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A Nonparametric Approach to The Analysis of HACCP/RMP Implementation Process

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Abstract. *In this paper we conduct an analysis of the implementation ~~process~~ of HACCP/RMP in the NZ Meat Industry based on the data collected from our recent survey. Nonparametric methods are used to measure the association between plant characteristics such as size, age, activities, and food safety management practices and HACCP/RMP adoption motivations, implementation problems, benefits, and costs. Results ~~will~~ give ~~more~~ insights into the ongoing process of mandatory RMP in New Zealand.*

Key words: *HACCP/RMP implementation, New Zealand Meat Industry, nonparametric methods.*

Introduction

The Animal Products Act 1999, which reformed New Zealand's food safety legislation, required all animal product primary processing businesses to have a risk management programme (RMP) based on the principles of Hazards Analysis and Critical Control Point (HACCP). This is phased in four stages from July 2003 till July 2006. Most licensed red meat processors, export seafood processors and packing houses are required to have a RMP by the end of the first period (July 2003).

The mandate of HACCP and/or RMP (hereinafter HACCP/RMP) has raised concerns over the impacts of these programs on the performance of the industries involved. International experience has shown significant impacts in terms of compliance costs which in turn may bring indirect impacts to the structure of the industry (see for example Unnevehr, 2000). There may also be management benefits beside food safety benefits as a result of the adoption of these programs (Nganje and Mazzocco, 2000). Moreover, firm motivation could be a significant input into the implementation process of HACCP/RMP (Henson, 2000).

In August 2003 the Economics Department of Waikato University conducted a survey on the adoption of HACCP/RMP in the Meat Industry. The main issues studied are the status of HACCP/RMP implementation by meat plants nation-wide, their motivations, implementation problems as well as their observations of the costs and benefits involved. Preliminary results were reported in Cao and Scrimgeour (2004).

The purpose of this paper is to analyse the relationship between plant characteristics and the motivations, implementation problems and the perceived costs and benefits of HACCP/RMP based on the data gathered from the survey. Particular firm characteristics considered are size, age, current food safety practices, activities (export/non-export), and the complexity of the production process. The following parts are organised as follows: part 2 summarises the characteristics of firms participating in the survey, part 3 discusses the methodology, and part 4 presents the results with discussion of the significant issues.

The survey

In the survey, respondents were asked to rank their motivation, problems, and benefits on a 7-point scale from unimportant to very important level. Costs are treated differently as the purpose is to see the weight of each cost item in the total cost. Therefore for cost items, respondents were asked to rank according to cost weight. There was also a rank 0 (in all ranked issues) for those items considered not appropriate or have not occurred. In this study we chose to include this zero rank together with other rankings. The reason is that excluding rank 0 sometimes leads to a very small sample size. Moreover, this rank 0 can be simply understood as the least important level in the ranking system.

The plants participating in the survey varied significantly in terms of size, age, and other production characteristics. The following figures show the distribution of plants in terms of these characteristics.

