

Private Costs of Implementing the HACCP Programme

In estimating private costs we use an indirect method of estimating the cost of the HACCP/RMP programme to the exporting and processing firms. We hypothesise that product safety, if quantifiable, would be characterised by a higher ratio of skilled labour to unskilled labour, a greater capital stock, higher prices of output, lower prices of labour and materials and the influence of demand factors. These attributes can be isolated from time series of factory production records. We then develop a regression model which estimates a proxy variable for product safety in historical terms (see Appendix 1).

In a second step, the cost of food safety regulation to an average firm is defined as the change in existing variable costs due to the imposed regulations. We have an estimate of industry variable costs from the factory production series from 1929-1984. The safety proxy variable is utilised to estimate an elasticity of variable cost with respect to safety from the time series data which is then utilised to estimate the change in industry average variable cost due to process changes. We make an adjustment to the estimate of the elasticity for possible efficiency changes since the cost survey finished in 1984. Different scenarios can be calculated by taking various levels of an effectiveness variable (ie reduced pathogen loads) and various levels of improvements in a food safety index (ie a percentage increase in satisfactory tests for pathogens) (Appendix 2).

To summarise, a quality-adjusted translog cost function is used to estimate changes in variable cost of production due to the implementation of HACCP/RMP. Data from the New Zealand Census of Manufacturing for the period 1929-1984 was employed to derive the cost function. Then the adjustment for technical progress was used to estimate the safety cost elasticities. HACCP/RMP implementation cost was estimated for three different scenarios based on the current safety practices at the average processing plant (Table 1).

Table 1. Increases In Industry Variable Cost And Unit Cost Due To Implementation Of HACCP Programme (Assuming 20 Per Cent Effectiveness)

(1999 NZ dollars)

Scenario[2]	Safety Elasticity = 1.04	Adjusted Elasticity[1] = 0.75
Base safety S = 50%		
Increase in cost (ΔVC)	427,383,000	306,399,000
Unit cost (u) ($/kg)	0.67	0.48
Base safety S = 70%		
Increase in cost (ΔVC)	183,164,000	131,341,000
Unit cost (u) ($/kg)	0.29	0.20
Base safety S = 90%		
Increase in cost (ΔVC)	47,487,000	34,044,000
Unit cost (u) ($/kg)	0.074	0.053

Notes:

1. In the time series analysis, the estimated elasticity of variable cost wrt `food safety' was 1.04; the trend in the cost function with respect to time was -0.02: thus by 2002, the elasticity could have declined to a value of 0.75.

2. Base safety S refers to the percentage of negative outcomes when product is tested for microbial contamination .There are 3 different percentages proposed (S=50%, 70%, and 90%) with the higher percentage means better level of food safety.

Survey results of the processing industry by one of the authors (Cao 2006) provide a *qualitative* assessment of the costs involved with HACCP/RMP implementation. The current literature suggests that food safety regulation such as HACCP/RMP has the potential to affect the operating efficiency of plants (Antle 2000) and hence results in productivity losses and increasing operating costs. Our interviews with plants' representatives reveal that HACCP/RMP has actually reduced the speed of the production lines. This implies that there are additional variable costs incurred such as increasing labour costs and increasing use of other material inputs. These costs are usually difficult to obtain in research using an accounting approach.

In the table, unit cost estimates range from 7 to 67 cents per kilogram without technical progress adjustment. This is equivalent to a range from $NZ47 million to $NZ427 million (1999 prices)[3] in total variable cost of production depending on the previous level of `safety'. With the efficiency adjustment, unit cost ranges from 5 to 48 cents/kg (or an increase in total variable cost of $NZ34 to $NZ306 million)[4]. These increases in cost represent the impact of HACCP/RMP implementation on the operating efficiency of firms. In other words, *this cost is associated with the slowdown of the production line due to monitoring, sampling and testing*. Using cost figures collected from the above survey, HACCP/RMP implementation (fixed) cost could be up to around $NZ100,000 for each plant. For the whole industry, the figure could be up to $NZ9 million (with a total of 90 plants nation-wide). It shows that

[3] $NZ52 to $NZ471 million in 2002 prices, using NZ 2002 CPI = 1103 (base period 1999 = 1000)
[4] $NZ37 to $NZ337 million in 2002 prices.

changes in variable cost due to HACCP/RMP implementation can make up a significant proportion of the total implementation cost.

This estimate of HACCP/RMP cost is based on published production cost data for the period 1929-1984 in 1999 prices. Although an efficiency adjustment has been made so that the estimate can be representative of the subsequent period, the differences in production cost structure of the post-1984 period may affect the estimation results. Overcoming this data limitation is a difficult task as the succeeding data series (Annual Enterprise Survey) – started in 1993 – does not provide detailed data as in the previous series (Statistics NZ, 2004). An alternative method would be to gather plant-level production data. However, this is a task beyond the present resources of the authors.

Private Benefits of Implementing the HACCP Programme

HACCP/RMP can bring gains in market access by (1) satisfying market requirements and (2) *minimising the occurrence of food safety hazards or outbreaks that may have adverse effects on market access*. Failure costs are costs related to the defects detected in the plant (internal failure), or after the product is delivered (external failure). Product wastages are internal failure costs. The costs of losing market due to bad quality or food safety outbreaks are external failure costs. In the case of HACCP/RMP, we could expect the avoidance of failure costs once firms invested in HACCP/RMP and exports were acceptable to overseas customers.

The purpose of this section is to quantify the cost of losing market access to the New Zealand meat industry and further, the whole economy. This cost estimate can be considered as a potential benefit of food safety practises that maintain and enhance market access such as HACCP/RMP. The analysis will focus on the significant export markets of the meat industry including North America, the European Union, and Asia (Appendix 3).

