University of Alberta

A study on quality-based pricing in the Canadian poultry industry

by

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Abstract

This thesis contributes toward the design of a novel pricing scheme that could be employed to compensate Canadian poultry producers according to their performance in specific quality traits. Based on biological data obtained from a set of growth experiments with chicken and data on chicken wholesale prices, a formula-based absolute performance pricing scheme is developed. Producer prices are simulated under the current and novel pricing scheme in the context of the Alberta chicken industry. Impacts of the key elements of the price formula are examined by both deterministic and stochastic methods. The results suggest that the novel pricing scheme is likely to increase the price risk for producers. Producer performance is found to be the most significant factor that affects prices, followed by requirements of processors regarding quality traits (cut-up part yield), and price mark-ups of cut-up parts.

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Chapter 1 Introduction

1.1 Background

The economic organization of North American chicken production is characterized by striking differences between the United States and Canadian broiler sectors. U.S. chicken production is coordinated almost entirely through systems of production contracts whereby producers are paid on the basis of their relative performance compared to other farmers (MacDonald and Korb, 2006). In contrast, Canadian chicken production is characterized by a supply management system, whereby grower compensation is based on a negotiation process between growers and processors (until 2003) or a formula-based pricing scheme (since 2003 to present). The system of relative performance and a quality-based pricing, so popular in the United States, is practically absent in Canada (Agriculture and Agri-Food Canada, 2006). These organizational differences raise important questions with regard to pricing and production efficiencies in Canada's poultry production sector, a major component of the country's overall meat sector (Willwerth, 2009).

In the past two decades, per capita chicken consumption in Canada has increased by 45.9% from 21.47kg in 1989 to 31.34kg in 2009 (Agriculture and Agri-Food Canada, 2011). As a result of the increased consumer demand, the production of chicken has grown by 83.68%, from 564,053 metric tons in 1989 to 1,036,054 metric tons in 2009 (Statistics Canada, 2011). Also, during 2009, Canada exported 147 million kilogram of chicken meat and edible bi-products totalling more than $288.5 million dollars to 73 countries. During the same time period the amount of imports of poultry products into Canada were about 107.2 million kilograms (Agriculture and Agri-Food Canada, 2011).

Although Canada has significantly increased production and has a positive balance of trade in chicken products, there is evidence that the Canadian poultry industry has been outperformed by the United States in terms of profitability and efficiency, and there is still opportunity to improve the competitiveness of Canada's poultry sector (Liu, 2005). In this context, a central issue is to understand to what extent the current economic organization of the Canadian poultry sector could be improved through greater focus on the efficient provision of specific quality traits as they are demanded by the final consumer.

1.2 Problem Statement

The Canadian poultry industry is organized by a supply management system where relative performance compensation and quality-based pricing – including absolute performance compensation - is lacking at the producer level. Therefore, to begin to understand how the sector could be made more competitive, it is important to start exploring novel means of compensating Canadian producers for their individual quality contributions. However, the scope of the following analysis is limited, since the central assumption is that supply management is here to stay. Therefore, the key question is whether the current way of compensating producers can be improved to benefit processors and producers, while increasing flexibility in accounting for consumer preferences for specific poultry quality traits.

In the global poultry industry, increased consumer demand for higher quality products has induced many management and technological improvements (Martinez, 2002). However, based on information that is publicly available, it appears that the current organizational structure of the Canadian poultry sector does not provide producers with the most effective incentives to reward the supply of differential quality. In other words there is an incomplete market for quality traits in the poultry sector in Canada.

Currently, Canadian poultry producers receive a set price per unit (kilograms), which is known as minimum live price or base price, from processors. This minimum live price is periodically determined by a price formula, and negotiations between the processors and the provincial marketing board, which represent all the producers in that province (Agriculture and Agri-food Canada, 2007). Extra costs associated with the adoption of new technologies or higher quality feeds are therefore not supported and are likely to result in a loss to the producer. In fact the current payment system appears to directly discourage producers from implementing new technologies in order to improve specific quality traits. There is scope for reforming the current system so that Canadian poultry producers can be compensated in accordance to an individual producer's ability to meet specific quality traits.

1.3 Study Objectives

The Canadian poultry industry is at a crossroad. Increasing demand in the domestic market, competition in the global market and rapid development in poultry production and management technologies is forcing a serious re-examination of efficiency and performance within the sector. Reforming the current pricing scheme, where incentives for quality are lacking, could be a way of improving performance without incurring substantial costs. The overall goal of this study is to contribute toward the design of a novel pricing scheme that compensates producers for quality, specifically in the context of the Alberta chicken industry.

The specific objectives include,

(1) To identify the relevant quality traits that could be integrated into the pricing scheme. In this context, we also seek to both characterize the significance of the traits in the consumer market and their growth trajectories;

(2) To design a pricing system that compensates producers based on the quality traits identified under objective 1;

(3) To quantify the exact price premiums/discounts for each quality trait under the constraint of maintaining supply management;

(4) To estimate key impacts of the novel pricing scheme on industry stakeholders (producers, processors).

1.4 Chapter outline

The remainder of the thesis is organized as follows: Chapter two gives a brief overview of the global poultry industry and a detailed introduction to the Canadian poultry sector in terms of its industrial organization and operative structure. The differences between pricing schemes in Canada and the U.S. poultry sector are also discussed. Chapter three presents a review of the literature about supply management, as well as the pricing schemes in North American agricultural sectors (which we use as a benchmark). In Chapter four, the experimental design and economic model are discussed, followed by the empirical results in Chapter five. Finally, Chapter six concludes and discusses possible implications for industry stakeholders.

Chapter 2 Industry Background

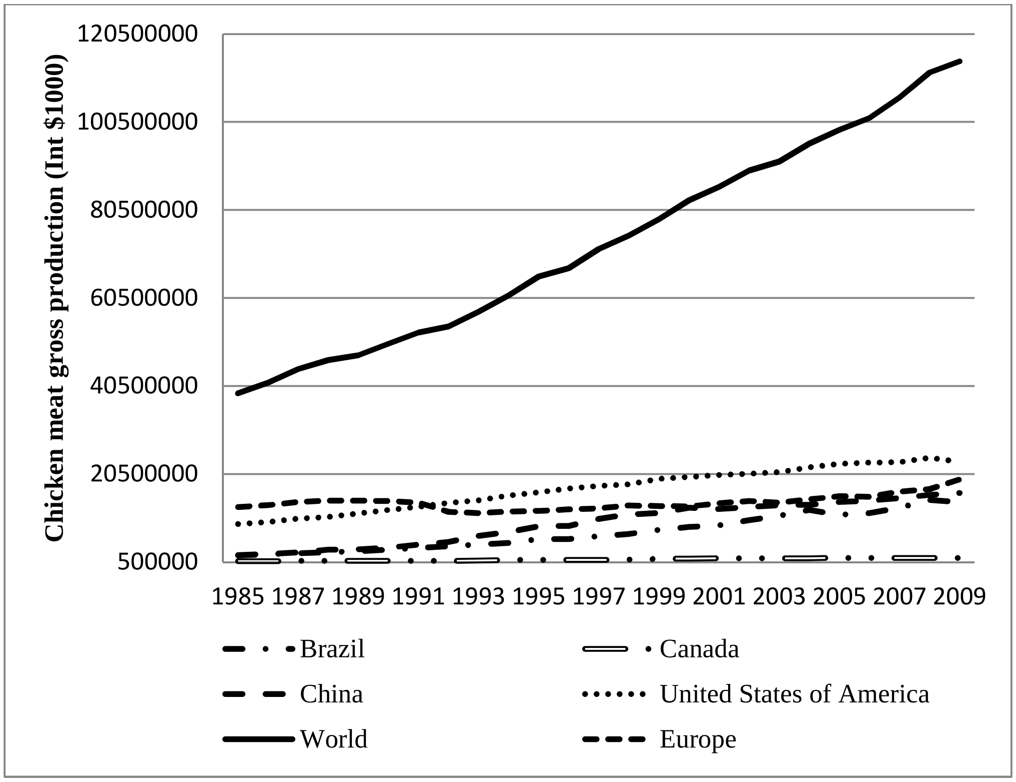
2.1 Overview of the global chicken industry

Chicken production has been growing steadily worldwide since the early 1990s. In 2009, world chicken meat production reached 80,211,982 metric tons, increasing by 193% from 27,294,445 metric tons since 1985 (FAO, 2011). The growth of the global chicken production is resulted from the surging production in emerging markets such as Brazil and Thailand, the greater demand in Western countries for high-protein, low-carbohydrate products and other factors (Agriculture and Agri-Food Canada, 2007).

Looking at the ranking in terms of domestic chicken meat production (including the meat equivalent of exports and excluding the meat equivalent of imports) in 2009 (Table 2-1), the United States, China, Brazil and the European Union are the four largest chicken-producing regions in the world. Together, they account for about 59.37% of world chicken production in 2009. As Figure 2-1 shows, along with the growth of the global chicken production, these countries increased their production significantly during the period from 1985 to 2009.

Compared with the leading chicken-producing countries, the growth of chicken production in Canada was much slower in the same period (Figure 2-1). In fact, Canada dropped from 9th largest chicken production country in 1999 to the 15th in 2009, with production of 1,009,000 metric tons chicken meats which represents 1.26% of the world's production in 2009 (Table 2-1).

Figure 2-1 Evolution of chicken meat gross production value from 1985 to 2009 (1000 Int$[1])



[1] International Dollar

Data source: FAOSTAT, retrieved Sept. 28, 2011, from http://faostat.fao.org/site/339/default.aspx

Table 2-1 Leading Chicken Producers -- chicken meat production, 1999 and 2009

1999			2009		
Rank	**Area**	**Production (MT)**[1]	**Rank**	**Area**	**Production (MT)**
1	United States of America	13,622,000	**1**	United States of America	16,338,100
2	China	8,157,072	**2**	China	11,400,086
3	Brazil	5,536,570	**3**	Brazil	9,967,000
4	Mexico	1,726,590	**4**	Mexico	2,622,070
5	France (EU)	1,314,000	**5**	Russian Federation	2,303,090
6	United Kingdom(EU)	1,238,630	**6**	Iran (Islamic Republic of)	1,674,220
7	Japan	1,210,160	**7**	Indonesia	1,527,960
8	Thailand	1,080,870	**8**	Argentina	1,500,150
9	Spain (EU)	1,003,330	**9**	United Kingdom (EU)	1,487,900
10	Argentina	927,800	**10**	Japan	1,393,110
11	Canada	860,700	**11**	Turkey	1,291,660
12	Italy (EU)	78,9800	**12**	Spain (EU)	1,120,230
13	Malaysia	740,323	**13**	France (EU)	1,113,800
14	Iran (Islamic Republic of)	725,226	**14**	Poland (EU)	1,073,900
15	South Africa	706,337	**15**	Malaysia	1,034,890
16	Russian Federation	690,941	**16**	Colombia	1,031,200
17	Netherlands (EU)	638,000	**17**	Thailand	1,017,380
18	Venezuela (Bolivarian Republic of)	615,100	**18**	Canada	1,009,000
19	Indonesia	602,618	**19**	South Africa	966,365
20	Turkey	590,687	**20**	Peru	966,350
	World total	55,074,411		**World total**	114,254,508

[1]Metric ton

Data source: FAOSTAT, retrieved Sept. 28, 2011, from http://faostat.fao.org/site/339/default.aspx

2.2 Overview of the Canadian chicken industry

2.2.1 Overall significance

In 2009, the value of all chicken products totalled $2.2 billion in Canada. Farm cash receipts of the sector totalled $2,023 million, representing approximately 4.6% of total farm cash receipts in Canada (Agriculture and Agri-Food Canada, 2011). At the processing level, the poultry processing industry generated approximately 26.08% ($5.5 billion out of the $21.4 billion) of the revenue of the meat product manufacturing industry and employed 21278 people in 2007 (Agriculture and Agri-food Canada, 2007).

On the demand side, chicken accounts for a significant proportion of Canadian's meat consumption. According to the Chicken Farmers of Canada, Canadian's per capita chicken consumption accounted for 34.6% of the per capita meat consumption in 2010, which is 3.3% higher than per capita consumption of beef and 10.1% higher than per capita consumption of pork.

The organization of the production sector in Canada is unique in that, unlike many other places in the world, over 90% of Canada's chicken farms are family-owned (Chicken Farmers of Canada, 2011). In 2008, there were 2,794 regulated chicken producers and 548 registered turkey producers in Canada. Production is also highly regionally concentrated. The majority of poultry (60%) was produced in Ontario and Québec. The third largest producing province was British Columbia. Together, these three leading provinces account for more than75% of Canada's total chicken production. Alberta is the fourth largest poultry producing province in Canada. In 2010, there were 277 registered chicken producers in the province, who produced approximately 120 million kg, or 9.2% of the country's domestic production annually (Alberta Chicken Producers).

At the processing level, Canada has 175 primary poultry processing plants (45 federally registered and 131 provincially registered). The five largest firms in the chicken sector are: la Coopérative fédérée de Québec (three plants in Québec), Lilydale Poultry Co-operative (one plant in British Columbia, three in Alberta and one in Saskatchewan), Maple Leaf Poultry (two plants in Ontario, one in Alberta and one in Nova Scotia), Exceldor (two plants in Québec) and Maple Lodge Farms (one plant in Ontario) (Agriculture and Agri-Food Canada, 2006). In Alberta, there are three federally inspected processing companies including the Maple Leaf Foods Inc. (1 plant in Edmonton), the Lilydale Inc. (1 plant in Calgary and 2 plants in Edmonton) and the Sunrise Poultry Processors Ltd. (1 plant in Lethbridge). In addition, there are numerous colonies with provincial meat inspection and one further processing facility located throughout the province (Government of Alberta, 2007; Canadian Poultry and Egg Processors Council, 2011).

2.2.2 Supply management

As mentioned in chapter one, the Canadian poultry industry is operated under supply management. Supply management is "a marketing system that regulates domestic production and imports with the objective to ensure that the supply of a product matches the demand for it and that the prices paid to agricultural producers are steady over time and provide the producers with fair returns" (Agriculture and Agri-Food Canada, 2011). The goal of supply management is to guarantee processors and consumers a "consistent supply of top-quality products at reasonable prices" (Agriculture and Agri-Food Canada, 2011). The Canada federal and provincial governments implemented a supply management system in the early 1970s based on collective marketing and production planning. The five commodities operate under the supply managed system in Canada are: Dairy, Turkey, Table Eggs, Chicken and Broiler Hatching Eggs.

Supply management has been implemented in the chicken industry since 1979. Chicken Farmers of Canada (CFC) is the national agency that oversees the orderly marketing of chicken in Canada. In addition to the federal marketing board, there is a provincial marketing board in each province. The provincial marketing board in Alberta is the Alberta Chicken Producers (ACP) established in 1966 under the Alberta Natural Products Marketing Council and operated under a Federal Provincial Agreement.

According to the Alberta Chicken Producers, there are three principles that govern supply management in the chicken industry the supply determination, price determination and import controls. Since the focus of this study is on the domestic market, we will mainly discuss the first two principles in the remainder of this section.

Quota determination in the Canadian chicken industry

Supply management aims to balance supply with demand. A bottom-up market approach of setting production level is employed to match supply with demand since 1995. Production level is set every 8 weeks at the National Agency level and production quotas are allocated to the provinces based on historic shares. Certified chicken producers in each province need production quotas in order to grow chicken for each 8-week cycle.

Under the bottom-up marketing approach, chicken processors survey market opportunities about 12 weeks before the actual production begins and negotiate with provincial marketing boards to determine their provincial requirements (Gervais et al., 2007). This stage of quota determination could be expressed as equation (2.1), where Q is the production level of the i_{th} province in period t, ED^i is the expected demand for period *t* of the i_{th} province.

$$Q_t^i = f(ED^i) \qquad (2.1)$$

Production quotas at the national level (Q_t) then become the adjusted aggregate of the individual provincial requirements (adjusted by coefficient λ, equation 2.2). Then each province obtains a share of the national production quotas, and the provincial marketing boards in turn allocate production quota to certified producers and ensure that they produce and market within this allocation.

$$Q_t = \lambda \sum Q_t^i \qquad (2.2)$$

In order to respond to changes of market demand for chicken meat, the quota utilization percentage changes from cycle to cycle. In Alberta, quota units can be reallocated between existing producers and to new producers in the province, without penalty. Quota can be traded from one certified producer to another either by purchasing or leasing. The Alberta Chicken Producer regulates quota transactions, sets allocation and price, and monitors chicken production on each farm, ensuring each farmer adheres to the guidelines of the On-Farm Food Safety Assurance Program, and the Animal Care Program.