Figure 1. Plant size

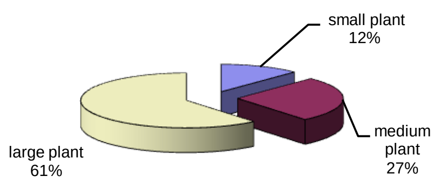


Figure 2. Plant age

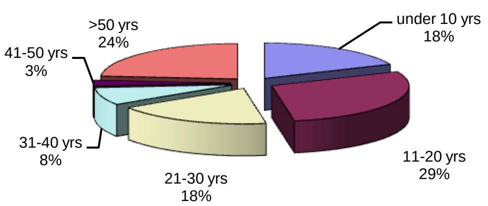


Figure 3. Plant activity

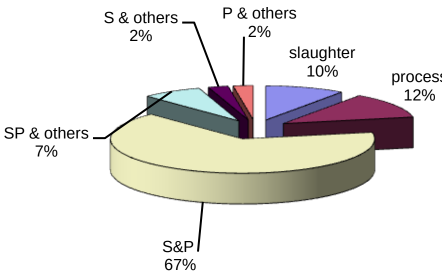


Figure 4. Plant Products

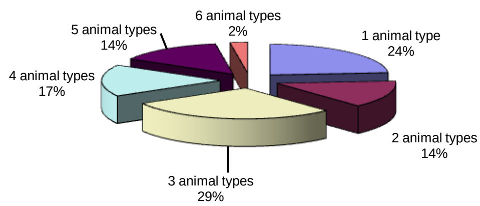


Figure 5. Number of QMS

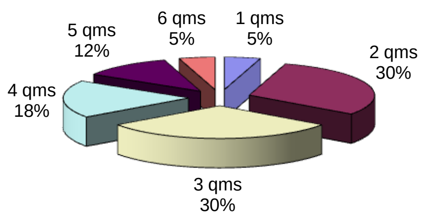
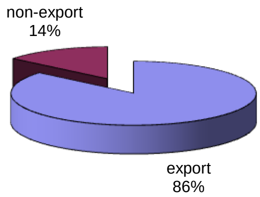


Figure 6. Exporting Plant



The international experience has shown that small plants may have disadvantages in their implementation of HACCP/RMP due to insufficient resources or diseconomies of scale (see for example Unnevehr, 2000; Siebert et al, 2000). Apart from plant size, other plant characteristics may have influences on the implementation process. Not many studies to date have focused on these influences, partly due to the lack of data available for analysis. This paper utilises the data gathered from the survey to analyse these relationships so as to provide more insight into the on-going implementation of HACCP/RMP in New Zealand. The analysis method is discussed in the next section.

Nonparametric approach

We chose to use a nonparametric method for measuring the association of the observed variables. Our primary goal is to see the connection between plant characteristics and observations of the HACCP/RMP implementation process. In other words, it is the signs of the association that we are interested in, not their sizes. Moreover, in conducting parametric methods, several assumptions on the population distribution or the error term need to be met. Also, nonparametric methods have proved to be useful in the case of categorical data (Argyrous, 1996).

We used Gamma to measure the association between two variables. It is commonly used for variables measured at the ordinal level. The value of Gamma is specified as:

$$G = (N_c - N_d)/(N_c + N_d)$$

where

N_c is the number of concordant pairs. Concordant pairs are defined as the two cases that are ranked the same on both variables. In other words, if Large firm A ranks an item higher than Small firm B, then A and B make a concordant pair.

N_d is the number of discordant pairs. Discordant pairs are defined as the two cases that are ranked differently on both variables. In the above example, if Large firm A ranks an item less than Small firm B, then A and B make a discordant pair.

Positive association between variables is found if the sample contains a lot of concordant pairs and few discordant pairs. In other words, in positive association, the value of Gamma is positive and vice versa. There will be no association between variables if the number of concordant pairs equals discordant pairs (Gamma is zero). Gamma takes value between -1 and +1. A value of -1 indicates perfect negative association while +1 shows perfect positive association.

To calculate Gamma, the two variables are arranged in a bivariate table so that concordant and discordant pairs can be counted. We made use of the SPSS procedure to calculate Gamma for all pair of variables between ranked items (motivations, problems, costs, and benefits) and plant characteristics (Size, Age, PROD, QMS, SP, and EXPT). Here, Size indicates plant size which takes value 1 for large plants and 0 for small plants[1]. Age is a variable measured by plant's operating years. PROD represents the number of products. QMS represents the number of quality/safety assurance systems. SP indicates plant activities, it takes value 1 if activities include both slaughtering and processing and 0 otherwise. EXPT takes value 1 for exporting plants and 0 for non-exporting plants. We also conducted chi-square significance tests to see if the sample correlation is representative for the whole population. Results are presented in the next section.

[1] 100 FTEs+ Large plant; 0-99 FTEs small and medium plants, called Small plant in this study

Results

Table 1-4 show values of Gamma and significance test results for all pairs of variables between HACCP/RMP adoption Motivation, Implementation Problems, Benefits, Cost and plant characteristics. Note that for Age, the correlation coefficient computed is Spearman's rho instead of Gamma as Age has a wide range of values, which makes it more appropriate to use Spearman's rho (Argyrous, 1996), although the two measures are similar.