To estimate the economy-wide effects of a loss in the New Zealand (NZ) meat export markets, the Global Trade Analysis Project (GTAP) model is employed. The use of the GTAP model offers some advantages, including: (1) The model and database are publicly available and ready to use; (2) The application fits neatly with our specific case as the beef and sheep meat sector is a separate sector in the database and NZ is one among several countries included in the model; (3) The simulation results will not only provide indications for the NZ meat sector and the NZ economy but also reveal the associated impacts on the international meat markets. The model, however, cannot provide a more focused approach than those provided by a single-country or single market model.

The GTAP was established in 1992. It provides a global database and a standard modelling framework, both publicly available. The GTAP model is a multi-region and multi-sector CGE model. It has been widely used for analysing the economy-wide effects of policy changes, especially on a global scale such as trade liberalisation or international environmental agreements (Hertel 1997).

The GTAP model assumes a perfectly competitive market. Prices and quantities of produced commodities are endogenously determined by households and firms optimising, subject to the resource limitations of the economy. On the supply side, it is assumed that producers choose inputs that minimise production costs subject to separable, constant returns to scale technologies. The assumption of separability in production means that there is no substitution between different intermediate inputs or between them and a composite primary factor. A constant elasticity of substitution (CES) function is assumed for the substitution possibilities between primary factors (natural resources, labour, capital). On the demand side, the non-homothetic preferences of private demands are captured through the use of a constant difference of elasticities (CDE) function. The GTAP model also assumes an Armington structure for imports. This means imported commodities are distinguished by origin and aggregated at the border, where the composite import is distinguished from the domestically produced commodities. The CES assumption is used for the substitution possibilities between imported products and between the composite import and domestic products. Hertel and Tsigas (1997) provide a detailed presentation of the structure of the GTAP model and the associated behavioural equations.

Data: The GTAP version 5 database is used. It includes 66 regions and 57 commodities. To provide a focused analysis regarding the NZ meat industry and the international meat market, regions are aggregated to show the significant players in the international meat markets and the important export markets of NZ meat. Sectors are aggregated to show the significant exporting sectors of the NZ economy and the sectors that have strong linkages with the meat industry.

For this study, *regions* in the GTAP 5 database are grouped into: (1) Australia, (2) New Zealand, (3) South & East Asia (Region no. 3-17), (4) EU-15 (Region no. 31-45), (5) The USA, (6) Other countries in North America (Canada, Mexico), (7) Latin America (Region no. 22-30), (8) Turkey and Middle East (Region no. 52-53), and (9) Rest of the World.

Sectors in the GTAP 5 database are grouped into: (1) Processing Red Meats (Sector no. 19), (2) Live Cattle (Sector no. 9), (3) Other Meat & Animal Products (Sector no. 10,12, & 20), (4) Dairy (Sector no. 11 & 22), (5) Fruit & Vegetable (Sector no. 4), (6) Forestry (Sector no. 13), (7) Fishing (Sector no. 14), (8) Other Agricultural sectors, (9) Manufacturing sectors, and (10) Services sectors

To estimate the cost of losing market access due to HACCP non-compliance, we assume 6 scenarios as follows:

1. a loss of 100% annual export volume of processed red meat access to the US market. This is the most likely scenario as the US is the first country that requires exporting countries to meet with its HACCP standards.

2. a loss of 100% processed red meat access to the North American market (i.e. USA, Canada, and Mexico), assuming that other countries in North America (Canada and Mexico) adopt a similar policy as the US.

3. 100% market access loss to the EU-15 market.

4. 100% market access loss to the South and East Asia market.

5. 100% market access loss to the Turkey and Middle East market.

6. Loss of all of the above significant markets, assuming all significant markets adopt the importing policy regarding HACCP implementation.

The first scenario provides the cost estimate of the *most likely* scenario while the last scenario provides the *upper bound* of the saved cost. The results also provide estimates on the 'size' of each significant market of NZ meats. It further signals the importance of maintaining access to these markets.

Results of the GTAP simulations are presented in Appendix 3. For the purpose of our benefit cost analysis, two types of impacts are important. The first is the change in export revenue due to the market loss shock, as this indicates the cost of losing market access or in other words, the *private* benefit of having HACCP/RMP. The second is the change in welfare (or equivalent variation) due to the shock, or in other words the *saved social cost* as a result of having HACCP/RMP.

Table 2 below shows the changes in total export values of all industries. There are *revenue losses* to the processed meat industry in all cases, with the smallest loss of $US68 million ($NZ 152 million) in the case of the Turkey & Middle East market, and the biggest loss in the case of losing all significant markets ($US1.7 billion or $NZ3.7 billion). Other industries however experience increases in their export volumes (though at smaller prices) due to the shifting of resources from the meat sector. The most likely scenario results in a loss of $US375 million or $NZ840 million. This is the cost to the NZ processed meat industry due to non-compliance with the USA HACCP standards, or in other words, the potential benefit of the implementation of HACCP/RMP. Compared with the estimated cost of HACCP/RMP implementation (previous section), which ranges from $NZ52 to $NZ471 million, the potential private benefits far outweighs the private costs.