Price determination in the Canadian chicken industry

Regarding price determination, supply management aims to ensure that the prices paid to farmers are steady over time, and are able to cover production costs and leave producers with a predictable income (Chicken Farmers of Ontario, 2007). In Canada, the price of live chicken is determined at the provincial level. From 1992 to 2003, live chicken prices were set through negotiations between marketing boards and processors in each province. Since May 2003, the live chicken price was changed to a formula-based pricing scheme. The formula, also known as the live price formula, contains three components including feed cost components (accounts for about 44% of the live price), chick cost components (accounts for about 23.5% of the live price) and producer margin component (accounts for about 32.5% of the live price). In each production cycle, the marketing board and primary processors negotiate and set the live chicken price based on the formula. This price recommended by the marketing board is known as the "*base price*" or "*minimum live price*". The minimum live price is adjusted every quota period for changes in feed and chick costs and once every six-quota periods (about a year) for changes in the producer margin (see Appendix 1 for detailed price determination descriptions).

The minimum live price established in Ontario (by the Chicken Farmers of Ontario CFO) is generally used as a basis for other provinces because Ontario is the biggest chicken-producing province (Gervais et al., 2007). In Alberta, the Alberta Chicken Producers Board is authorized through the Marketing of Agricultural Products Act and Regulations to set the minimum live price paid to producers during every production cycle. Currently, the minimum live price in Alberta is set based on a Live Price Memorandum of Understanding. For example, price for the period A-96 to A-102 (January 2010 to January 2011) is based on the MOU which reflected a 3.25 cent differential over the Ontario live price, subject to substantial changes in chick costs or major structural changes to the industry.

In addition to the formula-based price, the price of live chicken also depends on the average live weight of all chicken contained in each truckload shipped by the producer to the processor. A discount is applied if the average live weight does not fall within the range requested by processors. For example, in Alberta, in Period A-96 from January 31, 2010 to March 27, 2010, the price paid by processor Lilydale to producers was $1.4535 per kg for broiler chicken with live weight range from 1.9kg up to 2.35kg, and $1.4035 per kg for those with live weight from 1.1 kg to 1.89kg or greater than 2.35kg. In other words, a $0.05/kg discount would be applied if the average weight falls outside of the range from 1.9kg to 2.35kg.

2.2.3 Wholesale price, retail price and product quality

After discussing supply management and current price determination at the production level, we now turn to the retail and wholesale level, and introduce relevant quality traits that could be integrated into a reformed pricing scheme.

In Canada, processors purchase live birds from producers. The processed birds then go into the retail market either as whole carcass or in the form of cut-up parts. At the production level, live bird is the only category that is traded between producer and processors, whereas at the retail and wholesale level, products are more diversified as the birds are also sold as different cut-up parts.

Looking at the historical retail price data in Canada from 2009 to 2011 of four categories including whole bird, breast, wings and leg quarter, the weighted average retail price of chicken breast is the highest for the whole period, followed by wing and fresh whole chicken, while the price of chicken leg quarters is the lowest (Figure 2-2). A similar price difference could also be found on the wholesale level. Figure 2-3 shows four market complexescompiled by Expressed Market Inc. (EMI), which measure the values of the four major cut-up part groups (breast, wing, leg and whole bird) based on actual invoice data from nine Canadian processors covering a significant portion of the Canadian wholesale volume. As Figure 2-3 shows, the average EMI breast complex and wing complex are constantly higher than leg complex and whole bird complex in the period from Dec 2001 to Jul 2010.

The price differences on retail and wholesale level both suggest that there are differences in terms of market values or consumer valuation across quality traits. However, such value differentiations are currently not translated into the price at the production level because of the lack of corresponding quality incentive components in the price formula. Therefore, in our analysis we consider introducing attributes related to cut-up part as an indicator of quality. For the rest of this study, we will focus on three cut-up parts -- breast, leg and wing. Specifically, we will employ the yield levels of these cut-up parts as the quality traits in the pricing scheme we are going to propose. We define breast yield, leg yield and wing yield as the proportion of the weight of breast meat with bone and skin, the proportion of the weight of leg quarters (including thigh and drumstick) and the proportion of weight of wings, respectively, to the weight of an eviscerated whole bird. These three quality traits are defined formally below:

$BY = \frac{WB}{BWEvis} \times 100\%$..(2.3)

$WY = \frac{WW}{BWEvis} \times 100\%$..(2.4)

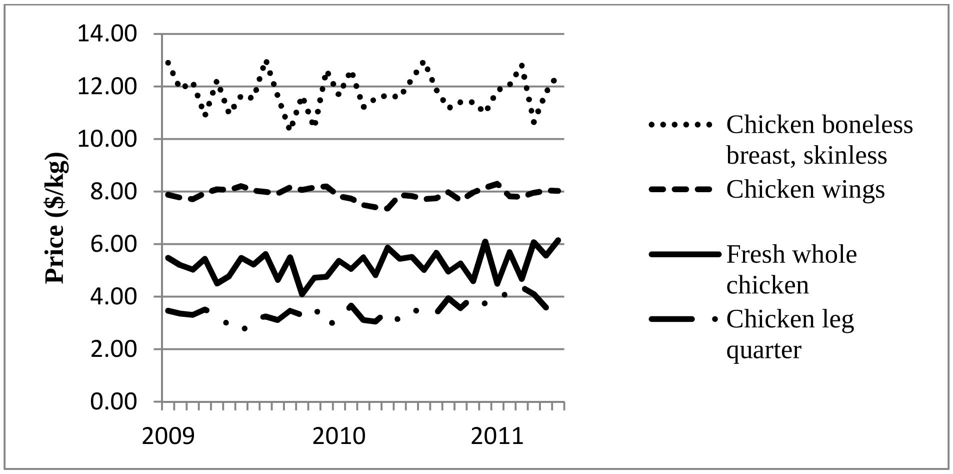
$LY = \frac{WL}{BWEvis} \times 100\%$..(2.5)

where BY, WY and LY denotes breast yield, wing yield and leg yield respectively;

WB, WW, and WL correspond to the weight of bone-in skin-on breast, weight of leg quarter and weight of wing respectively;

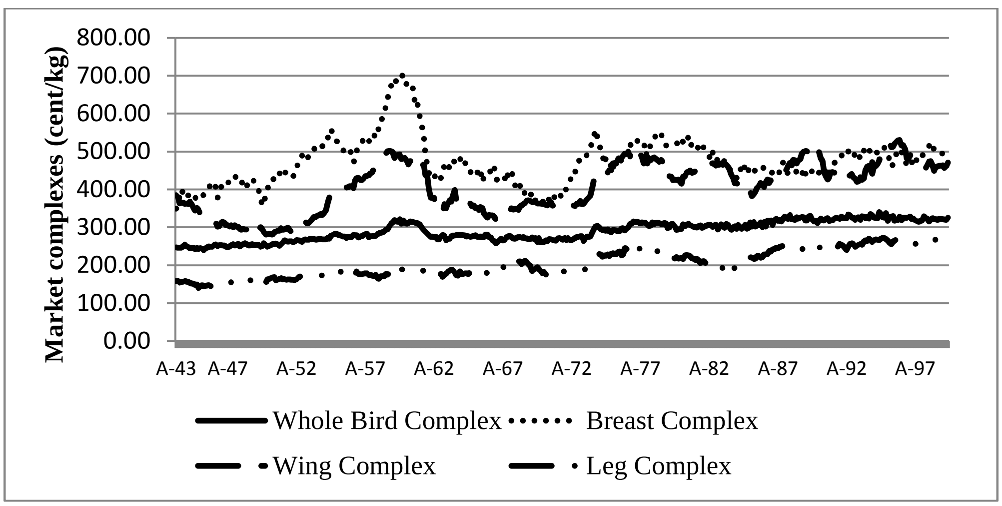
$BWEvis$ is the eviscerated body weight of a bird.

Figure 2-2 Weighted average monthly chicken retail price in Canada from Jan. 2009 to Apr. 2010



Data source: Agricultural and Agri-food Canada, retrieved Sept. 28, 2011, from http://www.agr.gc.ca/poultry/index_eng.htm

Figure 2-3 Chicken wholesale price in Canada from Dec. 2001 to Jul. 2010 (A-43 to A98)



Data source: Chicken Farmers of Canada and Express Market, Inc., 2011

2.3 Overview of the U.S. chicken industry

Since we are interested in comparing aspects of efficiency and quality in both the Canadian and the U.S. poultry industry, the following sections aim to briefly review how performance evaluation is typically implemented in the United States and to compare it with the Canadian system.

2.3.1 Overview of performance evaluation in the U.S. chicken industry

The primary difference between the chicken industry in the United States and in Canada is that the U.S. chicken industry is highly vertically integrated. In the United States, integrators control typically every stage of the supply chain via company-owned farms or production contracts (MacDonald, 2008). They usually own or control hatcheries, feed mills, slaughter plants, and further processing plants and rely on networks of growers for broiler production through production contracts. The contract chicken producers in the United States do not own the birds they raise, rather, they provide production facilities and labour. Their responsibility is to raise the company's birds until they reach market weight and then exchange them for monetary compensation (MacDonald, 2008). Therefore, contract chicken producers are paid for their growing *service* instead of directly for the commodity they grow.

Payment between integrators and producers in the U.S. chicken industry is typically based on the relative performance by comparing a given producer with other producers who deliver broilers within a specified time period (often a week) (MacDonald, 2008). Under a typical relative performance standard, all producers receive a base fee. Further, producers who deliver more meat, given the number of chicks placed with them, receive higher payments. Therefore, the differences in producers' relative performance are driven by differences in chick mortality and feed efficiency (Knoeber, 1989). For each individual producer, the performance in chick mortality and feed efficiency is measured by settlement cost, which is typically the total cost of chicks, feed as well as medicine provided by the integrator divided by the weight of meat produced. In equation form, and following Knoeber (1989), settlement cost can be written as:

$$SC_{jk} = \frac{PC \times C_{jk} + PF_k \times F_{jk}}{W_{jk}} \qquad (2.6)$$

where SC_{jk} is the actual settlement cost of producer j in period k;

PC is price per chick (medical cost included);

C_{jk} is number of chicks delivered to producer j in period k;

PF_k is the price of feed per calories in period k;

F_{jk} is the amount of feed delivered to producer j in period k;

W_{jk} is the total weight of meat produced by producer j in period k.

From equation (2.6), settlement cost could be further decomposed into two parts: $\frac{PC \times C_{jk}}{W_{jk}}$ and $\frac{PF \times F_{jk}}{W_{jk}}$, which measures producer's performance in mortality rate and feed efficiency respectively.

The price determination under relative performance payment scheme adopted from Knoeber (1989, p.275) can be expressed as:

$$P_{ijk} = (BP_k + \overline{SC_k} - SC_{jk}) \times W_{jk} \qquad (2.7)$$

where P_{ijk} is the payment by integrator i to contract producer j in period k;

BP_k is the base price in period k;

$\overline{SC_k}$ is the average settlement cost of all producers in period k;

SC_{jk} is the actual settlement cost of producer j in period k;

W_{jk} is the total weight of the meat produced by producer j in period k.

As shown in equation (2.7), producer performance is measured by the difference between the settlement cost of an individual producer and the average settlement cost of the group. When a producer's performance is above average, its settlement cost is lower than the average level ($SC_{jk} < \overline{SC_k}$), as a result $\overline{SC_k} - SC_{jk} > 0$, and a premium will be applied. Similarly, if the producer's performance is below average, a discount will be applied. In general, under the relative performance pricing scheme, the three crucial components of the price determination are: Base Price, Mortality Rate and Feed Conversion Rate. For contract producers, the base price is exogenous as it is given when they sign the contract; mortality rate and feed conversion rate are endogenous as these two variables depend on producers' efforts and the quality of management. In other words, the pricing scheme described in equation 2.7 offers incentives for producers to minimize mortality rate and maximize feed conversion rate while the number of chicks and ingredient of feed are given.

Under the U.S. system, producers have little control of the ingredients of feed as it is provided by the integrator. Therefore, there are no explicit incentives to improve quality (e.g. yield of cut up parts) that could be affected by varying dietary ingredients. However, because the integrated U.S. poultry system is a very tightly controlled and thus effectively closed production system (Schmitz and

Schmitz, 1994), processors ensure that minimum quality criteria are being met in other ways, outside of the relative performance pricing formula (e.g. by the threat of contract exclusion).

In terms of cost of production under production contract in the United States, while chick and feed are integrator-provided inputs, contract growers mainly invest in production facility and labour. According to a report by Taylor and Domina (2002), the costs for contract growers mainly consists of the cost of specialized production facilities (houses, associated equipment, and utilities), grower service (labour and management), waste management and dead bird disposal.

Beside the U.S. chicken industry, contract farming and vertical integration is also adopted by many major poultry producing countries such as Brazil, Thailand and China. A brief description of the poultry industry in Brazil and China which also adopt the relative performance scheme is provided in Appendix 2.

2.3.2 Comparison between the U.S. and Canadian chicken industry

Compared with the U.S. chicken industry, there is significantly less coordination between hatcheries, feed mills, growers, slaughter plants, and further processing plants in Canada. In fact, under the Canadian supply management system, the coordination among different stages of the supply chain depends on the participation of the marketing boards (Martin et al., 1993). Although the quantity of production and price of live chicken are predetermined by the marketing boards, chicken producers in Canada still have relatively more freedom in terms of production decisions such as choosing hatchery firms and feed mills. Moreover, previous studies suggest that producers in Canada have been better off because supply management gives them some degree of bargaining power (e.g. Schmitz 1983).

In Canada, chick and feed cost are not provided by processors (the integrator) as in the U.S. system. Instead, chick and feed are the primary components of production costs for the Canadian chicken producers and an important part of the live price formula. Moreover, the chicken producer is the one who makes the final decision regarding the nutrition program used on their farm. As Canadian chicken producers have more freedom to select feed ingredients than U.S. producers, they are likely to have a greater influence on the qualities which could be influenced by dietary nutrition (the relationship between nutrition and yield quality will be further discussed in the chapter 3).

2.4 Summary

The chicken industry is a fast growing sector in the global meat market. The Canadian chicken industry also experienced a fast growing period in the last two decades. Operated under a supply management system, where price and supply levels are predetermined, the industry ensured consistent supply for consumers and also stable income for producers. Prices at the wholesale and retail level suggest that values of chicken meat differ across cut-up parts. However, due to the lack of a quality-based compensation scheme under the supply management, the value mark-up at the wholesale and retail level does not appear to transmit to the price given to producers by processors. We don’t have sufficient evidence to judge to what extent this system creates a welfare loss (income transfer) due to the nature of higher consumer prices (compared to the absence of supply-management) while maintaining income stabilization for producers.

By reviewing the performance evaluation in the United States, we have highlighted several key differences between the organization of the U.S. and the Canadian poultry industry, as they affect price determination, cost determination and means to affect quality by individual producers While the U.S. system appears more focused on cost efficiencies and size performance, the Canadian system is similar in its overall absence of focus on providing producers with incentives to focus on particular quality traits. It appears that the Canadian system is set to ensure stable income for producers. The system also gives producers more control over meat quality traits, since they have more flexibility regarding the use of inputs. However, the incentives for producers as they are currently set under the existing supply management scheme do not seem to be strongly focused on quality, as payment is largely based on weight as well as cost of production. Aside from this lack in focus on quality, there are other costs and benefits that have been identified for supply management systems. The following section aims to summarize these by reviewing the previous studies.

Chapter 3 Literature Review

3.1 Introduction

The main objective of this study is to develop a pricing scheme for the Canadian chicken industry that integrates quality traits, while accounting for consumer demand for such traits. To meet this objective, the literature review in this chapter will provide more detailed background from previous studies before such a pricing scheme can be developed.

The literature review consists of two parts. First, given the unique marketing system of the Canadian chicken industry, we will review previous studies on supply management in order to examine the rationale for and the impact of the supply management system. Second, we review previous studies with regard to the pricing schemes used in the North America agricultural sector, in order to provide a benchmark against which a novel pricing scheme can be developed.

3.2 Literature on supply management

Supply management was not adopted by the Canadian poultry industry until 1979. However, the formation of provincial marketing boards and their control over production decision can be traced back to 1963 (Martin and Holliday, 1977). The role of marketing boards, as well as the cost and benefit of supply management have been topics of considerable research attention since then. In this section, we will first summarize the key findings of these studies and then review each study in chronological order.

Based on previous studies, several conclusions can be drawn regarding supply management in the Canadian poultry industry:

First, the implementation of supply management has been able to meet its objective of enhancing price stability of the Canadian poultry industry. During the early stage of implementing supply management in the 1970s, marketing boards did not significantly enhance the stability of producer prices. But eventually, producers, or more precisely, large producers in the industry, became better off as they were capturing a certain degree of monopoly power, while the farm level price became higher and more stable as time went on. Many of the previous studies suggest that the gain at the farm level was a result of the income transfer from the processors, retailers and consumers to producers under supply management. However, the issue of social cost of supply management is still under debate. The diverging results on this topic greatly depend on the method that is employed in the research.