Motivations

Gamma values for Size show that for those plants participating in the survey (sampled plants), there are positive associations between plant size and those of meeting legal requirement or customer's requirements (Gamma positive). In other words, for participating plants, large plants tend to give higher ranks for those requirements. On the contrary, small plants tend to give higher ranks for those of attracting new customers or accessing new markets (Gamma negative). Also, small plants seem to rank the recommendations from MAF and Industry Board more importantly. The rankings of internal factors (reducing waste, increasing efficiency…) are mixing and show weak associations. Most results for Size can not be generalised to the whole population as they are insignificant. Only one positive relationship between 'Meeting the needs of customers' and Size is significant, for which we can conclude that large meat plants in general regard customer's requirements as an important reason for adopting HACCP/RMP.

Results for Age are significant in several cases. There is a significant and negative association between plant age and 'Meeting the needs of customers', which implies that in general young plants think it important to satisfy customer's requirements by adopting HACCP/RMP. Similarly, young plants tend to give higher ranks for attracting new customers and accessing new markets. In most cases, results show that the older the plant the less motivated the plant to adopt HACCP/RMP.

Results for PROD show that plants with more products in general give lower rank for meeting the needs of customers but higher rank for attracting new markets. They also give smaller ranks for the internal factors such as improving product quality.

QMS is the variable with the most significant results. It shows that plant's current (or pre-HACCP/RMP) food quality/safety practices have a significant influence on the motivation to adopt HACCP/RMP. Moreover, Gamma values are negative in most cases showing that plants with various QMS other than HACCP/RMP are less motivated to adopt HACCP/RMP.

Results for SP show that in most cases, participating plants with both SP activities are more motivated in adopting HACCP/RMP. Results are significant for one case of internal factors (reducing waste) and one case of external factors (accessing overseas markets).

Table 1. Association between Motivations and Plant characteristics

Motivations	Size	Age(r)	PROD	QMS	SP	EXPT
Meet legal requirements	0.245 (0.417)	-0.178 (0.299)	-0.322 (0.425)	-0.310 (0.012)**	-0.127 (0.296)	0.535 (0.021)**
Meet the needs of major customers	0.275 (0.068)*	-0.301 (0.074)*	-0.085 (0.001)***	-0.044 (0.007)***	0.072 (0.242)	0.578 (0.027)**
Attract new customers for products	-0.207 (0.474)	-0.431 (0.009)***	0.028 (0.032)**	-0.141 (0.304)	-0.043 (0.799)	-0.073 (0.853)
Access new overseas markets	-0.098 (0.868)	-0.309 (0.066)*	0.096 (0.320)	-0.242 (0.134)	0.307 (0.044)**	0.237 (0.809)
Reduce customer complaints	0.141 (0.870)	-0.039 (0.823)	-0.081 (0.847)	0.165 (0.119)	0.404 (0.286)	-0.157 (0.431)
Reduce product wastage	0.031 (0.878)	-0.054 (0.756)	-0.039 (0.841)	0.152 (0.027)**	0.261 (0.055)*	-0.350 (0.103)
Improve control of production process	-0.031 (0.428)	-0.260 (0.125)	-0.196 (0.545)	-0.013 (0.100)*	0.249 (0.648)	-0.082 (0.774)
Improve product quality	-0.055 (0.304)	-0.210 (0.218)	-0.295 (0.052)*	-0.118 (0.048)**	0.106 (0.605)	0.271 (0.750)
Improve efficiency/profitability of plants	0.073 (0.433)	-0.040 (0.815)	-0.297 (0.603)	-0.038 (0.025)**	0.321 (0.376)	-0.063 (0.460)
Recommended by MAF/Industry Association	-0.196 (0.395)	-0.144 (0.402)	0.000 (0.246)	-0.124 (0.009)***	0.114 (0.752)	-0.048 (0.290)
Generally regarded as good practice	-0.110 (0.806)	-0.324 (0.054)*	-0.073 (0.109)	-0.302 (0.000)***	0.004 (0.681)	-0.318 (0.774)
Generally regarded as Board or CEO country wide policy	0.168 (0.179)	-0.133 (0.438)	-0.495 (0.107)	-0.074 (0.013)**	0.412 (0.332)	0.259 (0.868)
Needed for plant to be third party accredited	0.241 (0.466)	0.035 (0.838)	0.080 (0.167)	0.258 (0.003)***	0.386 (0.681)	-0.183 (0.143)
Reduce need for quality audits by customers	-0.013 (0.214)	-0.021 (0.903)	0.000 (0.693)	-0.043 (0.069)*	0.061 (0.164)	-0.291 (0.830)