Table 2. Impacts On Export Values Of Meat And Other Industries

'95 US million (% changes in brackets)

Changes in export Values (qxw)	(1) USA	(2) NA	(3) EU	(4) SEA	(5) TME	(6) ALL
Meat (PRM)	-374.88 (-20.43)	-476.47 (-25.96)	-685.90 (-37.37)	-338.09 (-18.42)	-67.83 (-3.70)	-1666.20 (-90.79)
Live Cattle (CTL)	2.03 (3.02)	2.53 (3.77)	3.22 (4.79)	1.87 (2.78)	0.34 (0.50)	8.53 (12.70)
Other Meats & Animal Products (OMA)	21.59 (2.92)	27.41 (3.71)	39.38 (5.33)	19.45 (2.63)	3.86 (0.52)	96.80 (13.11)
Dairy (DAI)	52.73 (2.07)	67.01 (2.63)	96.73 (3.79)	47.61 (1.87)	9.56 (0.37)	233.50 (9.16)
Fruit & Vegetable (FRV)	9.73 (1.99)	12.36 (2.53)	17.70 (3.62)	8.77 (1.79)	1.76 (0.36)	42.79 (8.75)
Fish (FSH)	0.65 (0.52)	0.83 (0.66)	1.20 (0.95)	0.59 (0.47)	0.12 (0.10)	2.79 (2.22)
Forestry (FOR)	2.83 (0.58)	3.56 (0.73)	5.05 (1.03)	2.54 (0.52)	0.53 (0.11)	11.13 (2.27)
Other Agricultural Sectors (OAG)	23.58 (2.16)	29.96 (2.75)	43.00 (3.95)	21.31 (1.95)	4.25 (0.39)	104.66 (9.60)
Manufacturing (MNF)	150.25 (2.52)	191.16 (3.20)	275.88 (4.62)	135.41 (2.27)	27.18 (0.46)	672.95 (11.28)
Services (SVS)	75.57 (1.92)	96.10 (2.45)	138.94 (3.54)	68.05 (1.73)	13.70 (0.35)	336.57 (8.57)

Table 3 reports the macroeconomic impacts on NZ of all six scenarios. For the most likely scenario (non-compliance with the USA's HACCP standards), there is a welfare loss of about US$90 million (1995 prices) (this is equivalent to NZ$200 million in 2002 dollars[5]). Losing market access to Turkey and Middle East results in smallest loss (US$16 million or NZ$36 million). The loss of all significant markets accounts for $US380 million or $NZ850 million reduction in NZ welfare. These losses in welfare are the costs of losing NZ processed meat markets to the whole NZ economy, in other words they indicate the potential social benefits of HACCP/RMP from the 'saving market access' point of view. These figures also suggest that the EU15 is the most significant market, followed by North America, South & East Asia, and Turkey and Middle East.

The GTAP simulation results also show that losing the US meat markets reduces 0.6% of GDP. Losing all significant markets results in 2.5% reduction in GDP. The biggest contribution in welfare loss is the terms of trade deterioration. This is a result of decreases in NZ meat export prices (Table A3.1, appendix). Appendix 3 also reports other results of changes in industry output and impacts on the international meat markets.

Table 3. Macroeconomic Impacts

		(1) USA	(2) NA	(3) EU	(4) SEA	(5) TME	(6) ALL
Equivalent Variation EV (NZ)	(US$m) ('95 pr)	-89.93	-113.84	-162.50	-81.20	-16.46	-380.66
Changes in per capita utility u (NZ)	(%)	-0.15	-0.20	-0.28	-0.14	-0.03	-0.65
Changes in value of GDP vgdp (NZ)	(%)	-0.60	-0.76	-1.09	-0.54	-0.11	-2.55
Changes in welfare due to Terms of Trade effect TOT (NZ)	(US$m) ('95 pr)	-87.35	-110.60	-157.83	-78.87	-15.97	-371.17
Changes in factor prices	(%)						
Land		-1.74	-2.20	-3.15	-1.57	-0.32	-7.10
UnSkLab		-0.69	-0.88	-1.26	-0.63	-0.13	-2.96
SkLab		-0.61	-0.77	-1.11	-0.55	-0.11	-2.60
Capital		-0.55	-0.70	-1.00	-0.50	-0.10	-2.35

Summary

In this section, the GTAP model is used to estimate the costs of losing the most significant markets of New Zealand processed meat products. As HACCP/RMP implementation satisfies market requirements and also minimises the occurrence of food safety hazards or outbreak that can have adverse effects on market access, the estimated saved costs show the potential benefits of this programme. The potential private benefits were estimated to be $NZ840 million in the most likely scenario (loss of the USA market). It rises up to $NZ3.7 billion for the case of all significant

[5] This is calculated with USA's 2002 GDP deflator (112, base year 1995 = 100) and average 2002 NZ/USA exchange rate of 0.5

markets. Compared with the estimated cost of HACCP/RMP implementation (previous section), which ranges from $NZ37 to $NZ337 million, these benefits far outweigh the cost. It shows that HACCP/RMP implementation can deliver net benefits to the New Zealand meat industry.

Social Net Benefit of the HACCP/RMP programme

As earlier discussion demonstrated**,** there are wider implications of the HACCP/RMP regulations to society. On the cost side there are the administrative costs of the whole initiative. The NZ Food Safety Authority (NZFSA) is the conduit through which international agreements were reached; it is also the administrative body responsible for putting the initiatives of the 1999 Animal Products Act into effect. On the benefits side, there are the economy-wide implications of the loss of the meat trade on other sectors of the economy, and also the saved cost of illness prevention. We therefore need to take the results of the GTAP model (Table 3) for each scenario to estimate the economy–wide saved costs of the regulatory programme as well as any estimates of the costs of foodborne illnesses. These costs and benefits can then be combined with the private costs and benefits to reach a nation-wide assessment of the programme.