Second, producers do not act as monopolists in the supply management system. Processors and retailers also hold a certain degree of market power. Regarding marketing power of key players of the industry, some earlier studies suggest that marketing boards tried to control production so as to increase price, which leads to higher retail prices. However, later studies (such as Coffin et al., 1989; Fulton and Tang, 1999; Gervais and Devadoss, 2006) find evidence that producer marketing boards are not acting as monopolist and it is the processors and retailers who likely hold greater marketing power.

Third, there is evidence that supply management may be an appropriate response to potential market failures. On the one hand, supply management has been routinely criticized for restricting new product development, and reducing output so that retail prices are higher than they would otherwise be. On the other hand, as concluded by Gervais et al. (2007), previous studies provide evidence that supply management may be an appropriate response in light of two potential market failures, which are associated with (i) market price risks associated with chicken production and processing activities while no insurance and/ or hedging mechanism exists to perfectly redistribute risks across agents in the supply chain (Coffin et al., 1989; Gervais et al., 2007), and (ii) imperfect competition, such that supply management can potentially counter-balance the existence of market power beyond the farm gate (Fulton and Tang, 1999; Gervais et al., 2007).

Last but not least, a few studies have touched upon the impact of supply management on product quality. Funk and Rice (1978) highlight that the presence of marketing boards reduces processors' incentive to adopt new technology, as both their margin and market growth decreased. Coffin and Romain (1989) point out that the pricing scheme underlying supply management in the Canadian poultry sector may discourage the producer to improve quality.

After highlighting the key findings from previous studies on supply management, we now turn to the review of each of these studies. Back in 1977, before the implementation of supply management began in the chicken industry, Martin and Holliday (1977) tried to explain the output decision of the broiler marketing board and its actual impact on output and price in the market. Martin et al. (1977) compare the data of five provinces/regions of Canada under production control with the pre-board period in Quebec and the US for the period from late 1960s to early 1970s. The results suggest that reaction of output to market signals (e.g. changes in broiler and feed price) under the board control was slower than those under the non-control system or the U.S. vertical coordinated system during the study period. Moreover, they also find that the marketing board in Ontario and Quebec were responsible for the inefficient resource allocation during the early 1970's as they limited output growth in order to increase boiler price and benefit producers during the period.

Martin and Warlay (1978), test whether marketing boards successfully enhanced stability in terms of output, producer price, consumer price and industry gross revenue in five commodities including tobacco, pork, chicken broiler, turkeys and eggs. By analyzing the price and production data of these five commodities, and comparing them with the U.S. data, Martin and Warlay (1978) find that there is no significant increase in stability in terms of production, producer price or consumer price in the Canadian broiler and turkey industry. One of the reasons may be that the control scheme was not mature at that time as the implementation of supply management system had just begun (Martin and Warlay, 1978, p.883).

Funk and Rice (1978) investigate the impact of marketing boards on overall industry structure and the different stages of the supply chain with a focus on the Ontario Chicken Producer Marketing Board's role in the Ontario boiler industry. Based on in-depth personal interviews with general managers from all the major sectors of the Ontario Broiler Industry conducted in the early 1978, Funk and Rice (1978) find that there were increases in hatchery and feed company's gross margin, and decreases in processors' gross margin after the introduction of marketing board. Moreover, they find that the presence of marketing boards reduces processors' incentive of adopting new technology, as both their margin and market growth decreased. The marketing board's power of determining price and production quota has little overall effect on feed and hatchery firms, while it is found to have had an overall detrimental effect on processors (Funk and Rice, 1978).

Veeman (1982) uses a comparative static framework to assess the transfer and social cost effects of supply management for poultry products in the short run and long run. It is found that supply management benefits producers in terms of a significantly higher and more stable price. However, in the short-run, these producer benefits are accompanied with the increase of consumer expenditure and losses of economic efficiency. And in the long-run, the potential efficiency loss is substantial. The author points out that, as the supply management program distributed most of their benefits to large producers, it is necessary to seek ways to limit consumer cost and efficiency loss.

Lermer and Stanbury (1985) focus on the social costs associated with the redistribution of income affected by means of direct regulations. Lermer et al. (1985) apply data of the Canadian egg, turkey and chicken industry taken from Veeman (1982) to a capital asset pricing model (CAPM) and take into account the uncertainty of the additional income streams that transferred from consumers to producers. The results of their study suggest that the estimated social welfare loss of supply management is much greater than those identified in previous studies. The additional loss comes from risks born by producers (quota owners) under the restriction of a transfer of quota between producers. Based on these results, Lermer et al. (1985) suggest to pay compensation to producers and to eliminate the supply management scheme in the Canadian egg, turkey and broiler sector.

While most supply management studies use a partial equilibrium framework to assess the impact of supply management, Moschini (1988) goes further to develop an output constrained multiproduct joint profit model to analyze the resource allocation effects of supply management on the Canadian agricultural sector as well as its impacts on the non-restricted sectors. Based on the analysis of production data of industries with and without supply management for the period 1961-1983 in Ontario, the regulation of outputs, as under the Canadian poultry supply management system, is found to affect the demand for variable inputs as well as the supply of outputs when these were restricted by regulation. The reduction in the level of output of regulated commodities is accompanied by limited input substitution.

By reviewing the sequence of stages in the industrialization of Canadian agriculture and the marketing boards' response in each stage across several commodities, Troughton (1989) examines the relationship between the process of industrialization and particular response by the marketing board arrangement. The author concludes that a marketing board is not the only or necessarily vital component of industrialization, but it does result in greater efficiency in getting a quality product to market. Troughton's (1989) study also sheds light on a marketing board's impact on price and concludes that the supply management system has not been able to meet producers' goal either individually or collectively, as the higher and more stable price in the industry under "full supply management" were just assured for a few large producers. This benefit to a subset of poultry producers was predicted at the expense of a drastic reduction of producers with low income.

A subsequent study by Coffin et al. (1989) examines supply management exclusively in the context of the Canadian poultry system. Compared to many previous studies, Coffin et al. (1989) conclude with a more positive evaluation of supply management. The authors suggest that the poor evaluations from previous studies are resulted from the use of inappropriate methods and assumptions, such as the assumption of the perfect competition as an alternative of supply management. By reviewing the economic dimensions of the Canadian poultry sector during the 1980s, Coffin et al. (1989) conclude that the industry witnessed an improvement in productivity and a reduction in real price at the farm and processing level since the implementation of the national supply management scheme although not all these developments are directly related to supply management. Product quality in terms of chicken condemnation rate has also improved during late 1960s to early 1980s. In a test of monopoly power, Coffin et al. (1989) find little evidence of monopolistic behaviour of the marketing board on the national or provincial level and conclude that there is a considerable degree of market power in the hands of retailers. Furthermore, Coffin et al. (1989)

conclude that stability in terms of prices, price ration, per unit gross margin and "aggregated gross margin" has increased. Such risk reduction induced an increase in the actual production scale during the 1980's, while it also enhanced the stability of producers' income without apparently transferring risk to processors.

More recently, Schmitz and Schmitz (1994) review studies that analyzed cost and benefits of supply management in the Canadian dairy and poultry sector within a rent seeking framework. By reviewing the many controversial results from previous studies, Schmitz and Schmitz (1994) address that the discrepancy of these studies partly result from the absence of processors and retailers in the models.

In a study on the Canadian egg and poultry sectors, Beck, Hoskins and Mumey (1994) estimate the social welfare loss created when farmers bear the investment risk associated with possible termination of quota protection (the cost of risk bearing is the cost of bearing the risk that quota life may turn out to be different than expected). Data of the Ontario poultry industry in the year 1991 is employed to this composite model. The results suggest that the annual social welfare loss in 1991 was between $98 million (U.S. prices approach) to $126 million (tariff equivalent approach), which accounted for 6%-8% of total product value. Moreover, approximately half of this social welfare loss was due to the cost of risk bearing and this cost could be eliminated by converting quota rights from an indefinite term to a fixed term. The authors conclude that "changing the quotas to a short fixed term might halve the social welfare loss without imposing capital losses on farmers and might facilitate a return to a free market or auctioning new fixed term quotas" (Beck, Hoskins, and Mumey, 1994, Abstract).

Based on previous studies' findings regarding the costs of supply management and the non-competitive behaviour of the stakeholders, Schmitz (1995) attempts to answer why such a system can exist in Canada for so long, by using a rent seeking framework and Stigler's theory of regulation. Schmitz (1995) concludes that the reasons for the existence of supply management may lie in (i) the considerable rewards that the producer gets from rent seeking behaviour without affecting the politician and the regulator; (ii) the same political and economic ideology across producers; and (iii) the costs of pulling out supply management.

Considering the question of market structure associated with a sector operating under supply management, there are a number of studies that shed light on the issue of market power among the players in the agricultural sector under supply management.

Cranfield et al. (1995) employ the conjectural variations model framework of Appelbaum (1982) to test to what extent competitive behaviour in four key Canadian food processing industries, including the dairy, fruit and vegetable, poultry, and red meat, departs from the assumption of perfect competition. Based on the data from 1965 to 1990, the authors find that oligopoly power exists in all four industries where the degree of market power associated with the poultry processing sector is the lowest compared to the other three processing industries.

Fulton and Tang (1999) study the market power of the key stakeholders in the Canadian chicken industry, considering all stages instead of only one sector of the industry. Based on the data on the Canadian chicken industry for the period 1965-66 and 1995-96, the empirical results of Fulton and Tang (1999) suggest that market power was present at the chicken retailing and processing sector over the entire study period. Nevertheless, the higher retail prices cannot be entirely associated with supply management at the farm gate and thus the inception of poultry marketing boards.

More recently, Gervais and Devadoss (2006) provide an analysis of bargaining weights between each party in the Canadian chicken industry, by applying monthly price and cost data on both farm level and processing level in Ontario for the period from March 1997 to December 2002 to a joint profit maximization model. Gervais and Devadoss (2006) find that Ontario chicken processors have exercised greater bargaining power than the chicken producers during the study period as the estimated bargaining power coefficient of processors is almost four times larger than the bargaining power coefficient of producers.

3.3 Literature on pricing schemes in North American agricultural sectors

Following the review of previous work on supply management, we now turn to the review of related studies of pricing schemes. The review focuses on the four main pricing schemes that are commonly used in the United States and in Canada.

3.3.1 Related pricing schemes used in U.S. agricultural sectors

In this section, we will review a number of previous studies that shed light on the relative performance pricing scheme and the absolute performance pricing scheme used in the U.S. agricultural sectors, focusing on the mechanism of the two pricing scheme as well as a comparison of their potential advantages and disadvantages.

Formal production contracts are heavily used in a number of U.S. agricultural sectors, such as in hog production and poultry production. The pricing schemes adopted in these sectors can be classified into two types according to whether the performance of contract producers is measured by absolute performance or by relative performance. In an absolute performance system, the farmer will be evaluated against a fixed standard. In a relative performance system, which is also known as yardstick competition (Shleifer, 1985) or piece-rate tournament (Tsoulouhas and Vukina, 1999), farmers' performance is evaluated against other growers in the same field and period. In the case where the farmer's performance is measured by relative performance, contracts can either be based on the farmer's performance rank or on the average of other farmers (Knoeber and Thurman, 1995). While the relative performance pricing scheme is most heavily used in the U.S. boiler industry and the absolute performance pricing scheme is more popular in the hog industry, a number of studies have shed light to the mechanism of the two pricing schemes and compare their advantages and disadvantages.

Knoeber and Thurman (1995) provide a detail description of the relative performance pricing scheme used in the U.S. boiler industry and measure the risk shifting effect of the contracts based on relative performance. The initial description of relative performance pricing is closely based on Knoeber (1989) (see section 2.3.1). Grower performance is measured by settlement cost (Knoeber and Thurman, 1995, p.487), expressed as:

$$Settlement\ Cost = \frac{Chick \times 12 + Kilocalories\ \times 6}{Live\ Pound} \qquad \text{……………………………..….(3.1)}$$

where *chick* is the number of chicks placed in a flock,

Kilocalorie is the number of kilocalories in the integrator-provided ration,

Constant *12* and *6* serve to weight (or "price") the integrator provided inputs.

Improvement in feed conversion rate, decrease in mortality rate and increase in bird weight all result in a lower settlement cost, and indicates better performance of a grower. Under the relative performance contract, an average settlement cost of flocks harvested in a given period is calculated and then a grower's relative performance is determined accordingly. Payment received by a contract grower is calculated as

$$Payment_{ijk} = \left[Base_k + \left(S_{ijk} - \overline{S_k}\right)\right]Q_{ijk} \qquad \text{……………………..………….. (3.2)}$$

where $Base_k$ is the base payment received by growers in period *k;*

S_{ijk} is the settlement cost of the producer *i* for flock *j* in period *k*;

Q_{ijk} is the slaughter weight of flock *j* by producer *i* in period *k*;

$\overline{S_k}$ is the pounds weighted average settlement cost of the same group of grower in period *k*. (Knoeber and Thurman, 1995, p.490)

Based on the production data of seventy five boiler growers over a four year period from November 1981 to December 1985, the authors simulate payment under relative performance contract, absolute performance contract and for independent growers. Further, payment variances are decomposed into price risk, which results from the variation of boiler and feed price, common production risk borne by contemporaneous growers and idiosyncratic production risk. The results suggest that the form of contracting used in the U.S. boiler industry shifts nearly all risk away from growers. Price risk, which accounts for 84% of all risks in their study, is found to be the primary source of risks in the broiler industry. Common and idiosyncratic production risks each accounts for three percent of the total risks, and the remainder is attributed to the joint contributions of the three components.

Martin (1997) provides an introduction to relative performance pricing as well as an analysis of absolute performance pricing used in the U.S. hog industry. Moreover, by using performance record data of 123 absolute performance contract growers from September 1985 to December 1992, Martin (1997) simulates the income of these producers, first as if they were operating on an independent basis and then as if they would operate under relative performance. The income variability under the three types of contracts is then compared.

According to Martin (1997), under the absolute performance pricing scheme, payment received by a producer is composed of a fixed price and a bonus paid per head. The size of the bonus is typically based on the difference between the grower's feed conversion ratio (pounds of feed divided by pounds of gain) and a standard feed conversion ratio. The absolute performance contract payment is expressed as (Martin, 1997, p.269):

$$Y_{it}^{AP} = XG_{it} + b(\widetilde{FC} - FC_{it})HD_{it} \quad \text{………………………….………………….} \quad (3.3)$$

where Y_{it}^{AP}= absolute performance contract payment;

X= fixed piece rate per pound gained;

G_{it} = pounds gained;

b = incentive coefficient used in calculating per head bonus;

$\widetilde{FC}$ = standard feed conversion ratio;

HD_{it} = head shipped to market;

i = grower; *t* = a specific herd.

Base on the relative performance pricing scheme used in the broiler sector, Martin (1997) models payment for hog producers under relative performance following the contracts used in the boiler industry. Under such relative performance contract, payment also consists of a fixed price component and a bonus component. The bonus is based on the head-weighted mean feed conversion ratio of a group of farmers who finish hogs in the same period. In equation form it is expressed as (Martin 1997, p.269):

$$Y_{it}^{RP} = XG_{it} + b(\overline{FC} - FC_{it})HD_{it} \quad \text{………………………………………...} \quad (3.4)$$

The only difference when comparing equation (3.4) with equation (3.3) is that the size of this bonus now depends on the difference between the grower's feed conversion rate (FC_{it}) and the average performance of the grower's group($\overline{FC}$).

Further, prices received by independent hog producers are simulated in Martin (1997) using production data of the 123 producers and monthly market prices of inputs and outputs. Income of an independent hog producer is calculated as equation in (Martin 1997, p.271),

$Y_{it}^{IND} = \left(P_J^H Q_{ijt}^H\right) - \left(P_J^F Q_{ijt}^F\right) - (P_J^P Q_{ijt}^P)$ ……………………………….. (3.5),

where Y_{it}^{IND}= income for an independent hog producer;

P_J^H = price per pound of hog;

Q_{ijt}^H= pound of hog produced;

P_J^F = price per pound of feed;

Q_{ijt}^F= pounds of feed consumed;

P_J^P = price of feeder pig;

Q_{ijt}^P= pounds of pig purchased;

i = farmer, *j*= month, and *t* =a specific herd.

By comparing income variability under the three types of contracts, Martin (1997) finds strong evidence to support the argument that contract farming reduces grower income variability relative to independent growers. However, only weak evidence is found to support that relative performance contracts, which are set up similar to contracts used in the chicken broiler industry, could further reduce income variability for hog producers. One explanation provided by Martin (1997) for such weak evidence in additional risk shifting is the very nature and structure of the pork industry. The pork industry is different from the broiler chicken industry as the pork industry is not uniform in such characteristics as weight. This means there is greater variation in the performance of hog industries. The author concludes that for a relative performance contract to be effective, the contract must rely on increased contract production and more uniform pork production and processing.

A study by Vukina (2001) is also an important reference for our design of a novel pricing scheme. In this study, Vukina (2001) reviews the reasons for the emergence of relative performance contracts (also called tournament contracting) in the U.S. poultry industry (broiler and turkey), as well as their advantages and disadvantages.