Note: P-value of significance test in brackets; * ** *** denote significance at 0.1, 0.05, and 0.01 level. Age(r) means the coefficient is Spearman's rho.

Table 2. Association between Problems and Plant characteristics

Problems	Size	Age(r)	PROD	QMS	SP	EXPT
We are too small for HACCP/RMP	-0.452 (0.021)**	0.051 (0.767)	0.169 (0.542)	0.171 (0.461)	-0.203 (0.215)	-0.583 (0.131)
Lack of expertise in HACCP/RMP implementation	-0.073 (0.870)	-0.022 (0.897)	-0.044 (0.991)	0.112 (0.119)	-0.268 (0.499)	-0.319 (0.326)
Need to retrain supervisory/managerial staff	0.030 (0.589)	0.019 (0.910)	0.043 (0.293)	0.076 (0.295)	-0.286 (0.594)	-0.024 (0.842)
Need to retrain production staff	-0.055 (0.448)	0.060 (0.727)	-0.019 (0.860)	0.075 (0.241)	0.037 (0.159)	-0.098 (0.811)
Attitude/motivation of supervisory/managerial staff	0.197 (0.862)	0.172 (0.315)	0.011 (0.415)	0.017 (0.410)	-0.045 (0.362)	-0.455 (0.513)
Attitude/motivation of production staff	0.092 (0.549)	0.189 (0.270)	-0.028 (0.919)	0.064 (0.437)	0.165 (0.133)	-0.488 (0.419)
Reduced staff time available for other tasks	0.099 (0.751)	0.276 (0.104)	0.265 (0.809)	0.055 (0.049)**	0.149 (0.533)	-0.140 (0.366)
Reduced flexibility of production process	0.134 (0.838)	0.130 (0.450)	0.221 (0.613)	0.228 (0.365)	0.336 (0.334)	0.099 (0.087)*
Reduced flexibility of production staff	0.211 (0.692)	0.115 (0.504)	0.296 (0.111)	0.362 (0.068)*	0.299 (0.276)	-0.075 (0.556)
Reduced flexibility to introduce new products	0.113 (0.877)	-0.049 (0.776)	-0.040 (0.281)	0.132 (0.236)	-0.054 (0.811)	0.416 (0.478)
Need to modify production process	-0.175 (0.727)	-0.176 (0.305)	0.243 (0.038)**	0.039 (0.400)	-0.032 (0.974)	0.013 (0.576)
Have to cut down number of products	-0.078 (0.356)	-0.016 (0.926)	0.127 (0.382)	-0.078 (0.729)	-0.237 (0.154)	-0.070 (0.888)
Recouping costs of implementing HACCP/RMP	-0.279 (0.787)	-0.069 (0.689)	0.125 (0.807)	0.000 (0.863)	-0.237 (0.485)	-0.086 (0.412)

Note: P-value of significance test in brackets; * ** *** denote significance at 0.1, 0.05, and 0.01 level. Age(r) means the coefficient is Spearman's rho.