In the past there used to be a large number of government staff involved in administering, monitoring, and auditing food safety standards. For example, Robinson (2006, p 182) showed that in 1994 MAFQual employed some 890 meat service staff at a cost of $48.6m, while MAFRA (M&S) had 29 staff and cost $49m per annum. This suggests a rounded cost of $100m a year in 1994 dollars ($120m in 2002 dollars). However, with the recent approach on cost recovery and the shift of more food safety management responsibilities to industry, government costs have been reduced. For HACCP/RMP plan verification and auditing, processing plants now have to hire verifiers/auditors who have been approved by the NZFSA. Table A4 (appendix) shows the various duties of the processing plants and the NZFSA regarding HACCP/RMP implementation. It shows that for HACCP/RMP the government administration costs have been reduced to the minimal, mostly just involved in the standard setting and enforcement stages. Due to data unavailability, we tentatively use 50% of the previous costs (as suggested in Robinson, 2006) as government administration costs.

In New Zealand it has been estimated that there are 119,320 cases (3% of the population) of food-borne illnesses each year (NZFSA, 2002). The estimated total cost of these cases was $55.1 million ($462 per case) made up of direct medical costs of $2.1 million, direct non-medical costs of $0.2 million, indirect cost of lost productivity of $48.1 million, and intangible cost of loss of life of $4.7 million (Scott et al, 2000).

Bringing this information together, Table 4 shows our estimates of the net return to the nation of the HACCP/RMP. Industry costs are lowest when the safety base level is already high. They are highest when food safety starts from a low level. Administrative costs are necessary whatever the level of safety. Trade impacts (measured by trade reductions in income) are lowest when only the US closes its market; highest when all export destinations follow suit. The economy trade impacts are relatively higher when only the US market closes but absolutely higher when all markets close. These are the net gain to NZ that compensates for the loss of the meat trade. Saved cost of NZ illness is considered to be a side benefit of the whole programme when instigated successfully.

Table 4: Economy-Wide Costs and Benefits - $NZm ($'02)

	LOW	MED	HIGH
Costs:			
Operating Costs	**37**	**187**	**337**
Implementation Costs	**9**	**9**	**9**
Administrative Costs	**60**	**60**	**60**
Total	**106**	**256**	**406**
Saved Costs:			
Economy Trade Impacts	**200**	**525**	**850**
Illness Effects Avoided	**55**	**55**	**55**
Total	**255**	**580**	**905**
Net benefit $NZm	**149**	**324**	**499**

Note: The Medium scenario is the mean of the Low and High scenarios. Operating costs are estimated by the cost model. Implementation costs are gathered from the meat plant survey. Economy-wide impacts equal to welfare impacts estimated by GTAP (EVresults, Table 3).

Bringing the wider costs and benefits together shows that the RMP is quite justifiable in national terms. However note that this is only a very simple picture of the social net benefit. For an ideal benefit cost analysis (as illustrated in figure 1), we need all costs and benefits involved in a time frame. This is not feasible at the time of writing this paper; however it opens the opportunities for future study once more data become available.

Conclusion

This paper is an attempt to isolate the impacts of enhanced hygiene regulations of NZ exports of meat. The costs are represented by implementations costs by exporters and the benefits are represented by the saved costs if meat market loss is avoided. On the private net benefits, there is a clear margin between the costs to exporters and the saved costs of their meat exports. Otherwise they would go out of business. On the public net benefits, over the longer run, there is not a clear margin of benefits over costs. This is because, given time for adjustment to take place, the loss of meat markets is compensated by the growth in other primary exports.

The analysis is restricted by the lack of comparable data from the meat industry itself and information on the spread of capital and maintenance costs over the relevant time periods. Equally the GTAP analysis only provides estimates of saved costs at one period of time, i.e. after full adjustments of the economy have had time to take place. In the short run, the loss of meat markets due to poor performance in hygienic preparation of meat products would have considerable dislocation in the both the primary industries such as farming but also in the processing industry as well.

APPENDIX

Appendix 1. Theoretical Framework for Cost Function

Antle (1999) showed that production cost can be divided into three components: (1) a variable cost component which depends on both output and product quality, (2) a separate variable cost component which depends on quality but is independent of output, and (3) a fixed cost component. Hence, if we characterised the quality-differentiated product by the triplet (y,s,**q**), where y is output quantity, s is product safety, and **q** is a vector of other non-safety quality attributes, then the cost function for a production process with quality control can be specified as:

$$C(y,s,\mathbf{q},w,k) = vc(y,s,\mathbf{q},\mathbf{w},k) + qc(s,\mathbf{q},\mathbf{w},k) + fc(k) \qquad (1)$$

where

w is a vector of input prices
k is the value of capital stock
vc(.) is the variable cost component that depends on both product quantity y and product quality s, q
qc(.) is the other variable cost component that is independent of y but depends on s and q
fc(k) is the conventional fixed cost component

The accounting method normally just accounts for the impacts of regulation on the cost components qc(.) and fc(.). Therefore, it is the purpose of this paper to measure the impacts on vc(.) or the productive efficiency impacts of food safety regulation.

The classical cost function usually does not account for product quality. The reason is that quality is normally treated as fixed in the short run. Additionally, many quality attributes are not readily observed and measured.. Antle (2000), following Gertler and Waldman (1992), developed a model with an *unobserved scalar safety variable* whose parameters can be estimated using other observable variables.

To derive a measure for that unobserved safety variable, Antle (2000) utilized a model of a market in which price-taking firms produce a quality-differentiated product. While this assumption requires careful consideration in a highly concentrated market, it seems to be a reasonable assumption for the New Zealand meat experience, where exporting firms are price-takers in international markets.