According to Vukina (2001), a reason for the emergence of the use of relative performance contracts is that on the one hand, it can provide incentives for growers to exert efforts; and on the other hand, filters away production uncertainties common to the same group of growers, such as the effects of weather or untried feed mixes. Furthermore, by comparing productivity and prices with other livestock industries such as pork and beef where tournament contracting (relative performance contracting) did not occur, Vukina (2001) finds that the pace of technological change in the boiler sector was exceptional from the 1950s to the 1980s, which suggests significant productivity improvement after the implementation of vertical integration and tournament contracting. In addition, Vukina (2001) emphasizes that contracting and vertical integration in the poultry sector also enabled the industry to respond to changes in consumer preferences more rapidly, and to have greater control over the volume and quality of the products. In terms of possible disadvantages, Vukina (2001) highlights that it is difficult for growers to accurately predict their incomes under the tournament scheme because the price depends on the performance of other growers in the same group.

A study by Levy and Vukina (2004) further analyzes the two specific types of relative performance pricing schemes, namely the rank-order tournaments and the piece-rate tournaments, as well as the "league composition effect" arises under piece-rate tournaments.

According to Levy and Vukina (2004), a rank-order tournament is pricing scheme where only the rank of the grower matters in the allocation of rewards. An undesirable property of this form of tournament is that when the growers in a group have unequal abilities, the incremental reward for better or worse performance is the same at the margin, irrespective of the ability of the grower. The implication is that better players have no incentive to exert effort once they have information that they are going to win, and symmetrically, low-ability growers have no incentive to exert effort once they have information that they will lose anyway (Levy and Vukina, 2004).

The other type of relative performance payment scheme, piece rate tournament, refers to a tournament where the reward is a continuous function of the difference between an individual player's performance and the group average performance. Such piece rate tournaments are typically composed of a fixed base payment per pound of live meat produced and a variable bonus based on the grower's relative performance measured by settlement cost (Knoeber and Thurman (1995). Different from Knoeber and Thurman (1995), bonus payments in Levy and Vukina (2004) are set up as a *percentage* of the difference between group average settlement costs and the producer's individual settlement costs. The piece-rate tournament pricing scheme is expressed as equation (3.6) (Levy and Vukina, 2004, p.336):

$$y_{it} = [A + K(\frac{1}{n}\sum_{j=1}^{n}\frac{c_{jt}}{q_{jt}} - \frac{c_{it}}{q_{it}})]q_{it} \quad \text{...(3.6)}$$

where A denotes the base payment per pound;

$\frac{c_{jt}}{q_{jt}}$ is the individual grower's settlement cost;

$K$is the marginal bonus payment expressed as a percentage (50%-100%) of the production cost savings that a grower retains.

Compared with rank-order tournament, there is no efficiency loss associated with mixing players with unequal abilities in the piece-rate tournament (Levy and Vukina, 2004). However, one potential disadvantage of the piece-rate tournament is the league composition effect which refers the unpredictability of individual producer's income results from the group composition changes from flock to flock at the integrator's discretion. Under piece-rate tournaments, since the payment received by an individual grower depends on other growers' performance, the growers have no way of estimating the payment they will receive due to the league composition effect, even so their cost and ability are constant.

An alternative remuneration mechanism that can eliminate league composition has also been discussed in Levy and Vukina (2004). This mechanism is similar to absolute performance pricing scheme analyzed by Martin (1997). The total payment is a combination of a fixed base payment and a variable payment based on a fixed performance standard s, which is a predetermined feed conversion benchmark (Levy and Vukina, 2004, p.336),

$$y_{it} = [A + K\left(s - \frac{c_{it}}{q_{it}}\right)]q_{it} \quad \text{……………………………………………………………(3.7)}$$

In the simple piece-rate scheme (absolute performance scheme) described in equation 3.7, the fixed standard (s) represents a predetermined technological benchmark. Therefore, the simple piece-rate pricing scheme can eliminate the league composition effect as payment for individual producers are independent of the performance of other producers. However, as Martin (1997) also highlights, a drawback of such a simple piece-rate scheme is that it exposes producers to common production risks, which tournaments eliminate.

By applying data of production performance and payroll data from the U.S. broiler industry to a moral hazard model, Levy and Vukina (2004) conclude that a larger variance in individual abilities or a larger variance in the idiosyncratic shock favors the piece rate while a large variance in the common shocks favors the tournament. However, in a sufficiently long time horizon with fixed leagues scenario, a simple piece-rate contract will offer less variance than any tournament.

More recently, Zheng and Vukina (2007) analyzed the welfare effects of replacing an ordinal (rank-order) tournament with a cardinal tournament (relative performance based on average settlement cost of the group). Using data from 75 growers under rank-order tournament contract, Zheng and Vukina (2007) construct an empirical model of a rank-order tournament and simulate growers' performance under the cardinal tournament contract. The results indicate that switching from a rank-order tournament to a cardinal tournament, while keeping the growers' *ex-ante* expected utility constant, improves efficiency. The principal (integrator company) gains from the switch, whereas some of the agents (growers) gain and others lose, depending on their realized productivity shocks.

In summary, the pricing schemes that have been reviewed in this section include absolute performance pricing scheme, also referred to as fix performance or simple piece rate; and the relative performance pricing scheme, also referred to as tournament. Relative performance pricing schemes could be further divided into two major forms, rank-order tournaments and piece-rate tournaments. The potential advantages and disadvantages of these pricing schemes as they have been discussed in the previous studies are summarized in Table 3-1. In general, the findings of previous studies suggest that relative to independent production, contract farming, including both absolute performance and relative performance contracts, results in risk-shift from growers to integrators and reduces grower income variability. When comparing absolute performance and relative performance pricing, there is no consensus on their impact regarding price variability or welfare of the stakeholders, since the results depend on the specific industry being studied and the study's assumptions regarding the group composition.

Table 3-1 Summary of the pricing schemes used in the U.S. agricultural sectors

	Potential advantages	**Potential disadvantages**
Absolute performance (simple piece rate or fixed standard)	• Eliminates league composition effect; payment for an individual producer is not affected by performance of other producers; • Price predictability; • Offers incentive for exerting efforts.	• Expose growers to common production shocks.
Relative performance		
Rank-order tournament (ordinal tournament)	• Filters common production shocks	• Efficiency loss results mixing players with uneven qualities; • Payment for an individual producer depends on performance of other producers; • Uncertainty in payment.
Piece-rate tournament (cardinal tournament)	• Filters common production shocks; • No efficiency losses associated with mixing players of uneven abilities.	• League composition effect: variation from expected outcome of a tournament resulting from exogenous change in group composition; • Uncertainty in payment

3.3.2 Pricing schemes used in the Canadian poultry sector

The previous section highlights the main pricing schemes used in the U.S. agricultural sectors. The following section aims to summarize the literature with a similar perspective on the Canadian poultry sector, by reviewing the studies by Gervais et al. (2007) and Abbassi and Gervais (2010), highlighting in particular bargaining and formula-based pricing schemes.

In 2003, a significant reform of the Canadian poultry pricing scheme took place. A formula-based live price that is a function of chicken producers' costs was introduced to replace the bargaining pricing mechanism. Gervais et al., (2007) conduct a study to compare the effects of price bargaining and cost-plus pricing on producers' and processors' welfare.

Comparing the theoretical models of bargaining price and the formula-based live price, the substantial difference between the two schemes is the timing of decisions (Gervais et al., 2007). Under the bargaining pricing scheme, the farm price of chicken is set about six weeks after the output decision is made, while under the formula-based pricing scheme, the farm price is determined at the same time as output decisions. The difference in terms of the uncertainty of output price under the two pricing schemes could be illustrated by the producer's profits function provided by Gervais et al. (2007) as in Table 3-2 where r denote the farm price of chickens, Q denote aggregate production, w denote input prices, $C(Q, w)$ be the aggregate cost function of chicken producers and the symbol $\sim$ denotes randomness in a variable.

Using data on 49 quota allocation periods starting in August 1995 and ending in December 2002, Gervais et al. (2007) estimate producers' and processors' welfares under the assumption of risk-adverse producers. The result suggests that the expected utility generated under the cost-plus formula pricing is less variable than under the bargaining scenario. But the bargaining pricing mechanism generally yields higher expected utility for producers than the formula-based price while processing firms obtain a higher expected utility under the formula-based pricing than under the bargaining framework.

Table 3-2 Sequence of decisions in the chicken supply chain and uncertainty under different marketing scenarios

Weeks before beginning of marketing period	Bargaining pricing	Formula-based pricing
18 weeks	$\pi = \tilde{r}\tilde{Q} - C(\tilde{Q}\tilde{w})$	$\pi = r\tilde{Q} - C(\tilde{Q}\tilde{w})$
12 weeks	$\pi = \tilde{r}Q - C(Q\tilde{w})$	$\pi = rQ - C(Q\tilde{w})$
4 weeks	$\pi = rQ - C(Q\tilde{w})$	$\pi = rQ - C(Q\tilde{w})$
Beginning	$\pi = rQ - C(Q\tilde{w})$	$\pi = rQ - C(Q\tilde{w})$

Source: Gervais et al., 2007, page 257

Abbassi and Gervais (2010) further investigate the impact of switching from a bargaining pricing scheme to a formula-based pricing scheme in the context of the Canadian chicken sector. In their study, Abbassi and Gervais (2010) take into account the role of inventories in determining market outcomes for the chicken and model the output and sales decisions of chicken processing firms under both pricing schemes using a linear-quadratic inventory model. The results of the simulations of the impact of change of pricing schemes suggest that producers' expected profits are lower on average under the bargaining system than under formula-based system. Moreover, the formula-based system reduces the variability of profits.

3.4 Summary

This chapter reviewed a number of previous studies on supply management and pricing schemes used in the North America agricultural sector, as they are relevant to the thesis's key objective of developing a quality-attribute based pricing scheme between chick producers and processors under the continuation of supply-management in the Canadian poultry sector.

Although a few studies (e.g.Funk and Rice, 1978; Coffin and Romain, 1989) point out that supply management has discouraged quality improvement, we find no strong evidence for the necessity of a fundamental reform of the supply management system, since the majority of these studies suggest that supply management has managed to meet the goal of enhancing price stability in the Canadian chicken industry without causing significant social cost or monopoly behaviour of producers. Therefore, for the remainder of this study, supply management will be considered as a given constraint under which the new pricing scheme is discussed.

This chapter has also reviewed studies which have analyzed the mechanisms as well as the potential advantages and disadvantages of four types of pricing schemes. Considering the lessons learned from these pricing schemes, a simple absolute performance pricing scheme is proposed for the Canadian poultry sector in the following chapter. Several implications of implementing this novel pricing scheme are subsequently explored after a detailed introduction to the empirical data.

Chapter 4 Methodology and data analysis

4.1 Introduction

In this section, a new pricing scheme is developed that rewards Canadian chicken producers for quality attributes, taking into account previous experiences with absolute and relative performance schemes in North America. Our approach is centered on three key considerations.

First, accounting for the fact that the Canadian chicken industry operates under a supply management system, the novel pricing scheme to be explored should be in conformity with supply management's key objective of ensuring a "fair return to producer and consistent supply" (Agriculture and Agri-Food Canada, 2011). To this end, production quantity in each period is assumed predetermined by a production quota. In order to ensure that the prices received by producers can cover the average total cost of production, production cost is one of the key components in the pricing scheme. Moreover, to meet the main objectives of this thesis, producers' performance in quality traits is explicitly taken into account in the pricing scheme.

Second, regarding the form of pricing scheme, we propose to maintain the core of the formula-based pricing mechanism. One reason is that, according to the studies by Gervais (2007) and Abbassi (2010), we expect that the formula-based pricing scheme reduces the cost-uncertainty faced by processors and improves efficiency of the industry. More importantly, a formula-based pricing scheme would be more suitable for a pricing scheme that considers producers' performance. This is because producers' performance, according to which the rewards or discounts are determined, should be evaluated relative to a specific standard instead of the negotiation between the two parties. In fact, the pricing schemes in the U.S. chicken industry that reward producers for better feed conversion performance or settlement cost can be considered to be in a formula-based form consist of the fixed fee and bonus components.

Third, with respect to the performance evaluation method to be used in this thesis, we propose to adopt an absolute performance scheme considering the available data and the objectives of the study. Recall as mentioned in the literature review section, within an absolute performance scheme a producer's performance is evaluated by considering a fixed standard. Compared with the relative performance scheme, a potential disadvantage of the absolute pricing scheme is that it exposes producers to common production risks. However, considering that the production data used in this study is obtained from biophysical experiments conducted in a Canadian experimental station where the production conditions faced by all hypothetical producer are similar, we anticipate that the impact of the common production risks associated with factors such as feed quality, animal genetics and weather are minor and the payments calculated under the two pricing schemes are unlikely to be significantly different.

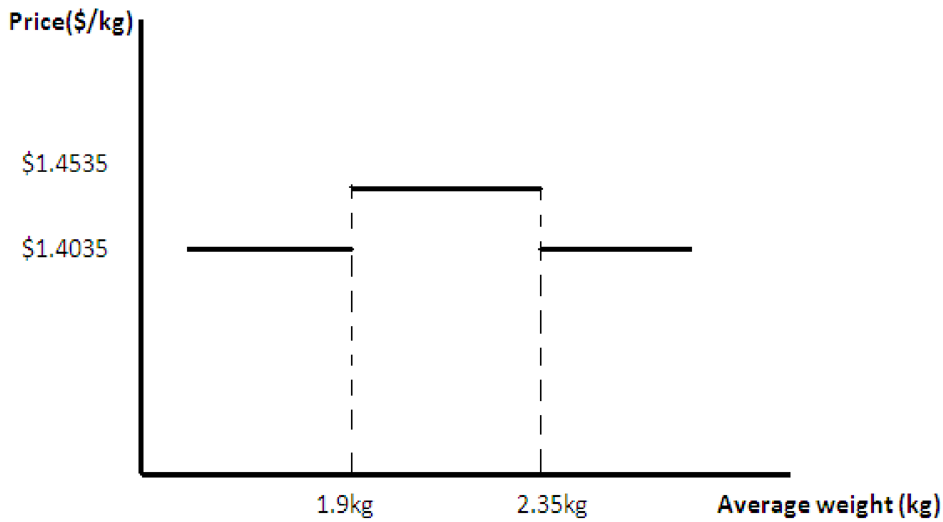
Considering that processors each have different requirements regarding quality traits (cut-up part yield in our context) due to the different markets they specialize in, we introduce varying producer requirements into the pricing scheme. Thus, to simulate a realistic scenario that accounts for varying producer requirements, we adopt an evaluation method based on absolute performance where the fixed standards with respect to quality are set by processors. The fixed standards are constrained by the overall performance of the producer groups and the technological level in the production period.

Taken together, the novel pricing scheme to be developed in this study is a formula-based, absolute performance pricing scheme. The pricing determination follows a two-step system. The first step is the base price determination which is consistent with the current pricing scheme. It is based on the average total cost of production of a representative sample of producers as well as the average live weight of all chicken contained in each truckload shipped by the producer to the processor. In the second step, premiums or discounts are determined based on producers' performance with regard to each quality trait. Producers who have better performance receive a premium while those with worse performance receive a discount. A stylized description of the two steps is presented in Figure 4-1 and 4-2 and the discussion that follows.

In the base-price determination, the price paid to producers is conditioned on production costs including chick cost, feed costs, plus producer margins. Average live weight will also be taken into consideration. Adopting the prices offered by Lilydale in period A96 as an example, Figure 4-1 describes the base-price determination with a target average weight that ranges from 1.9-2.35kg. The horizontal axis represents the average live weight. The vertical axis represents the price level for each weight category. As shown in Figure 4-1, chicken that fall into the target weight range would receive a relatively higher base price

($1.4535/kg) while those who fail to meet the target average weight would receive a lower price ($1.4035/kg) with a $0.05/kg penalty.

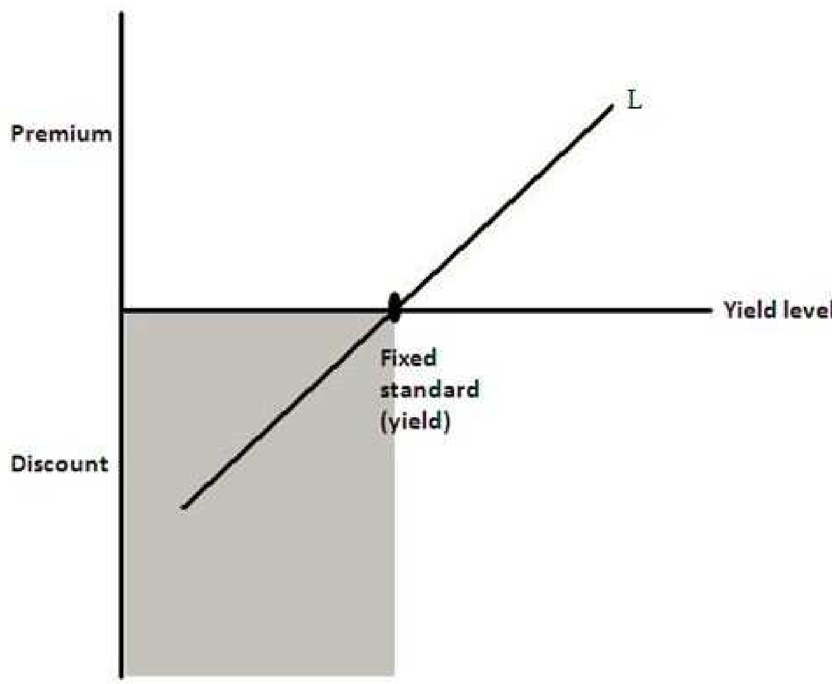
Figure 4-1 Step 1: Base-price determination



In the second step, a premium or discount is applied based on a grower's performance. In this study, the reward scheme is set up similar to the absolute performance scheme used in the U.S. hog industry as described by Martin (1997) and Levy and Vukina (2004), which takes processors' requirements into account by employing a fixed standard, while abstracting from the league composition effect by employing a piece-rate relative performance scheme.