Table 3. Association between Benefits and Plant characteristics

Benefits	Size	Age(r)	PROD	QMS	SP	EXPT
Increased product shelf life	0.062 (0.843)	-0.004 (0.983)	0.136 (0.000)***	0.068 (0.282)	0.389 (0.775)	-0.143 (0.240)
Reduced product microbial counts	-0.212 (0.196)	-0.068 (0.695)	0.191 (0.413)	-0.062 (0.486)	0.096 (0.231)	-0.237 (0.582)
Reduced product rework	0.082 (0.142)	0.125 (0.467)	0.056 (0.400)	-0.037 (0.387)	0.277 (0.783)	-0.081 (0.649)
Increased efficiency in the use of inputs	-0.099 (0.284)	-0.025 (0.883)	0.135 (0.500)	-0.063 (0.322)	0.214 (0.588)	-0.132 (0.519)
Increased control over operating process	-0.122 (0.230)	-0.058 (0.738)	0.143 (0.176)	-0.080 (0.134)	0.034 (0.180)	-0.256 (0.381)
Reduced production costs	-0.302 (0.560)	0.019 (0.910)	0.116 (0.261)	-0.134 (0.927)	-0.020 (0.180)	-0.316 (0.474)
Increased product prices	-0.007 (0.207)	-0.148 (0.389)	0.096 (0.502)	-0.217 (0.449)	-0.032 (0.192)	0.000 (0.054)*
Increase sales	-0.057 (0.303)	0.049 (0.776)	0.175 (0.222)	-0.072 (0.630)	0.210 (0.489)	-0.037 (0.037)**
Increased ability to retain existing customers	0.095 (0.633)	0.048 (0.779)	0.004 (0.221)	-0.074 (0.320	0.292 (0.167)	0.073 (0.859)
Increased ability to attract new customers	0.101 (0.828)	0.064 (0.710)	0.075 (0.374)	-0.054 (0.102)	0.259 (0.453)	0.125 (0.890)
Increased ability to access new overseas markets	-0.093 (0.874)	-0.110 (0.524)	0.256 (0.765)	-0.289 (0.260)	0.073 (0.763)	-0.212 (0.869)

Note: P-value of significance test in brackets; * ** *** denote significance at 0.1, 0.05, and 0.01 level. Age(r) means the coefficient is Spearman's rho.

Table 4. Association between Costs and Plant characteristics

Costs	Size	Age(r)	PROD	QMS	SP	EXPT
Implementation costs						
Design and development costs	0.161 (0.536)	0.381 (0.032)**	-0.159 (0.614)	0.237 (0.214)	0.148 (0.912)	0.333 (0.678)
Evaluation/Register costs	0.126 (0.435)	-0.100 (0.593)	0.010 (0.249)	-0.249 (0.735)	0.664 (0.332)	0.278 (0.873)
Training costs	0.116 (0.708)	0.326 (0.097)*	-0.119 (0.458)	0.276 (0.021)**	0.472 (0.508)	-0.170 (0.421)
Equipment purchases, new building	-0.053 (0.413)	-0.410 (0.164	-0.265 (0.595)	-0.289 (0.239)	-0.429 (0.569)	-0.714 (0.696)
Operating costs						
Verification	0.008 (0.929)	0.278 (0.130)	-0.190 (0.956)	0.645 (0.108)	0.580 (0.472)	-0.105 (0.901)
Sampling/Testing	-0.484 (0.109)	-0.259 (0.192)	-0.086 (0.371)	0.226 (0.313)	-0.339 (0.462)	-0.379 (0.447)
Record-keeping	0.330 (0.186)	0.269 (0.167)	0.055 (0.552)	0.014 (0.039)**	0.106 (0.903)	-0.517 (0.654)
Recurred training costs	0.237 (0.688)	-0.035 (0.867)	-0.112 (0.678)	0.274 (0.746)	0.179 (0.856)	0.564 (0.125)

Note: P-value of significance test in brackets; * ** *** denote significance at 0.1, 0.05, and 0.01 level. Age(r) means the coefficient is Spearman's rho.

Exporting plants in adopting HACCP/RMP generally view it more important to meet legal requirement and customer requirements. In other cases, it seems that they rank the internal factors lower. The results are similar for MAF/Industry recommendations and auditing activities. However those results cannot be generalised to the whole population.