Let product demand be described as $Y^D = D(P,S,\mathbf{Q},\mathbf{Z})$, where P is output price, S is product safety, **Q** is a vector of other quality attributes, and **Z** is a vector of other demand variables. Y^D is increasing in desirable quality attributes, for example, derivative with respect to S, $D_S > 0$. Market supply is given by $Y^M = M(P,S,\mathbf{Q},\mathbf{W},K)$ where W is a vector of input prices and K is the industry capital stock. Y^M is decreasing in quality attributes, for example, $M_S < 0$. As S is not observed, equating Y^D and Y^M to solve for S, we have:

$$S = F(\mathbf{Q},P,\mathbf{Z},\mathbf{W},K) \qquad (2)$$

which has the following properties:

• F(.) is increasing in price: $F_P > 0$

- Derivative with respect to elements of Q: $F_Q < 0$ for a given product price
- Derivatives with respect to elements of Z are opposite in sign from the derivatives of the demand function, and
- Derivatives with respect to W and K have the same sign as the derivatives of the supply function with respect to these variables.

Quality-Adjusted Translog Cost Functions: Recall that the theoretical variable cost component, which depends on both product quality (s, q) and quantity y, is defined as vc(y,s,q,w,k). Here, q is a vector of other non-safety quality attributes. Following Antle (2000), we use management intensity (q_{man}), which is defined as the ratio of non-production labour to production labour, as a non-safety quality variable. The other quality variable (q_{mix}), which measures the proportion of processed product in total output, as used by Antle (2000), is not considered in this study due to data unavailability. This can also be explained by the fact that most meat processing businesses in New Zealand during the period studied specialized in either slaughtering or packaging. Hence, defining the input variable as consisting of labour (L) and other materials (M), the empirical variable cost function is specified as:

$$\begin{aligned}\ln VC = &\alpha_0 + \alpha_M \ln w_M + \frac{1}{2}\alpha_{MM}(\ln w_M)^2 + \alpha_L \ln w_L + \frac{1}{2}\alpha_{LL}(\ln w_L)^2 + \beta_y \ln y + \frac{1}{2}\beta_{yy}(\ln y)^2 \\ &+ \delta_k \ln k + \frac{1}{2}\delta_{kk}(\ln k)^2 + \alpha_{ML}\ln w_M \ln w_L + \beta_{yM}\ln y \ln w_M + \beta_{yL}\ln y \ln w_L + \beta_{yk}\ln y \ln k + \\ &+ \delta_{kM}\ln k \ln w_M + \delta_{kL}\ln k \ln w_L + \gamma_s \ln s + \gamma_{sM}\ln s \ln w_M + \gamma_{sL}\ln s \ln w_L + \gamma_{sy}\ln s \ln y + \\ &+ \gamma_{sk}\ln s \ln k + \theta_{man}\ln q_{man} + \beta_{Mt}\ln w_M t + \beta_{Lt}\ln w_L t + \beta_{yt}(\ln y)t + \beta_{kt}(\ln k)t + \beta_{st}(\ln s)t + \\ &+ \beta_{mant}(\ln q_{man})t + \beta_t t + \beta_{tt}t^2\end{aligned} \tag{3}$$

where

k is the value of capital stock at the beginning of the year,

t is a time variable which captures change in technology over time.

Following Antle (2000), the second-order term of safety $(\ln s)^2$ and the second-order terms of other quality variables are omitted in order to reduce the number of parameters and the potential collinearity caused by the large number of variable interactions in the unrestricted model.

Applying Shephard's lemma, the first-order condition for labour input is:

$$C_L = \alpha_L + \alpha_{LL}\ln w_L + \alpha_{ML}\ln w_M + \beta_{yL}\ln y + \delta_{kL}\ln k + \gamma_{sL}\ln s + \beta_{Lt}t \tag{4}$$

where C_L is the labour cost share

The conditions for linear homogeneity of the cost function are $\alpha_M + \alpha_L = 1$, $\beta_{yM} + \beta_{yL} = 0$, $\gamma_{sM} + \gamma_{sL} = 0$, $\delta_{kM} + \delta_{kL} = 0$, $\beta_{Mt} + \beta_{Lt} = 0$, $\alpha_{MM} = \alpha_{LL} = -\alpha_{LM} = -\alpha_{ML}$. (5)

The theoretical safety function (2) is written in log-linear form is:

$$\ln s = \tau_0 + \tau_{man} \ln q_{man} + \tau_p \ln p + \tau_Z \ln z + \tau_M \ln w_M + \tau_L \ln w_L + \tau_k \ln k \quad (6)$$

where

- q_{man} is management intensity, which is the ratio of non-production labour to production labour,
- p is output price,
- k is capital stock at the beginning of the year
- w_M, w_L are prices of materials and labour respectively, and
- z is a demand variable; here we use per capita income as Antle's study shows that other demographic variables are highly correlated with income, and that estimation using per capita income produces the lowest estimate of costs.

Following Antle (2000), we use two restrictions with the quality equation. First, $\tau_0 = 0$ as the intercept in this case cannot be identified. Second, $\tau_p = 1$ as derivative with respect to p is positive and the units of safety cannot be defined.

Data: Production data for the New Zealand red meat industry taken from the census of manufacturing data for the period 1929-1984 is used for estimation. CPI deflators are taken from the New Zealand Official Yearbook 2000, and New Zealand per capita income for the period is taken from Maddison (1995). A statistical summary of the variables is presented in Table A1.

The limitation of the data set is that it is limited to the period 1929-1984. Contacts with Statistics New Zealand revealed that there was no production data published for the period between 1984 and 1993. Data from 1993 onwards however is not as detailed as in the previous publication and hence cannot be used for this estimation. Due to data limitation, estimates using data up to 1984 are adjusted to get estimates of HACCP/RMP implementation impacts on variable costs.