In contrast to the schemes as proposed by Knoeber and Thurman (1995) and Levy and Vukina (2004) (discussed in detail in the literature review in chapter 3) where performance of growers is reflected in terms of settlement cost, and in contrast to the study by Martin (1997), where performance is measured by a feed conversion ratio, performance of producers in this study is measured exclusively by the yield level of the three cut-up parts, namely, breast yield, wing yield and leg yield. We abstract from settlement costs because of the lack of available detailed cost data from the producer and processor level (slaughtering costs). Similarly, since we don't have precise knowledge about individual processor's preferred quality parameters, and as these parameters likely change over time, we will first abstract from this issue and consider one representative processor only (we will use historical weight parameters from one processor, Lilydale, as a benchmark).

Figure 4-2 Step 2: Premium/discount determination



The premium/discount determination as part of the proposed pricing scheme can be illustrated by Figure 4-2. The vertical axis in Figure 4-2 represents the premium/discount of a specific cut-up part for an individual producer. The horizontal axis represents the performance of the producer measured by cut-up part yield level. The line *L* indicates a linear relationship between the premium and cut-up part yield level by a producer, where the slope of line L is the unit premium β. Notice that this linear relationship does not necessarily exist between premiums and the underlying actual production effort with regards to the observable quality. As will be discussed below (section 4.3.4), the relationship among the three cut-up part yields and the underlying production efforts for yield are affected by multiple elements, such as the cost of effort and the elasticity of demand for the qualities. Moreover, given the fact that yield level is constrained by the biological characteristics of chickens and by the technology employed, the underlying production effort is expect to have diminishing marginal returns and a nonlinear relationship with price.

In equation form, the basic proposed pricing scheme could be expressed as follow:

$$\mathrm{P}^{i} = BP_i + \beta_B \times \left(\mathrm{BY_i} - \widetilde{BY}\right) + \beta_W \times \left(\mathrm{WY_i} - \widetilde{WY}\right) + \beta_L \times \left(\mathrm{LY_i} - \widetilde{LY}\right) \quad \ldots\ldots\ldots\ldots..(4.1) \quad ,$$

where P^i is the price received by producer i, $i \in$ N = {1, 2, 3, … m};

BP_i is the base price paid to producer i;

BY_i , WY_i, and LY_i are the breast yield, wing yield and leg yield of producer i;

$\widetilde{BY}$,$\widetilde{WY}$ and $\widetilde{LY}$ are the fixed standard on yield level of each cut-up part predetermined by processor;

β_B, β_W and β_L are unit premium or discount parameters applied on the three cut-up parts, where the total premium/discount depends on the distance between performance of producer i relative to requirement of processor.

In order to develop the above pricing scheme further, we need to answer two key questions:

1) To what extent can producers control the three quality traits?

2) What appropriate price premiums/discount (β_B,β_W,β_L) for each quality trait should be offered by the processor?

To answer the first question, we use data from a biological experiment on the variation among the three quality traits and their relationship with feed ingredients. For the second question, aggregate wholesale level price data are employed to determine a range of price premiums and discounts.

4.2 Introduction to the biological experiments

Data about quality traits and feed intake were obtained from a previous project by Zuidhof et al. (2008), investigating the impact of dietary balanced protein (DBP) and metabolizable energy (ME) levels on performance of Cobb Avian 48 broilers to 56 d of age. Chicks were randomly assigned to a 2 x 2 x 3 x 5 factorial treatment arrangement, with 2 sexes; 2 levels of early nutrition (0 to 11 d); and after 11 d, 3 dietary ME levels and 5 dietary balanced protein (DBP) levels, balanced for 6 amino acids: Methionine, Methionine + Cysteine, Tryptophan, Threonine, and Arginine (Met, Met+Cys, Trp, Thr and Arg). The three ME levels were 94%, 97%, and 100% of Cobb-Vantress dietary specifications for maximum growth rate and feed efficiency. The five DBP levels were 85%, 92.5%, 100%, 107.5%, and 115% of the same specifications. From 0 to 11 days, two pre-starter nutrient densities were used, based on Cobb's starter recommendations for maximizing growth rate and feed efficiency (HighPS), or for reduced feed cost (LowPS).

Individual body weight (n=1200) and feed intake data (n=60) were collected weekly, and at the 11-day of age (the end of the pre-starter phase). Average daily feed intake (g/bird/d), crude protein intake (g/bird/d), and ME intake (kcal/bird/d) were calculated. 4 birds per pen (per DBP*ME*Sex interaction) were processed at 21, 28 d of age (n=120 per age), and 8 birds per pen at 31, 36, 42,45,49,52 and 56 d of age (n=240 per age). Body weight at the time of feed withdrawn, weight of eviscerated carcass, weight of cut-up parts were measured when the birds were processed. Carcass yield, breast yield, wing yield, leg yield were calculated afterwards. A summary of data gathered from the above experiments will be presented further below.

4.3 Analysis of experimental data

As mentioned in chapter two, prices producers receive under the current pricing scheme are based on the average live weight of birds of the same truckload from a given producer. In the following analysis, the weight range used by Lilydale in period A-96 (06-Febuary-2010 to 03-April-2010) is employed as a benchmark for live weight categories in our study. In the A-96 period, the price of chicken with average weight below 1.90kg was $1.4035/kg, the price of chicken between 1.90kg to 2.35kg was $1.4535/kg, and the price of chicken above 2.35kg was $ 1.4035/kg.

4.3.1 Distribution of quality traits in the same weight range

Given the above weight ranges and corresponding prices, the first question to be answered is that to what extent the three quality traits actually vary by different hypothetical producers (considering the biological experiments in terms of representative producers, where the chicken from each pen in the experiment correspond to the chicken from one representative producer), even if they fall into the same weight category and thus would receive the same price?

To answer this question, we use the prices offered by Lilydale in period A-96 as an example, and sort out the chicken from the experiments that fall in the weight range between 1.90kg to 2.35kg and examine the distribution of the three qualities within this weight range. The descriptive statistics with regard to weight and yield of breast, wings, legs, and eviscerated weight are presented in Table 4-1. The total number of birds in the experiment that fall into the weight category is 322 with 125 males and 197 females in age range from 31 to 52 days old. Yield of cut-up part is the proportion of the weight of the corresponding cut up part to the weight of eviscerated bird.

The distribution of the three cut-up parts yields are shown in Figure 4-3, 4-4 and 4-5 respectively. As the figures show, although the birds would currently receive the same price as they are in the same category, there is heterogeneity in terms of quality since their cut-up yield level varies. For example, breast yield of the sample varied from 22.97% to 35.09%, with a mean of 30.07% and a standard deviation of 1.78%; and leg yield varied from 28.73% to 35.85%, with a mean of 32.48% and a standard deviation of 1.32%.

Notice that in the experiment, feed ingredients are formulated and prepared by the same institution, which means that the raw material used in the feed in the experiments are likely to have similar quality. In comparison, producers in the real market buy feeds from different feed mills. The variation in raw materials used in feed production across feed mills may results in even greater variation in the quality of feed used by real producers compared to the experiment scenario (Kirkwood, 2010). Assuming feed is a significant factor that affects quality traits (which we will discuss in the following section), it can be expected that the variations of quality traits in the real world are larger than those in the experiment. The higher variation in quality traits that we expect in the real world has an important implication: the results from a quality-based pricing scheme that builds upon the experimental data are expected to be robust in the sense that greater quality variations in the real world should justify a pricing scheme that explicitly accounts for such quality variation.

Table 4-1 Descriptive statistics of weight and yield data that fall in the weight range between 1.9kg to 2.35kg

	N	Mean	St. Dev	Min	Max
age(days)	322	37.54	2.47	31.00	52.00
breast(g)	322	391.64	41.08	256.20	510.70
wings(g)	322	163.90	13.37	131.60	201.60
legs(g)	322	422.24	31.75	348.20	522.80
eviscerate body weight(g)	322	1300.80	93.30	1101.00	1512.80
body weight (g)	322	2132.10	133.68	1901.00	2350.00
breast yield(%)	322	30.07	1.78	22.97	35.09
wing yield(%)	322	12.61	0.74	10.74	15.90
leg yield(%)	322	32.48	1.32	28.73	35.85
carcass yield(%)	322	61.00	1.77	54.64	65.83

Figure 4-3 Distribution of breast yield within the weight range 1.90kg to 2.35kg

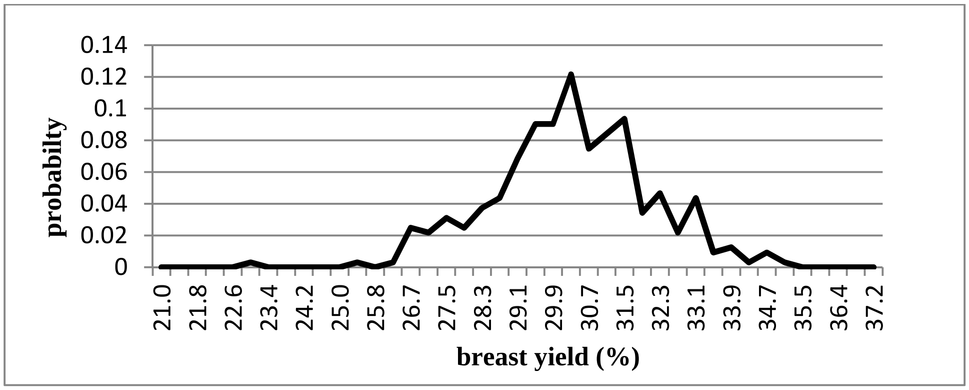


Figure 4-4 Distribution of wing yield within the weight range 1.90kg to 2.35kg

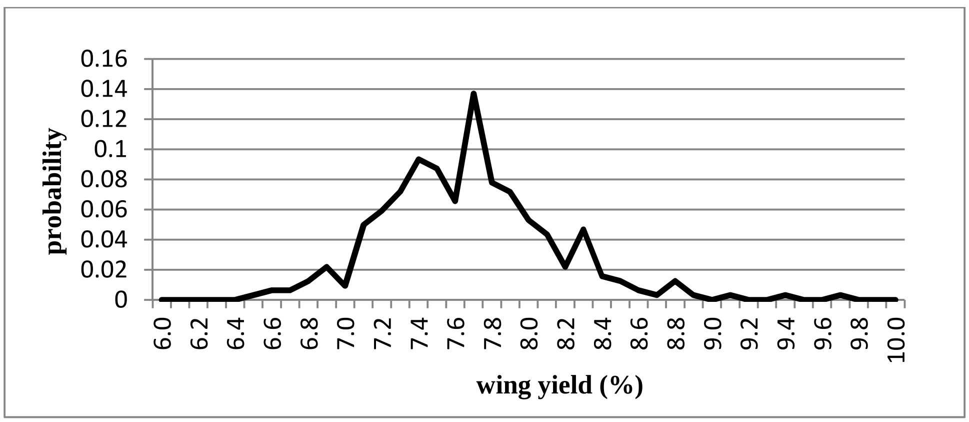
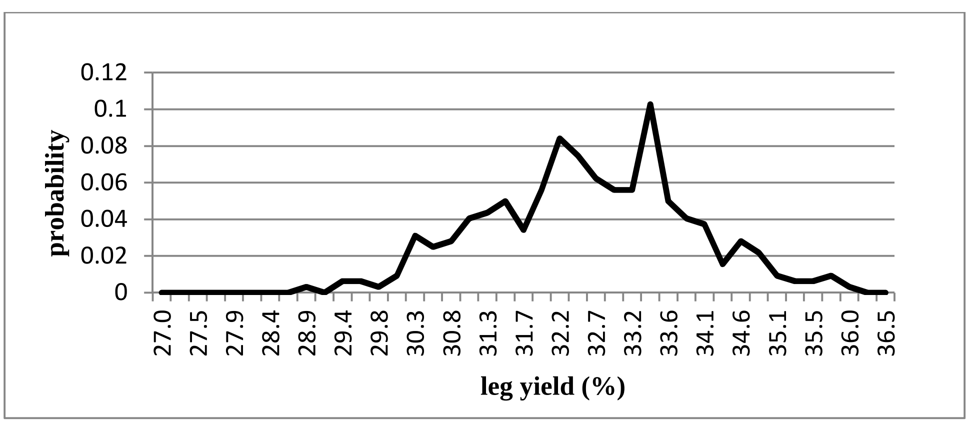


Figure 4-5 Distribution of leg yield within the weight range 1.90kg to 2.35kg



4.3.2 Biological models of quality and treatment methods

In this section, the relationship between quality traits and dietary balanced protein (DBP) and metabolizable energy (ME) levels is examined. There are two questions that will be explored in this section:

1. What is the impact of DBP and ME level on the levels of the three quality traits (yield of cut-up parts)?
2. To what extent the quality trait can be predicted in specific scenarios?

Experiment data of 1130 Cobb Avian 48 broilers from age 21 to 56 days is the basis of the analysis in this section. Ordinary least squares regression is employed to identify the factors that affect yield level of each cut-up part. Key factors being examined include age, sex, pre-starter diet treatment, and energy level and protein level in feed. An explanation of variables underlying the biological model is provided in Table 4-2 and the results are presented in Table 4-3.

Breast yield results

As shown in Table 4-3, age is positively related to breast yield, the proportion of breast meat to the eviscerated body weight increases as the bird get older. The interaction terms between average daily feed intake and metabolizable energy (*AMEFI)* and the interaction term between average daily feed intakes with crude protein level (*CPFI*) are statistically significant in the model, indicating the significant impact of the energy intake and protein intakes on breast yield. A negative parameter of energy intake suggests that a lower metabolizable energy level results in higher breast yield, while the positive parameter of protein intake suggests that a higher protein level increases breast yield. However, the negative sign of the squared term of protein intake (*CPFI2*) indicates diminishing return with high protein levels. Sex of chicken is statistically significant in the model. The positive parameter of sex indicates that female is likely to have a higher breast yield than male birds. The parameter of the interaction term between sex and protein level is significant and negative, a higher protein level results in lower breast yield in the case of female birds compared to male birds. Pre-starter treatment is not statistically significant in the breast yield model.

Wing yield results

In the wing yield model, age (*AGE*) is the only significant factor. From day 21 to 56, the growth of wing yield is negatively related to age. It implies that the growth of wings is slower than the growth of the rest of the body from day 21. Metabolizable energy and protein level, pre-starter treatment, sex do not significantly affect wing yield in this model.

Leg yield results

Similar to the wing yield model, age (*AGE*) is a significant and negative factor in the leg yield model. Pre-starter treatment (*PS*) and the interaction term between pre-starter treatment and metabolizble energy level (*PREAME*) are statistically significant. Birds in high pre-starter treatment have higher leg yield than in the low pre-starter treatment. High pre-starter treatment combined with high metabolizable energy level has a negative impact on leg yield.