Problems

The only significant result for Size is that small plants tend to claim they are too small for HACCP/RMP. Small participating plants also indicate that they lack expertise for the implementation task and are more concerned about implementation costs. Large sampled plants seem to have problems with attitude and motivation of staff (both managerial and production) and to view HACCP/RMP as a constraint on the flexibility of staff and production processes.

Similarly, older plants seem to have problems with the flexibility of the production process once they have adopted HACCP/RMP. They also seem to have problems with staff motivation. However, none of these results can be generalised to the whole population.

There is one significant result for PROD. It shows that in general plants with more products may have to modify their production process when adopting HACCP/RMP. We observe no significant results for SP and EXPT (except for one case but quite weak association). For participating plants, it seems non-exporting plants are more concerned with the listed problems, perhaps due to the lack of exporting incentives.

Benefits

We found a few significant results with benefits. In one case, a significant result between PROD and ‘Increased product shelf life’, results suggest that plants with more products seem to observe more the benefit of improving product shelf life as a result of HACCP/RMP. Some other cases have significant results but the associations are weak. For those participating, Gamma values indicate that small plants tend to give higher ranks for the internal benefits but lower for external benefits. Similarly, older plants seem to observe more of the internal benefits than external benefits. Plants with more products ranked higher for all benefits, however plants with more QMS give lower rank in all cases. It suggests that those who are doing well at food safety management tend to rank HACCP/RMP benefits less importantly. However, there is not enough evidence to generalise this result to the whole population.

Costs

Results for costs should be interpreted differently. The reason is that rankings for costs are done according to the weights of the cost items. For example, if a respondent ranks 1 for an item, it means the item has the biggest weight in the total HACCP/RMP cost. The higher the rank the less important the cost item. This is opposite to the other three cases. Therefore, in the computation of Gamma we excluded rank 0. A positive Gamma for Size, say, indicates that large plants rank higher for the cost items, which shows their lesser importance from their point of view.

For Implementation costs, among participating plants, large plants tend to give higher ranks to Design, Register, and Training costs but smaller ranks to Equipment and Building. It shows that large plants seem to spend more on new investment due to HACCP/RMP. However, this result cannot be generalised.

Older plants in general spent less in HACCP/RMP design and development and staff training. Both results are significant.

Plants with more products tend to spend more on implementation costs. However, this applies to the participating plants and cannot be generalised. We found one significant result between QMS and training costs, which indicates that in general plants with more QMS may have to spend more on staff training.

For Operating costs, among participating plants, large plants tend to spend more on sampling and testing. Older plants also tend to spend more on sampling and testing and repeated training. Plants with more products seem to spend more on operating costs as well.

There is one significant result between QMS and record-keeping costs. It shows that in general plants with more QMS may have to spend more on this type of costs. There are some other strong associations. For example, plants with more activities and exporting tend to spend more on sampling and testing. However, this applies to the sample studied only and cannot be generalised to the population.

Conclusion

In this paper we have presented a nonparametric approach to the analysis of HACCP/RMP implementation process. Issues addressed include plant motivations in adopting these systems, implementation problems, and observations on benefits and costs. Based on the data gathered from our recent survey, the relationships between the rankings of these issues and plant characteristics are analysed. Results showed some strong correlations which can be generalised to the whole population. For example, there is a significant relationship between the number of QMS and the motivations to adopt HACCP/RMP. It showed that pre-HACCP/RMP food safety practices do have influence on plant motivations in adopting these systems. It was also found that plants with more complicated production processes (more product types) may have problems with modifying their production process and thus may bear higher costs. Nevertheless, they may gain benefits in terms of improving the quality of their products. Plant size is not a significant influence with respect to the above-mentioned issues. This is interesting given small plants tend to claim that they are too small for HACCP/RMP.

This analysis could be enhanced by incorporating more information concerning the HACCP/RMP implementation process. For example, a bigger sample size maybe able to improve the association measurement estimates. As indicated in Cao and Scrimgeour (2004), the survey questionnaires were sent to the whole population of NZ meat plants (about 90 plants at that time). However, the response rate is about 48%. A longitudinal approach to HACCP/RMP implementation research maybe useful as more information could be obtained once plants are more aware of the issues associated with the implementation process.

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