Table A1. Statistical Summary of Variables (Prices in 1999 Dollars)

Variable	Unit	Obs.	Mean	Standard Deviation	Minimum	Maximum
w_M	*PPI* (base 1982=1000)*	52	229.92	225.00	67.00	1317.00
w_L	$ (000)	52	19.45	11.01	7.67	40.01
Y	Tonnes(000)	52	637.32	331.46	191.25	1234.30
K	$ (000)	52	622,260	676,760	150,190	2,604,800
q_{man}	-	52	0.14	0.018	0.07	0.18
P	$ per tonne	52	3123.70	1057.60	1846.30	6311.40
Z	1990internl $	52	8804.40	2702.90	4349.00	13891.00
VC	$ (000)	52	2,051,600	1,556,100	412,380	6,436,300
C_L	-	52	0.17	0.095	0.09	0.50

* Producer Price Index

Appendix 2: Estimation of Variable Cost of production

To estimate the system of cost and cost share function, equation (6) is substituted into (3) and (4). Then the system is estimated with the linear homogeneity restrictions imposed (group of equations (5)), using the nonlinear seemingly unrelated regression routine in Shazam. Results are presented in Table 3.

To confirm that food safety regulation does affect productive efficiency in the red meat industry, a test for the hypothesis of safety exogeneity is conducted. For the cost function (3), safety exogeneity holds if and only if γ_S and γ_{Si} (i = y, M, L, k, t) are all equal to zero. Our test results strongly reject this hypothesis (p = 0).

The interaction term of safety and labour price γ_{sL} is negative which means that a higher labour price lowers the marginal cost of safety. On the contrary, as γ_{sM} has an opposite sign from γ_{sL}, a higher material price leads to higher marginal cost of safety. These results are similar to those presented by Antle (2000) for the US meat industry. The interaction term of safety and capital γ_{sk} is positive which means that increasing capital stock leads to increasing marginal cost of safety. Also, γ_{sy} being positive means higher rates of production are associated with higher marginal cost of safety.

The interaction term of time and material β_{Mt} is negative which shows that technical change is material saving. On the contrary, β_{Lt} is positive which implies that technical change is labour using. Moreover, β_{st} is negative, indicating that the marginal cost of safety decreases as technology progresses.

Estimation of the Effect on Variable Cost of Production: To estimate impacts of food safety regulation on variable cost, the elasticity of cost with respect to safety is calculated. Elasticities are calculated for each observation and the mean is calculated Results show that food safety cost elasticities lie in the range of 0.94 to 1.21, with a mean of 1.04.

Table A2. Estimation Results

(Standard errors in parentheses)

Coefficient	*Estimate*	Coefficient	Estimate
α_0	23.58 (13.91)	γ_{sy}	0.17 (0.15)
α_L	1.25 (0.33)	β_{yk}	0.22 (0.14)
γ_S	-2.13 (1.092)	δ_{kL}	0.026 (0.013)
τ_M	-0.93 (0.052)	τ_{man}	-0.16 (0.102)
α_{LL}	0.053 (0.022)	θ_{man}	0.32 (0.12)
γ_{SL}	-0.19 (0.017)	τ_z	-0.034 (0.063)
τ_L	-0.12 (0.052)	β_t	0.17 (0.16)
β_y	-4.44 (3.88)	β_{tt}	0.000065 (0.00062)

β_{yy}	0.41 (0.73)	β_{Mt}	-0.0034 (0.0016)
δ_k	-0.67 (1.33)	β_{st}	-0.02 (0.0069)
τ_k	-0.21 (0.047)	β_{Lt}	0.0034 (0.0016)
δ_{kk}	-0.041 (0.060)	β_{kt}	-0.00031 (0.0065)
γ_{sk}	0.17 (0.061)	β_{yt}	-0.024 (0.028)
β_{yL}	-0.21 (0.032)	β_{mant}	-0.0025 (0.0018)

The fact that mean safety cost elasticity is positive shows that cost of production rises as the safety level increases. This result is somewhat higher than that observed for the US meat industry, which is around 0.7 for beef plants (Antle, 2000). As this is the result associated with the production technology of the period from 1929 to 1984, the estimates are subsequently adjusted to take into account technical change since 1984.

Adjustment for Technical Change: As technology progresses, the elasticity of cost with respect to safety will also change. Estimation results of the cost function show a negative interaction between safety and time (β_{st} = -0.02). This indicates that marginal cost of safety decreases as technology progresses. Assuming nothing else changes, from 1984 to 2002, safety cost elasticity could reduce as much as 0.36 (which is 0.02*18years). Therefore the safety cost elasticity of the present time is estimated to be 0.75 (which is elasticity of 1984 minus 0.36). Although this might seem a naïve approach, it does allow us to reach an estimation of the safety cost elasticity of the present time, given the data set used.

Estimation of HACCP/RMP Cost: To estimate the cost of food safety regulation, Antle (1999) has presented a theoretical framework for measuring impacts of both performance standards and process standards. HACCP as a pathogen reduction regulation for meat and poultry is viewed as a combination of design (process) standard and performance standard (Unnevehr and Jensen, 1996; Antle, 1999). Changes in variable cost of production due to food safety regulation such as HACCP/RMP are then calculated as follows**:**

$$\Delta VC = VC.E.e.(100-S)/S \qquad (7)$$

where

VC is variable cost of production; here we take the mean of variable costs during the period, mean VC = 2,051,600,000 (1999 dollars) (see Table A1).

E is the mean of safety cost elasticities, E = 1.04 for the period before 1984, and E = 0.75 in 2002.

e is the effectiveness of the regulation in enhancing food safety (or reducing microbial pathogen as in the case of HACCP), following Antle (2000), we assume e = 20 %.