Table 4-2 Explanation of variables in the biological model

	Variable explanation
Dependent variables	
Y_i	Yield of cut-up part *i*, *i*=breast, wing or leg. Yield (%)=weight of cut-up part divided by weight of eviscerated carcass
Explanatory Variable	
AGE	Age of the bird when it is eviscerated. age= 21, 28, 31,36, 38,42,45,49,52 and 56 days
AME	Apparent metabolizable energy (kcal/g)
CP	Crude protein level (%)
FI	Average daily feed intake
SEX	Sex of the bird (female=1, male=0)
PS	Pre-starter treatment (high=1, low=0)
AMEFI	Interaction term between AME and FI, indicating energy gain from feed
CPFI	Interaction term between CP and FI, indicating intake of protein
CPFI2	Square of CPFI
PRECP	Interaction term between Pre-starter treatment (PS) and protein level (CP)
PREAME	Interaction term between Pre-starter treatment (PS) and energy level (AME)
SEXCP	Interaction term between Sex (SEX) and protein level (CP)
SEXME	Interaction term between Sex (SEX) and energy level (AME)

Table 4-3 OLS results of the biological model

	breast yield		**wing yield**		**leg yield**	
Variable Name	Estimated Coefficient	P-VALUE	Estimated Coefficient	P-VALUE	Estimated Coefficient	P-VALUE
AGE	0.127***	0.000	-0.062***	0.000	-0.024**	0.00
AMEFI	-0.005***	0.003	0.001	0.386	0.001	0.329
CPFI	0.313***	0.000	0.020	0.566	0.016	0.801
CPFI2	-0.002*	0.055	-0.0004	0.378	-0.001	0.297
SEX	2.835**	0.028	-0.734	0.165	-0.640	0.511
PS	-1.108	0.612	0.824	0.358	3.387**	0.040
PREDBP	-0.024	0.595	-0.026	0.159	0.041	0.228
PREAME	0.559	0.474	-0.109	0.734	-1.405**	0.017
SEXDBP	-0.082**	0.065	0.024	0.194	-0.012	0.712
SEXME	-0.001	0.243	0.001	0.198	0.000	0.621
CONSTANT	18.655	0.000	14.354	0.000	33.764	0.000
R-SQUARE		0.478		0.429		0.090

Notes: *** denotes significance at the 99% of confidence; ** denotes significance at the 95% of confidence; * denotes significance at the 90% of confidence.

4.3.3 Prediction of cut-up part yield ---- Scenario-specific analysis

In order to examine the impact of different dietary treatments on the growth rate of cut-up parts, pens that use the same combination of DBP and ME level are treated as representative producers, and each combination of DBP and ME is treated as a specific scenario. In total, there are fifteen scenarios in the experiment.

An allometric model is employed next to examine the cut-up part growth rate in each scenario. Allometric models ($y = ax^b$) have been used to predict animal growth rate in many previous studies. According to Fisher and Boorman (1986), an allometric relationship exists for a given kind of animal when the graph of $ln(C)$ against $ln(P)$ is plotted as a straight line, where C represents the whole body and P represents a part of the body.

Correlation coefficients are used for exploratory analysis. Correlation coefficients between the logarithm of cut up part weights and eviscerated body weight are thus presented in Table 4-4. All correlation coefficients are close to one, indicating a strong linear relationship between these cut up parts and eviscerated body weight, which thus supports the use of the allometric function.

Table 4-4 Correlation coefficient matrix of ln(breast), ln(wing),ln(leg) and ln(bwebis) (1124 observations)

$ln(bwevis)$	0.99499	0.99288	0.99685
	$ln(breast)$	$ln(wing)$	$ln(leg)$

For the purpose of this study, the allometric model of the weight of three cut-up parts is expressed as:

$breast = A(bwevis)^{B}$ ……………………………………………….(4.2)

$wing = C(bwevis)^{D}$ ……………………………………………….(4.3)

$leg = E(bwevis)^{F}$ ……………………………………………….(4.4)

where *breast*, *wing*, *leg* and *bwevis* is the weight of breast meat, wing meat, leg quarter and eviscerated body weight, respectively;

A, B, C, D, E and F are coefficients that describe growth rates.

The model can be converted into the following system that can be used to predict yield level via dividing both sides by *bwevis*, and the three corresponding yield models are thus:

$BY = A(bwevis)^{(B-1)}$ ……………………….………………………..(4.5)

$WY = C(bwevis)^{(D-1)}$ …………………………………..…………..…(4.6)

$LY = E(bwevis)^{(F-1)}$ ……………………………...…………………..(4.7)

Sign and magnitude of the estimated coefficients could be used as an indicator of the relationship between of eviscerated body weight and cut-up part yield in different scenarios. Take breast model as an example, if B <1 and $A > 0$, the first derivative of the model would be less than zero ($BY' < 0$), which indicates that a one unit of eviscerated body weight increase decreases breast meat yield (%), and vice versa.

The above allometric models for the three cut-up parts (equation 4.2 to 4.2) have been estimated by Zuidhof (2009) based on the same dataset and the results are presented in Table 4-5

Table 4-5 Result of the allometric models, scenario specific

		breast		wing		leg	
Scenarios		Estimated coefficient		Estimated coefficient		Estimated coefficient	
ME	**DBP**	A	B	C	D	E	F
94	**85**	0.1851	1.0656	0.2896	0.8813	0.3619	0.9848
	92.5	0.1826	1.0700	0.2849	0.8845	0.3417	0.9916
	100	0.1671	1.0831	0.2905	0.8005	0.3580	0.9865
	107.5	0.1444	1.1041	0.3024	0.8756	0.3745	0.9804
	115	0.1398	1.1090	0.3196	0.8666	0.4176	0.9647
97	**85**	0.1608	1.0824	0.2715	0.8893	0.3575	0.9882
	92.5	0.182	1.0691	0.3201	0.8699	0.2866	1.0164
	100	0.1867	1.0682	0.3291	0.8649	0.3200	1.0001
	107.5	0.1924	1.0635	0.3243	0.8660	0.2705	1.0248
	115	0.2253	1.0429	0.2739	0.8894	0.2602	1.0291
100	**85**	0.1803	1.0664	0.3049	0.8761	0.3217	1.0021
	92.5	0.1743	1.0725	0.2970	0.8798	0.3431	0.9930
	100	0.1638	1.0844	0.4024	0.8371	0.3812	0.9776
	107.5	0.1573	1.0919	0.2632	0.8949	0.3545	0.9865
	115	0.1559	1.0938	0.2828	0.8846	0.3158	1.0021

Source: Zuidhof, 2009, page 26

According to the results of the allometric model, all of estimated coefficients *B* in the breast yield model are greater than 1, which indicates that breast yield increases as eviscerated weight increases. Coefficients *D* in the wing model range from 0.8 to 0.9, indicating that wing yield decreases as eviscerated weight increases. Coefficients *F* in the leg model are closed to 1, indicating that leg growth occurs at a similar rate than the body as a whole. This set of coefficients could be applied to equation 4.5 to 4.7, and used in the prediction of cut-up part yield given the DBP and ME level and eviscerated carcass weight.

Notice that the growth model in section 4.3.1 and coefficients for the prediction of the cut-up part yield estimated in section 4.3.2 are based on the experiment with a certain strain of broiler (Cobb Avian 48). The impact of a same feeding treatment is likely to be different across broiler strains (Smith and Pesti, 1998). Therefore, these results are not universally applicable to all strains and different stains should have different feeding programs to optimize growth and quality.

4.3.4 Correlation and production relationships among the three quality traits

In addition to the relationship between the three cut-up part yields and the growth of the whole bird which is examined in previous section, we are also interested in the relationship among the three cut-up parts. Therefore, the correlation of the three quality traits is examined and the correlation coefficient matrix is presented in Table 4-6.

Table 4-6 Correlation coefficient matrix of three quality traits (n = 986)

Breast Yield	1		
Wing Yield	-0.34	1	
Leg Yield	-0.19	0.44	1
	Breast Yield	*Wing Yield*	*Leg yield*

Correlation coefficients indicate the strength of the linear relationship between two variables. Correlation coefficients ranging from 0.0 to 0.2 indicate very weak to negligible correlation, 0.2 to 0.4 indicates weak or low correlation and 0.4 to 0.7 indicates moderate correlation. As Table 4.6 shows, the linear relationships among the three quality traits are weak to moderate indicating no significant positive or negative correlation. Therefore, we can expect that it will be possible for producer to get both premium and discount for different qualities. As a result, the income variation that may be induced by the new pricing scheme could be reduced to some extent.

Notice that the linear correlation of the three quality traits discussed above does not necessarily correspond to their production relationship. This is because the producer effort related to these qualities can be related to various factors such as the cost of effort, the uncertainty related to each quality, the elasticity of demand for the qualities (Slade,1996). The production relationship of the three qualities could be a factor based on which the optimal magnitude of premium/discount of the pricing scheme is designed. However, due to the lack of data, we cannot examine the actual production relationship of the three quality traits in this thesis.

Considering these results, and the above insights from the biological model, the question now is how to combine the biological growth model results with market valuations as reflected in processors' willingness to pay. To do this, the following sections employ wholesale price data, to identify market value of each cut-up part and the explicit quality incentives the chicken producers could receive for their production process.

4.4 Price data and premium determination

In this section, wholesale prices of different cut-up parts are used to design the premiums and discounts for a quality based pricing scheme. An introduction to wholesale prices will be provided followed by an analysis of price mark-ups of cut-up parts in section 4.4.1. The determination of premiums and discounts will then be discussed in section 4.4.2.

Notice that the analysis of this section relies on a “constant mark-up” assumption, i.e. it assumes that the mark-up from processor to producer is identical, irrespective of the nature of the cut. In other words, the value of the mark-up of cut up parts relative to the whole carcass in percentage form is assumed constant at the production level and processing level. As a result, the price mark-up at wholesale level is used to derive premiums and discounts to be applied to the producing level.

4.4.1 Introduction of wholesale price data

Wholesale price data collected by Express Markets, Inc. (EMI) based on actual invoice data from nine Canadian processors is accessed from the Chicken Farmers of Canada and the Canadian Poultry and Egg Processors Council. Weekly weighted average Whole Bird Complex, Breast Complex, Wing Complex and Leg Complex, which are the indices measure the values of the four major cut-up part groups in cent per kg, are available from January 2002 to August 2010 at the national level. The four market complexes cover products sold in bulk, Air-chilled and wet-chilled, Ice pack and Fresh. The Whole Bird Complex is the simple average of prices of the “whole bird” group and “wog” group. The “whole bird” group includes: whole bird < 1.36 kg, whole bird > 1.36 kg and whole bird unsized. The “wog” group includes: wog < 1.13 kg, wog 1.13-1.80 kg, wog >1.80 kg and wog unsized. The Leg Complex is the simple average of the prices of leg quarters, whole legs, thighs and thighs with back and drumsticks. The Breast complex is the simple average of the price of “breast meat” group, “fronts” group, whole breast and split breast. The “breast” group include b/s breast unsized, b/s breast sized and tenders. The “fronts” group includes front halves and fronts without wing. The Wing Complex is the simple average of the prices of whole wings, wings, drumettes and midjoint (Chicken Farmers of Canada, 2011). Descriptive statistics of the wholesale price data is presented in Table 4-7 and the price trend is shown in Figure 4-6.

As Table 4-7 and Figure 4-6 show, breast is the most expensive cut-up part during most of the study period. The breast complex peaked at 701.40cents/kg in January 2004 and then maintain at around 500cents/kg for the rest of the period. The wing complex (average weekly price = 406.64 cents/kg) is lower than breast complex but it has been gradually moving up since June 2006 and exceed the breast complex in several weeks during 2009 and 2010. The whole bird complex and leg complex witnessed a steady upward trend during the whole period with less variation compared to breast and wing complex. The leg (average weekly price = 204.60 cents/kg) remained the category with the lowest price for the whole period.

In the following, the concept “price mark-up” is employed to derive the market value of cut-up parts. The price mark-up is the price difference between the wholesale price of the corresponding cut-up part and the price of the whole bird complex in the same period. It is calculated as equation (4.8). The price mark-up could be either greater, equal to or less than zero. A negative price mark-up indicates that the market value of a particular cut-up part is lower than the whole chicken, and vice versa.

$$MK_i = \left[\left(\frac{P_i}{P}\right) - 1\right] \times 100\% \qquad (4.8)$$

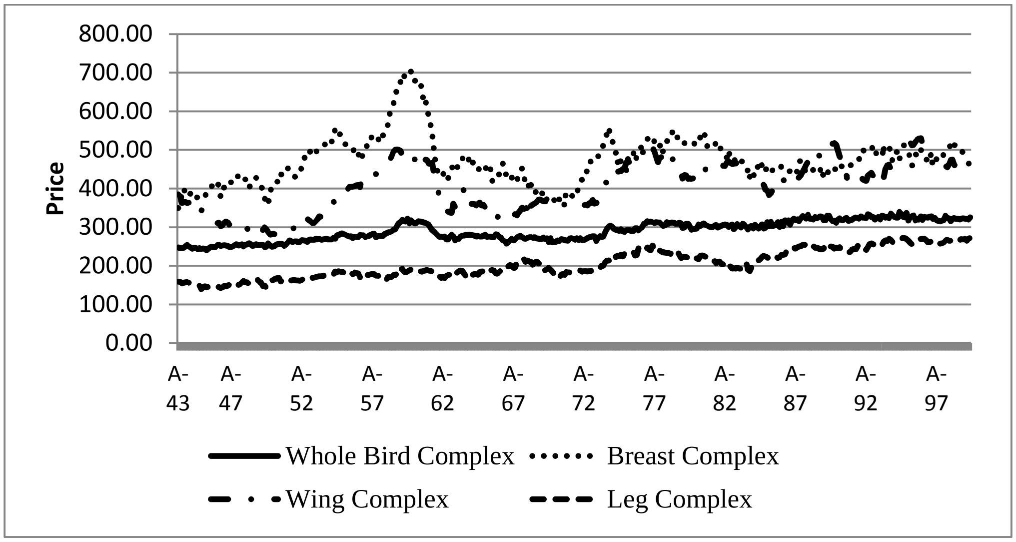
where *MK* is price mark-up of part *i*, *i* = breast, wings or leg;

P_i is the wholesale complex of the corresponding cut-up part;

P is the whole bird complex.

Table 4-8 and Figure 4-7 show the price mark-up of the three cut-up parts from 2002 to 2010. The price mark-up of the breast and wing are positive. The breast mark-up ranged from 31% to 125% while the wing mark-up ranged from 9% to 70%. The breast mark-up was higher than wing mark-up at the beginning of the period, but the two gradually approached to approximately the same level from 40% to 60% after mid-2008. The mark-up of leg has been negative for the whole period, indicating that the market value of chicken leg is lower than the whole bird.

Figure 4-6 Chicken wholesale price in Canada from A-43 to A98

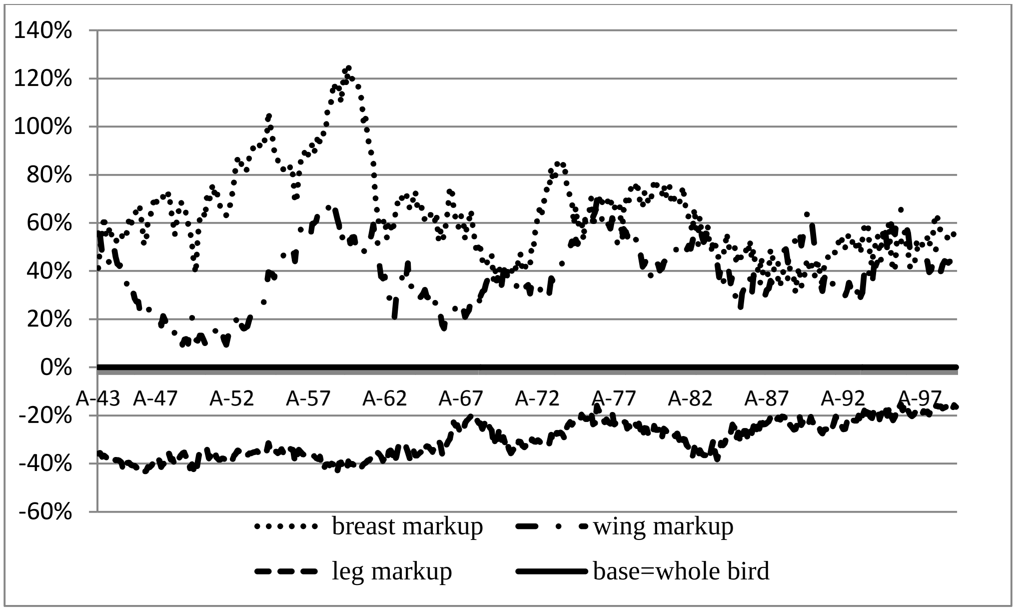


Data source: Chicken Farmers of Canada and Express Market, Inc., 2011

Table 4-7 Summary of wholesale price data

Variable	N	Mean	Std. Dev	Min	Max
whole bird complex	450	290.13	25.89	239.63	339.63
breast complex	450	473.45	63.72	349.15	703.28
wing complex	450	406.64	66.78	278.88	530.38
leg complex	450	204.60	37.10	139.37	272.52

Figure 4-7 Price mark-up of the three cut-up parts relative to whole chicken



Source: own calculations based on EMI market complexes

Table 4-8 Summary of wholesale price mark-up

Variable	N	Mean	Std.Dev	Min	Max
breast markup	450	0.6346	0.1873	0.3113	1.2497
wing markup	450	0.3949	0.1429	0.0929	0.7021
leg markup	450	-0.2993	0.0765	-0.4403	-0.1524

4.4.2 Determination of price premiums and discounts

In a reformed pricing scheme, the market value of a cut-up part is one of the factors according to which the price premiums and discounts are determined. The price mark-up at wholesale level, which is an indicator of a cut-up part's market value, is introduced into our pricing scheme through premium parameters β_B β_W and β_L.

Another important component of the βs is a weighting factor which is based on the proportion of the cut-up part, indicated by the three fixed standards ($\widetilde{BY}$, $\widetilde{WY}$ and $\widetilde{LY}$). These weight factors are introduced in the pricing scheme so as to relate the premium or discount only to the corresponding cut-up part instead of to the whole carcass. As a result, premium parameter β for each cut-up part could be expressed as equation 4.9 to 4.11:

$$\beta_B=(MK_B \times BP) \times \widetilde{BY} \quad (4.9)$$

$$\beta_W=(MK_W \times \mathrm{B}P) \times \widetilde{WY} \quad (4.10)$$

$$\beta_L=(MK_L \times BP) \times \widetilde{LY} \quad (4.11)$$

Using historical price mark-up data from 2002 to 2010, calculation of premium for breast yield is as follow:

The premium for breast yield in dollar term equals to price mark-up in percentage (MK_B) times the base price $63.5\% \times \$1.4535 = \$0.9230$. Suppose the processors' requirement (fixed standard) on breast yield equal to average yield level by all producers in the period, referring to the yield data of the 30 pens, the average breast yield level is 30.23%, then $\widetilde{BY}$ = 30.23%

β_B=$MK_B \times$ BP $\times \widetilde{BY}$= 63.5% $\times$ 1.4535 $\times$ 30.23% $= 0.27$

The same calculation procedure applies on the other two premium parameters β_W andβ_L. Then $\beta_W = 0.07$, $\beta_L = -0.14$.

As mentioned previously, how much premium a producer gets depends on the difference between the individual performances relative to fixed standard. For example, the average breast yield of pen one BY_1 is 30.64%, such that the difference from the fixed standard (which is the average of all 30 producers in our example) $\widetilde{BY}$ is given by $BY_1 - \widetilde{BY} = 0.4047\%$

Then the premium per kilogram for producer one with respect to breast yield is

$\beta_B \times \left(BY_1 - \widetilde{BY}\right) = \$0.2276 \times 0.4047\% = \$0.0921$

4.5 Summary

In chapter four, an introduction to an absolute performance pricing scheme with fixed standards is presented. To examine the feasibility of introducing cut-up part yield to the pricing scheme and to identify the suitable values for the parameters, both biological data and economic data have been analysed.

According to the analysis based on the yield data obtained from a biological experiment, and the market valuation of cut-up part at the wholesale; it appears appropriate to employ breast yield, wings yield and leg yield as the key quality traits to be introduced into the pricing scheme. This is supported due to the following facts that: 1) Yield levels of the three cut-up parts vary even if the birds fall into the same weight range and currently receive the same price. It implies that quality differences in terms of yield level are not accounted for and incentive for better quality are currently lacking from the pricing system; 2) Quality in terms of yield level could be effectively controlled by the effort of producers since yield levels are correlated to factors such as dietary balanced protein, metabolizable energy levels, age and so on; and 3) the three cut-up part have different market value at the wholesale level.

Estimates of premium (discount) parameters are based on the price mark-ups of the three cut-up parts over price of fresh whole bird at the wholesale level. Results of the analysis on wholesale price data from January 2002 to August 2010 suggest that breast and wing have positive price mark-up over fresh whole bird, while leg has negative price mark-up. This suggests that producers should be rewarded by higher breast yield and wing yield and lower leg yield under the novel pricing scheme.

Considering the formula of our novel pricing scheme discussed in this chapter and taking the estimates of parameters into account, an empirical analysis will be conducted in the next chapter using actual experimental data. The impact of the proposed pricing scheme on price variability affecting chicken producers and processors will also be examined.

Chapter 5 Empirical analysis and policy implication

5.1 Introduction

Following the detailed introduction to the data in chapter 4, this chapter applies the data to a model which compares a stylized status-quo payment scheme with a reformed payment scheme. In the absence of real production cost and sufficiently disaggregated price data (prices paid to producers by processors, and their relationship to retail prices), this model employs simulations to estimate the impact of the novel pricing scheme on price of live chicken paid by processors to producers. Sensitivity analyses are conducted to simulate heterogeneity in terms of processors' requirement on quality, as well as heterogeneity with regards to different markets which processors may wish to address. The simulations abstract from production cost heterogeneity, but this abstraction is justifiable, since it retains the focus of the analysis on linking the market's valuation for attributes with differential producer payments for quality traits.

5.2 Empirical analysis: Baseline scenario

To estimate prices received by producers under the novel pricing scheme, we make the following assumptions for the baseline scenario:

1. Constant mark-up across producing and processing, so that the price mark-up on the wholesale level could be used to estimate approximate price premiums/discounts;

2. There is a single processor and multiple producers in the market; each pen of the experiment represents a single hypothetical producer;

3. The processor' requirement regarding average yield level equals the average yield level of all the 30 representative producers.

Recall the two steps of the quality-based payment scheme introduced in chapter 4. A base price is determined at step one and is consistent with the current pricing scheme where price is based on production cost and the average weight. Premium or discount are determined in step two according to the difference between the yield level of a producer compared and the fixed standard set by processor. The price formula for the novel pricing scheme (equation 4.1) can now be written as

$$P^i = BP_i + \beta_B \times \left(BY_i - \widetilde{BY}\right) + \beta_W \times \left(WY_i - \widetilde{WY}\right) + \beta_L \times \left(LY_i - \widetilde{LY}\right) \quad \ldots..(5.1)$$

where $\beta_B = (MK_B \times BP) \times \widetilde{BY}$, $\beta_W = (MK_W \times BP) \times \widetilde{WY}$, $\beta_L = (MK_L \times BP) \times \widetilde{LY}$

Given the above price formula, the payment for each hypothetical producer under the novel pricing scheme can be calculated and compared with those payments under the current pricing scheme. For the current pricing scheme, body weight data of birds at age 38 is used because of the fact that the average age of birds that fall within target weight range (1.9kg to 2.35kg according to Lilydale A96) is 37.53 days in the experiment. Moreover, using data of the birds that were harvested at the same point in time could minimize the variation in production costs that result from differences in production length. The descriptive statistics of the performance-related variables are presented in Table 5-1.

Table 5-1 Descriptive statistics of average cut-up part yield

	N	Mean	Std. Dev	Min	Max
Average weight (kg)	30	2.23	0.20	1.94	2.64
Average breast yield (%)	30	30.23	0.60	28.78	31.12
Average wing yield (%)	30	12.24	0.09	12.09	12.46
Average leg yield (%)	30	32.45	0.36	31.74	33.09

The estimation of prices under the novel pricing scheme is calculated using Excel 2010. The performance of each representative producer (measured by $BY_i - \widetilde{BY}$, $WY_i - \widetilde{WY}$ and $LY_i - \widetilde{LY}$) and the estimated premiums/discounts specific to each cut-up part are presented in Table 5-2. As the results show, under the novel pricing scheme, all producers receive both premium and discount for different quality traits as expected. Premiums and discounts received by a particular producer could to some extent offset each other so that the variation in price resulting from the new pricing scheme is diminished.

Estimated prices for each producer in both pricing schemes as well as the price difference between the two prices are presented in Table 5-3 and Figure 5-1. Fifteen of the thirty producers get a higher price under the novel pricing scheme, and the premiums range from 0.36% to 1.98% of the current price. The other fifteen producers receive a lower price ranging from -2.58% to -0.1%. As both higher and lower prices would result from the novel pricing scheme, the sum of prices paid by the processor to the 30 producers is just slightly differ from the current one (0.1% higher), which suggests that such a scheme should meet acceptance from industry participants. To compare the prices under both schemes, the prices are plotted in Figure 5-2. The price line for the novel pricing scheme varies around the current prices, indicating that the new pricing scheme creates greater variation in the distribution of prices given to the thirty producers. However, it would not change the mean of prices which affect the processor. This implies a potential price risk shifting to the producers without changing the total payment due from the processor.

Regarding the magnitude of the price differences between the two pricing schemes, the price change which results from the new pricing scheme ranges from -2.58% to 1.89%. This only accounts for a very small proportion of the price compared to the base price component, and suggests that in the proposed pricing scheme, the weight of the quality component is significantly smaller than the feed component, chick component and the producer margin component. This indicates that quality as modeled here has likely little influence on producers' income. Therefore, the reallocation of the weights of the key components, especially the producer margin and quality incentive components, deserve further scrutiny.

Table 5-2 Payment under the novel pricing scheme, baseline scenario

Producer	$BY_i - \widetilde{BY}$	Breast premium ($/kg)	$WY_i - \widetilde{WY}$	Wing premium ($/kg)	$LY_i - \widetilde{LY}$	Leg premium ($/kg)	Price in novel scheme
1	0.4047	0.0092	-0.0563	-0.0004	-0.2397	0.0025	1.4648
2	0.5197	0.0118	0.0039	0.0000	-0.4708	0.0048	1.4702
3	0.4767	0.0109	-0.0005	0.0000	-0.1936	0.0020	1.4663
4	0.5757	0.0131	-0.1106	-0.0007	0.2278	-0.0023	1.4136
5	0.3927	0.0089	-0.1183	-0.0008	-0.0904	0.0009	1.4626
6	-0.2813	-0.0064	0.0729	0.0005	0.3788	-0.0039	1.4437
7	0.0667	0.0015	-0.0168	-0.0001	-0.4356	0.0045	1.4594
8	0.5417	0.0123	-0.0088	-0.0001	-0.5264	0.0054	1.4712
9	0.1087	0.0025	0.0241	0.0002	-0.2607	0.0027	1.4588
10	0.3547	0.0081	-0.0292	-0.0002	-0.3151	0.0032	1.4646
11	0.3257	0.0074	-0.1015	-0.0007	-0.0497	0.0005	1.4108
12	0.4147	0.0094	-0.0334	-0.0002	-0.0604	0.0006	1.4134
13	0.3967	0.0090	0.0277	0.0002	-0.4715	0.0049	1.4676
14	-1.2443	-0.0283	-0.1267	-0.0008	0.6378	-0.0066	1.4178
15	-0.6893	-0.0157	0.0037	0.0000	0.4339	-0.0045	1.3834
16	-0.9483	-0.0216	0.0009	0.0000	0.1084	-0.0011	1.4308
17	-0.7563	-0.0172	0.1055	0.0007	0.0137	-0.0001	1.4368
18	-0.2413	-0.0055	0.1743	0.0011	-0.3713	0.0038	1.4529
19	0.6327	0.0144	-0.0798	-0.0005	-0.0472	0.0005	1.4179
20	-0.0463	-0.0011	0.1592	0.0010	0.0813	-0.0008	1.4026
21	0.8887	0.0202	-0.0177	-0.0001	-0.7103	0.0073	1.4809
22	-1.4543	-0.0331	0.2163	0.0014	0.5562	-0.0057	1.4161
23	-0.5693	-0.0130	0.1453	0.0009	0.0504	-0.0005	1.4409
24	0.8117	0.0185	-0.0380	-0.0002	-0.0307	0.0003	1.4721
25	0.2597	0.0059	-0.1534	-0.0010	0.4879	-0.0050	1.4534
26	0.0497	0.0011	0.0728	0.0005	0.4035	-0.0042	1.4009
27	-0.6373	-0.0145	0.0109	0.0001	0.3077	-0.0032	1.3859
28	-0.0423	-0.0010	-0.0270	-0.0002	0.1989	-0.0020	1.4003
29	0.1107	0.0025	-0.0444	-0.0003	0.4984	-0.0051	1.4006
30	-0.4223	-0.0096	-0.0552	-0.0004	-0.1115	0.0012	1.4447

Table5-3 Comparison of prices under the two schemes

Producer	Price under old scheme ($/kg)	Price under novel scheme ($/kg)	Differences between pricing schemes (base=price under current scheme)
1	1.4535	1.4648	0.78%
2	1.4535	1.4702	1.15%
3	1.4535	1.4663	0.88%
4	1.4035	1.4136	0.72%
5	1.4535	1.4626	0.63%
6	**1.4535**	**1.4437**	**-0.68%**
7	1.4535	1.4594	0.41%
8	1.4535	1.4712	1.22%
9	1.4535	1.4588	0.36%
10	1.4535	1.4646	0.77%
11	1.4035	1.4108	0.52%
12	1.4035	1.4134	0.70%
13	1.4535	1.4676	0.97%
14	**1.4535**	**1.4178**	**-2.46%**
15	**1.4035**	**1.3834**	**-1.43%**
16	**1.4535**	**1.4308**	**-1.56%**
17	**1.4535**	**1.4368**	**-1.15%**
18	**1.4535**	**1.4529**	**-0.04%**
19	1.4035	1.4179	1.02%
20	**1.4035**	**1.4026**	**-0.06%**
21	1.4535	1.4809	1.89%
22	**1.4535**	**1.4161**	**-2.58%**
23	**1.4535**	**1.4409**	**-0.86%**
24	1.4535	1.4721	1.28%
25	**1.4535**	**1.4534**	**-0.01%**
26	**1.4035**	**1.4009**	**-0.18%**
27	**1.4035**	**1.3859**	**-1.25%**
28	**1.4035**	**1.4003**	**-0.23%**
29	**1.4035**	**1.4006**	**-0.21%**
30	**1.4535**	**1.4447**	**-0.61%**
Total payment	43.1050	43.1050	0.00%

Figure5-1 Price differences of the two pricing schemes

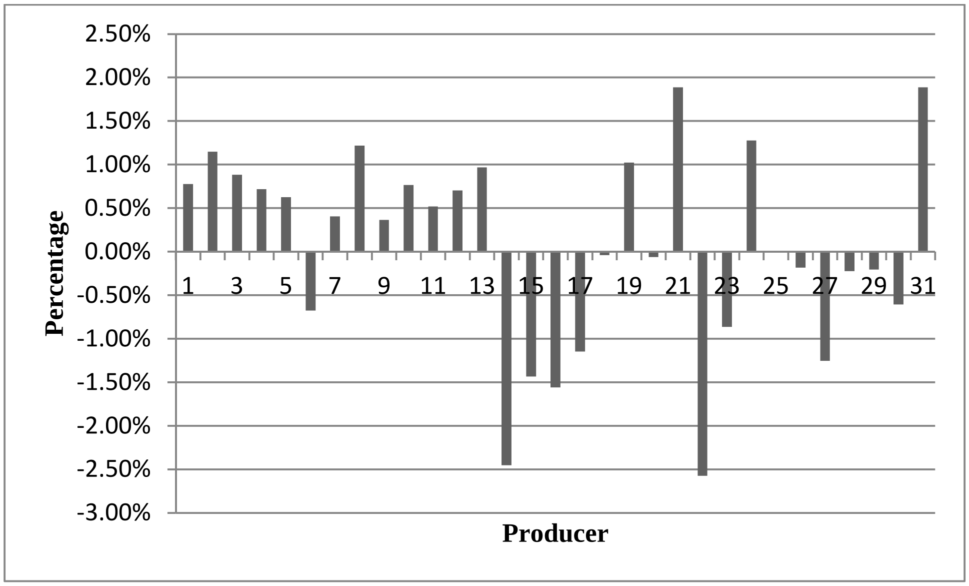
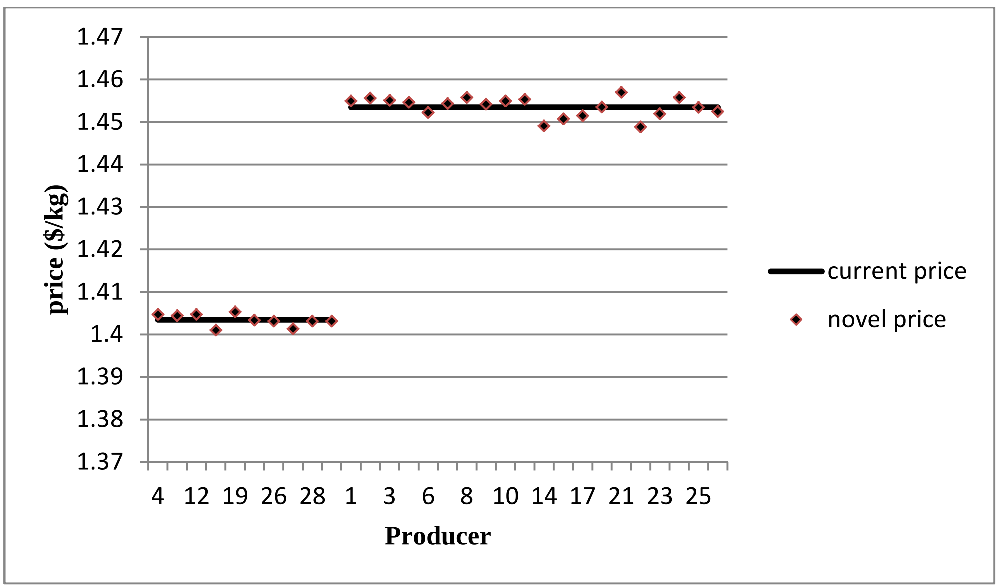


Figure 5-2 Prices under two pricing schemes



5.3 Sensitivity analysis

For the purpose of simplification, several assumptions have been made for the baseline scenario discussed in the previous section: Firstly, there is only one fixed standard for each cut-up part yield level ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$), which implies that there is only one representative processor in the market or there are multi processors who have same requirement for quality traits – we call this the "**single processor assumption**". Secondly, there is only one value for each BY_i, WY_i and LY_i, which implies that the performance of each producer is constant irrespective of whether the grower operates under the old or the new pricing. We label this as the "**constant performance assumption**". Thirdly, in the baseline scenario, there is only a constant value for each premium parameter β**,** and such values are based on the average price mark-up ($MK_{B,} MK_W, MK_L$) at the wholesale level. This indicates that we assume that all producers and processors are facing a single market, so that values/price mark-ups of cut-up parts ($MK_{B,} MK_W, MK_L$) are constant. We call this the "**single market assumption**".