S is the level of product safety before the introduction of the new regulation, here S is defined as the percentage of negative outcomes when product is tested for microbial contamination in a unit of time. ($0 < S \leq 100$)

Change in unit cost can be calculated as:

$$u = \Delta VC/y \qquad (8)$$

where y is output volume, y = mean output = 637,320 (tonnes) (see Table A1).

We calculate change in variable cost and the resulting unit cost for six scenarios (three different base safety levels S = 50%, 70%, and 90% in two different stages of technology). Results are presented in Table 1 in the text.

Estimation results show that for a mean variable cost of about $2 billion, an increase in variable cost due to HACCP/RMP implementation is in the range of $34 million to $427 million (or 1.7% to 21% respectively). Cost per unit is in the range of 5 cents to 67 cents per kilogram depending on assumptions. If using the adjusted safety elasticity (0.75), unit cost ranges from 5 cents to 48 cents, depending on the level of safety practices at the plant.

Appendix A3: GTAP Simulation Results

Table A3.1. Impacts on Prices

% change

Market prices (pm)	(1) USA	(2) NA	(3) EU	(4) SEA	(5) TME	(6) ALL
Meat	-0.57	-0.72	-1.03	-0.51	-0.10	-2.41
Cattle	-0.71	-0.90	-1.29	-0.64	-0.13	-3.03
Other Meats	-0.63	-0.80	-1.15	-0.57	-0.12	-2.7
Dairy	-0.56	-0.71	-1.02	-0.51	-0.10	-2.38
Fruit&Veg	-0.59	-0.75	-1.07	-0.53	-0.11	-2.5
Fish	-0.11	-0.14	-0.20	-0.09	-0.02	-0.46
Forestry	-0.13	-0.16	-0.23	-0.12	-0.02	-0.51
Other Agr’s	-0.48	-0.61	-0.88	-0.44	-0.09	-2.07
Manufactures	-0.44	-0.56	-0.80	-0.40	-0.08	-1.89
Services	-0.53	-0.68	-0.97	-0.48	-0.10	-2.28

Table A3.2. Impacts on Industry Output

% change

Industry Output (qo)	(1) USA	(2) NA	(3) EU	(4) SEA	(5) TME	(6) ALL
Meat	-12.38	-15.73	-22.65	-11.16	-2.24	-55.02
Cattle	-3.60	-4.58	-6.63	-3.25	-0.65	-16.07
Other Meats	-1.29	-1.64	-2.37	-1.16	-0.24	-5.72
Dairy	0.96	1.22	1.76	0.87	0.17	4.24
Fruit&Veg	0.80	1.01	1.44	0.72	0.14	3.48
Fish	0.18	0.23	0.32	0.16	0.03	0.76
Forestry	0.71	0.90	1.29	0.64	0.13	3.01
Other Agr's	0.13	0.16	0.22	0.11	0.02	0.53
Manfactures	1.00	1.26	1.82	0.90	0.18	4.40
Services	0.01	0.01	0.02	0.01	0.00	0.05

Impacts on the International Processed Meat Market

For the most likely scenario, when NZ loses the USA market, there is a big gain for other North American countries (Tables A3.3 and A3.4). Their meat exports rise by 14%. Australian meat exports increases by 3.4%, while Latin America has a modest gain (0.7%). In the last scenario, when NZ loses all of its significant markets, there are increases in all regions' meat exports. Other North American countries still have the largest gain with a 16% increase in their meat exports. EU15 countries meat exports rise by 10%. Australia and Latin America both gain about 8%.

Table A3.3. Impacts on the International Meat Market (Most Likely Scenario)

% change

Export Volume (qxw)	USA	ONA	LAM	EU15	SEA	TME	AUS	NZ	ROW
Meat	-0.1	14.21	0.68	-0.04	0.74	2.31	3.37	-20.43	1.8
Cattle	0.44	0.05	0.1	0.06	0.24	0.07	-0.56	3.02	0.05
Other Meats	-0.22	-0.08	0.01	0	0.02	-0.01	-0.25	2.92	0
Dairy	-0.25	-0.26	-0.25	-0.08	-0.21	-0.15	-0.37	2.07	-0.13
Fruit & Vegetable	-0.04	-0.15	0	0	-0.01	-0.01	-0.25	1.99	0
Fish	-0.02	-0.01	0	0	0	0	-0.01	0.52	0
Forestry	-0.03	-0.02	-0.03	0	-0.02	-0.01	-0.05	0.58	-0.01
Other Agriculture	-0.03	-0.06	0	0.01	0.01	0.01	-0.16	2.16	0
Manufacturing	-0.02	-0.04	0	0	0	0	-0.1	2.52	0
Services	-0.02	-0.05	-0.01	0	-0.01	0	-0.06	1.92	-0.01

Table A3.4. Impacts on the International Meat Market (All Case Scenario)

% change

Export Volume (qxw)	USA	ONA	LAM	EU15	SEA	TME	AUS	NZ	ROW
Meat	6.43	16.18	7.97	10.19	6.45	9.17	8.14	-90.79	5.77
Cattle	1.03	0.21	0.22	1.32	0.92	1.34	-0.9	12.7	1.36
Other Meats	-0.29	-0.27	-0.1	-0.08	-0.12	-0.06	-0.59	13.11	0
Dairy	-1.09	-0.86	-1.13	-0.36	-0.93	-0.66	-1.34	9.16	-0.53
Fruit & Vegetable	-0.13	-0.23	-0.06	-0.03	-0.1	-0.01	-0.63	8.75	0.01
Fish	-0.03	-0.01	-0.06	0.01	-0.03	0.03	0.04	2.22	-0.01
Forestry	-0.11	-0.05	-0.14	-0.05	-0.07	0.02	-0.09	2.27	-0.06
Other Agriculture	-0.04	-0.08	-0.04	-0.01	0.01	0.03	-0.4	9.6	0.03
Manufacturing	-0.03	-0.06	-0.06	-0.03	0	0	-0.23	11.28	0
Services	-0.04	-0.07	-0.07	-0.05	-0.01	-0.01	-0.1	8.57	-0.03

As a result of the shock to the NZ meat export markets, some countries/regions may be better off while others may be worse off. Often, when a country/region loses its meat imports from NZ, it also experiences a reduction in welfare. This is shown in all scenarios (Table A3.5). For example, in the case of NZ losing the USA market, the two countries that lose are NZ and the USA. For the USA, there is a welfare loss of $US145 million, which is even higher than that of NZ ($US90 million). The same things happen for other cases, with the EU15 experiences a considerable welfare loss of $US1.3 billion. On the other hand, countries/regions which are NZ's competitors in the international meat market such as North America, Latin America, and Australia gain. For example, in the ALL case scenario, Australia has the highest welfare gain ($US56 million), followed by Latin America ($US38 million). However in the first scenario (USA), Other North American countries gain the most. The distribution of welfare gains is likely to be influenced by the trading patterns between countries/regions before the shocks.

Table A3.5. Equivalent Variation (All Countries, All Scenarios)

1995 $US million

EV	(1) USA	(2) NA	(3) EU	(4) SEA	(5) TME	(6) ALL
USA	-145.53	-136.16	-9.49	29.17	1.66	-119.43
ONA	28.13	-9.40	2.45	1.84	0.26	-5.31
LAM	4.79	5.24	24.85	2.68	3.71	38.08
EU15	17.70	22.54	-1,290.24	18.66	-2.31	-1,300.44
SEA	7.92	11.91	24.12	-141.46	2.95	-108.89
TME	0.28	0.50	-5.66	0.73	-67.34	-76.93
AUS	21.15	23.37	5.70	21.12	2.32	56.36
NZ	-89.93	-113.84	-162.50	-81.20	-16.46	-380.66
ROW	8.97	10.39	-5.51	5.40	0.78	12.06

Table A4. RMP Tasks

RMP Task	Responsibility	Description
Design & Development of RMP	Business Operator or Operator may hire External Consultants to do this task	Designing all the components of RMP which based on the 7 principles of HACCP
Validation of RMP	Business Operator	Required when RMP is first developed to verify that it complies with requirements and is capable of achieving its outcomes
Independent Evaluation of RMP	Operator must contract a MAF accredited evaluator	On-site assessment to recognising the validity of the developed RMP with the intent of recommending registration
Registration of RMP - Application for registration - Registration approval	 - Operator - MAF (NZFSA)	Business Operator to apply to the Director of Animal Products, NZFSA to register RMP
Operation of RMP - Specific operational duties (e.g. sampling/testing, record-keeping) - Ongoing verification activities - Independent verification - Application for amendments to RMP when there are major changes in the production process - Updates and notification of minor amendments to RMP - Re-registration of RMP after 3 years	 - Operator - Operator - Operator must contract an accredited verifier - Operator - Operator - Operator	Business operators in general are responsible for RMP operational tasks such as monitoring, testing or record-keeping. They are also in charge of ongoing verification activities such as internal audits or reviewing of monitoring records. When there are major changes in their production process (e.g. changes that modify product outcomes), operators must apply for the approval of RMP amendments. Minor changes do not need to be registered.
Cessation of RMP - Surrender of registration - Suspension of registration or Deregistration	 - Operator - MAF (NZFSA)	RMP are terminated when the operation is no longer exist or it is suspended by NZFSA due to unsatisfaction with APA requirements or deregistered due to failures.

Source: adapted from RMP Manual (http://www.nzfsa.govt.nz/animalproducts/subject/rmp/index.htm)

REFERENCES

Antle, J. M. (1999). Benefits and costs of food safety regulation. *Food Policy*, *24*, 605-623.

Antle, J.M. (2000). No such thing as a free safe lunch: the cost of food safety regulation in the meat industry. *American Journal of Agricultural Economics, 82*(2), 310-322.

Cao K (2006), *An Economic Analysis of Hazards Analysis Critical Control Point-Based Risk Management Program in the New Zealand Meat Industry*, Unpublished PhD thesis, Waikato University.

Gertler, P. J., and Waldman, D. M. (1992). Quality-adjusted cost functions and policy evaluation in the nursing home industry. *Journal of Political Economy, 100*(6), 1232-1256.

Global Trade Analysis Project. (2004). Web site available at: http://www.gtap.agecon.purdue.edu/

Hertel, T. W. (1997). *Global trade analysis : Modeling and applications*. Cambridge University Press.

Hertel, T. W. and Tsigas, M. E. (1997). Structure of GTAP. In T. W. Hertel (Ed.) *Global trade analysis : Modeling and applications* (pp. 13-73). Cambridge University Press.

gribusiness, *16*(3), 309-320.

Maddison, A. (1995). *Monitoring the world economy 1820-1992*. Development Centre Studies, OECD.

Meat and Wool Innovation (MWI). (2004). Available at http://www.mwi.co.nz/economicservice/quickstats.html

Robinson DJ (2006), *No News is Good News: A History of New Zealand's Meat Hygiene Service 1898-2002*, Steele Roberts,Wellington.

Scott, W. G., Scott, H. M., Lake, R. J, and Baker, M. G. (2000). Economic cost to New Zealand of food-borne infectious disease. *New Zealand Medical Journal*, *113*, 281-284.

Statistics New Zealand (SNZ). (2004). Web site http://www.stats.govt.nz