In this section, we will relax these assumptions and examine the impact of the key variables in the proposed pricing scheme by conducting sensitivity analyses. To do this, we employ the approaches used in two previous studies, both of which estimate the potential economic impact of new transgenic technologies.

The first one is the study by Alston et al. (2002), which estimates the potential benefits from the corn rootworm resistant transgenic corn technology (CRW-resistant transgenic corn technology). Using a partial budgeting approach they estimate the per-acre net benefits of CRW-resistant transgenic corn, relative to conventional CRW control technologies. Sensitivity analysis is then conducted to show how the benefits from adoption depend on key variables. Three scenarios - the high, moderate and low corn rootworm pressure - are assumed to represent different level of damage rating. Yield and farm-level income in each scenario are estimated and compared in the analysis.

The second study which we follow is a paper on genetically modified rice by Bond, Carter, and Farzin (2005). Partial-budgeting approach is also employed in this study to estimate the potential net economic grower benefits associated with the adoption of one cultivar of GM rice in California. In the sensitivity analysis, Bond et al. (2005) not only use the deterministic approach in different scenarios, but also use the stochastic approach by conducting Monte Carlo simulations after specifying probability distributions for the key variables of interest. Thereby, not only heterogeneity of key variables is captured, but also the distribution of the benefits of the adoption of the new technology can be described.

Following these studies, we employ both deterministic and stochastic approaches for the sensitivity analyses, by varying the key components in the pricing formula (equation 5.1). The following sections outline first how deterministic and stochastic are implemented in the context of the proposed pricing scheme, before presenting the simulation results.

5.3.1 Deterministic Sensitivity Analysis

Relax single processor assumption

In the deterministic sensitivity analysis, we first relax the single processor assumption by deterministically varying the average fixed standard of the three quality traits ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$). In other words, processors are now assumed to be heterogeneous and have different fixed standards regarding quality traits. We are trying to explore to what extent the price paid to producers will be affected by the change in processors' requirements in terms of a specific quality trait. Three new parameters $\theta_B, \theta_W, \theta_L$ are generated to represent the change in terms of $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ respectively. Assuming that there is a processor who has stricter requirement for breast yield and he sets the fixed standard of breast yield 1% higher, then θ_B will be 1+1%=1.01, such that the new fixed standard $\widetilde{BY}' = \theta_B \times \widetilde{BY}$= 1.01$\widetilde{BY}$

Introducing θ_B into the payment scheme, the payment for producer *i* (P_i') becomes

$$P_i' = BP_i + \beta_B' \times \left(\mathrm{BY_i} - \widetilde{BY}'\right) + \beta_W \times \left(\mathrm{WY_i} - \widetilde{WY}\right) + \beta_L \times \left(\mathrm{LY_i} - \widetilde{LY}\right) \quad \text{....(5.2)}$$

where $\beta_B' = (MK_B \times BP) \times \theta_B \times \widetilde{BY} = \theta_B \times \beta_B$ ……………………….….….(5.3)

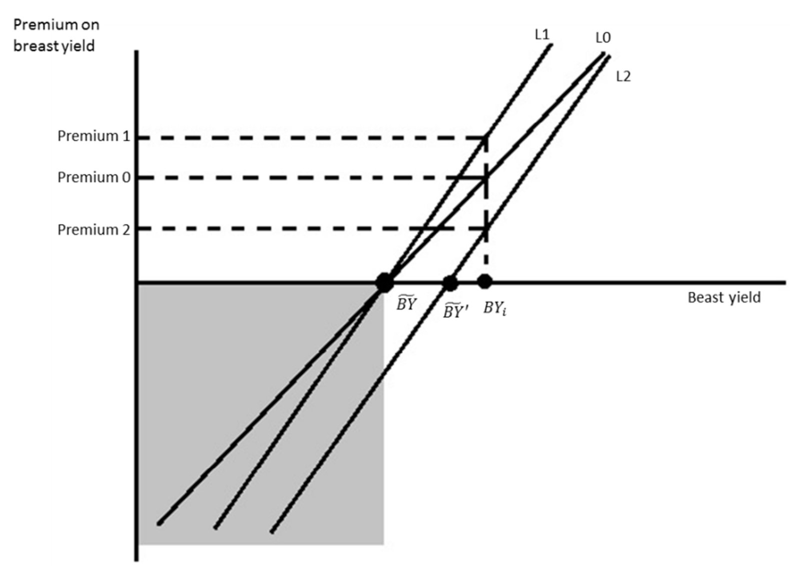
$$\widetilde{BY}' = \theta_B \times \widetilde{BY} \quad \text{……………………………………..……….……(5.4)}$$

The effect of increasing the fixed standard of breast yield can be illustrated in Figure 5-3, where the vertical axis represents the premium a producer gets from breast yield; the horizontal axis represents a producer's breast yield level. Lines

L_0 , L_1 and L_2 are defined as the premium line in different scenarios and the slope of the premium line equals to the absolute value of the unit premium/discount β_B.

There are two main effects result from changing the fixed standard of breast yield ($\widetilde{BY}$). First, it affects the magnitude of premium parameters (unit parameters) β. According to equation (5.3), θ_B is positively correlated with the absolute value of β'_{Bi} , which essentially drives the change in premium/ discount level. This indicates that a processor who has stricter requirement on a specific quality trait is likely to offer a higher premium (β) for those producers who have better performance (higher discount for those producers who have worse performance). We call this effect the "**bonus effect**" (BE). In Figure 5-3, the bonus effect of increasing the breast yield fixed standard results in an increase in the slope of the premium line and causes it to rotate from L_0 to L_1. The premium received by producer *i* increases from $Premium_{\,0}$ to $Premium_{\,1}$.

Figure 5-3 Effect of changing fixed standard



Second, another component that is affected by the fixed standards is the measurement of the performance of producer *i*, namely $\left(BY_i - \widetilde{BY}\right)$, $\left(WY_i - \widetilde{WY}\right)$ and $\left(LY_i - \widetilde{LY}\right)$. A higher level of $\widetilde{BY}, \widetilde{WY}$ and lower level of $\widetilde{LY}$ indicate stricter requirements by processors and thus have a downgrading effect on the evaluation on the performance with regard to the corresponding quality trait. We call this effect the "**evaluation effect**" (EE), which is negatively correlated with payment. As Figure 5-3 shows, the evaluation effect of a higher fixed standard in terms of breast yield causes the premium price to shift to the right to L_2. The premium paid to producer *i* declines to $Premium_{\,2}$.

As the bonus effect and the evaluation effect affect payment P_i in different directions, the total effect of changing a fixed standard depends on the sum of the two effects. Continuing with the previous example where $\widetilde{BY}$ varies, suppose there is a processor who has stricter requirements on breast yield and sets the fixed standard $\widetilde{BY}' = \theta_B \times \widetilde{BY}$, $\theta_B > 1$, then

$$P_i' = BP_c + \beta_{Bi}' \times \left(\mathrm{BY_i} - \widetilde{BY}'\right) + \beta_{Wi} \times \left(\mathrm{WY_i} - \widetilde{WY}\right) + \beta_{Li} \times \left(\mathrm{LY_i} - \widetilde{LY}\right)$$

The total effect of changing fixed standard $\widetilde{BY}$ equals to the sum of the bonus effect and the evaluation effect (equation 5.5).

$$TE = BE_{\widetilde{BY}}(+) + EE_{\widetilde{BY}}\,(-) \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (5.5)$$

Also, the total effect is reflected in the difference in payment before and after the pricing scheme change. Let ΔP_i denotes the difference between P_i' and P_i then

$$\Delta P_i = P_i' - P_i \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.6)$$

$$= [BP_i + \beta'_B \times \left(BY_i - \widetilde{BY}'\right) + \beta_W \times \left(WY_i - \widetilde{WY}\right) + \beta_L \times \left(LY_i - \widetilde{LY}\right)]$$

$$- [BP_i + \beta_B \times \left(BY_i - \widetilde{BY}\right) + \beta_W \times \left(WY_i - \widetilde{WY}\right) + \beta_L \times \left(LY_i - \widetilde{LY}\right)]$$

$$= \beta'_B \times \left(BY_i - \widetilde{BY}'\right) - \beta_B \times \left(BY_i - \widetilde{BY}\right)$$

$$= \theta_B \times \beta_B \times \left(BY_i - \theta_B \times \widetilde{BY}\right) - \beta_B \times \left(BY_i - \widetilde{BY}\right)$$

$$= \theta_B \times \beta_B \times BY_i - {\theta_B}^2 \times \beta_{Bi} \times \widetilde{BY} - \beta_B \times BY_i + \beta_B \times \widetilde{BY}$$

$$= (\theta_B - 1) \times \ \beta_B \times BY_i - \left({\theta_B}^2 - 1\right) \times \beta_B \times \widetilde{BY}$$

$$= (\theta_B - 1) \times \ \beta_B \times BY_i - (\theta_B - 1) \times (\theta_B + 1) \times \beta_B \times \widetilde{BY}$$

$$= (\theta_B - 1) \times \beta_B \times [BY_i - (\theta_B + 1)\widetilde{BY}]$$

Because $\theta_B > 1$, and since $\theta_B - 1 > 0$, the price mark-up of breast meat is positive, so β_B>0, therefore when $BY_i - (\theta_B + 1)\widetilde{BY} < 0$, $\Delta P_i < 0$, and vice versa. In other words, when $BY_i > (\theta_B + 1)\widetilde{BY}$, the evaluation effect exceeds the bonus effect (EE<BE), an increase in breast yield fixed standard $\widetilde{BY}$ increases the price received by producer i, and vice versa.

Notice that θ_B is greater than one as we assumed the processor has a stricter requirement on breast yield than in the baseline scenario. As a result, only when $BY_i > 2\widetilde{BY}$ (the breast yield level of a particular producer is twice as high as the fixed standard), the bonus effect exceeds the evaluation effect. Referring to the yield data obtain from the biological experiment, where the maximum breast yield level (39.09%) is no more than 1.6 times higher than the minimum breast yield (22.97%), we expect that the evaluation effect from changing the fixed standard to be stronger than the bonus effect in most of the cases. A stricter fixed standard set by processors is likely to result in price reductions for all producers in the biological experiment.

Consider this situation from the producers' perspective, and suppose a producer is facing two processors, one of them sets a higher breast yield fixed standard and offers a lower price, while the other sets a lower fixed standard and offers a higher price. It is obvious that the producer will choose to contract with the former processor as he can get a higher price from less effort. Therefore, under the novel pricing scheme, it is not realistic for a processor to solely increase the fixed standard for a specific quality trait without decreasing the fixed standards of other quality traits or providing other source of incentive that could result in bonus effect to offset the down-grading effect.

For simplicity, we will keep the fixed standards of other quality traits at the baseline level, and further examine the effect of changing the price mark-up component.

Relaxing the single processor and single market assumption

To further investigate the impact of introducing heterogeneity into the payment scheme, we are relaxing one more assumption ---- the single market assumption. We assume that there are different processors who have different requirements for quality, and that each processor is facing different markets. In those markets, values of cut-up parts are different, that is to say, there will be different values for each price mark-up (MK_B, MK_W, MK_L), reflecting differences in terms of consumers' willingness to pay. We generate another three new parameters λ_B, λ_W and λ_L to represent the variation in MK_B, MK_W, MK_L. Suppose the processor in our previous example is facing a market where the price mark-up of breast meat MK_B'' is higher than in the baseline scenario MK_B, then MK_B'' can be expressed as $MK_B'' = \lambda_B \times MK_B$, where $\lambda_B > 1$. It follows that the price for producer i (P_i'') can be expressed as

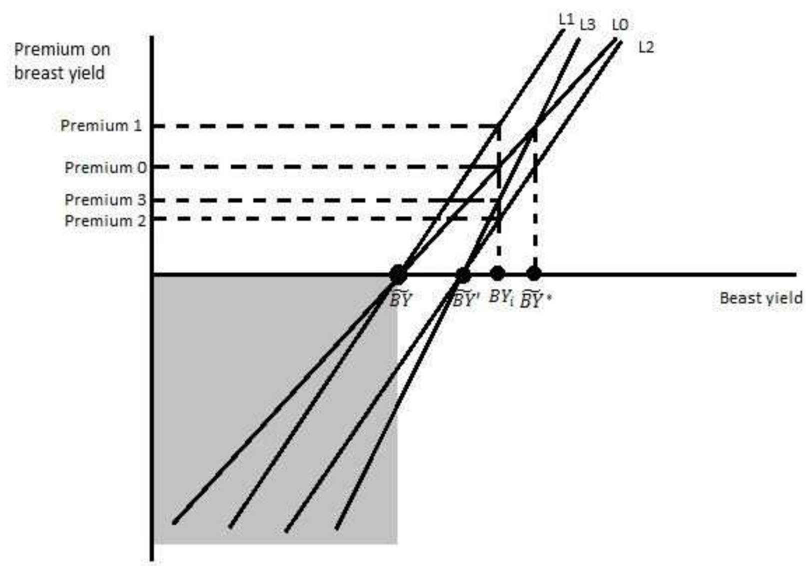
$$P_i'' = BP_c + \beta_{Bi}'' \times (\mathrm{BY_i} - \widetilde{BY}') + \beta_{Wi} \times (\mathrm{WY_i} - \widetilde{WY}) + \beta_{Li} \times (\mathrm{LY_i} - \widetilde{LY}) \quad ..(5.7)$$

where

$$\beta_{Bi}'' = (MK_B'' \times \mathrm{BP}) \times \widetilde{BY}' = \lambda_B \times MK_B \times \mathrm{BP} \times \theta_B \times \widetilde{BY} = \lambda_B \times \theta_B \times \beta_{Bi} \quad ....(5.8)$$

And $\widetilde{BY}' = \theta_B \times \widetilde{BY}$ ……………………………………….……………..…(5.9)

Figure 5-4 Effect of changing both fixed standard and price mark-up



The change in MK_B, MK_W and MK_L only affect the magnitude of β_B, β_W and β_L. Therefore, the change in price mark-up only results in the bonus effect(BE_{MK_B}). A processor is thus anticipated to pay a higher premium (bonus) for better performance as well as symmetric higher discount for worse performance when the market value/ price mark-up of such cut-up part is higher. As show in Figure 5-4, an increase in the price mark-up in terms of breast meat causes the premium line rotate from L_2 to L_3. The premium paid to producer i increases from $premium_2$ to $premium_3$.

Since changing the breast yield fixed standard $\widetilde{BY}$ has both a bonus effect $(BE_{\widetilde{BY}})$ and an evaluation effect $(EE_{\widetilde{BY}})$, the total effect of relaxing the single processor and single market assumption is the sum of the bonus effect caused by the changes in both average yield standard and price mark-up of each cut-up part, and the evaluation effect caused by the changes in average yield standard.

$TE' = BE_{\widetilde{BY}}(+) + BE_{MK_B}(+) + EE_{\widetilde{BY}}\,(-)$ …………………………..(5.10)

Let $\Delta P_i'$ denote the price difference between the baseline scenario and the scenario where both "single market assumption" and "single processor assumption" are relaxed.

$\Delta P_i{}' = P_i'' - P_i$……………………………………………………………..(5.11)

$= [BP_c + \beta_{Bi}'' \times \left(BY_i - \widetilde{BY}'\right) + \beta_{Wi} \times \left(WY_i - \widetilde{WY}\right) + \beta_{Li} \times \left(LY_i - \widetilde{LY}\right)]$

$- [BP_c + \beta_{Bi} \times \left(BY_i - \widetilde{BY}\right) + \beta_{Wi} \times \left(WY_i - \widetilde{WY}\right) + \beta_{Li}$

$\times \left(LY_i - \widetilde{LY}\right)]$

$= \beta_{Bi}'' \times \left(BY_i - \widetilde{BY}'\right) - \beta_{Bi} \times \left(BY_i - \widetilde{BY}\right)$

$= \lambda_B \times \theta_B \times \beta_{Bi} \times \left(BY_i - \theta_B \times \widetilde{BY}\right) - \beta_{Bi} \times \left(BY_i - \widetilde{BY}\right)$

$= \lambda_B \times \theta_B \times \beta_{Bi} \times BY_i - \lambda_B \times {\theta_B}^2 \times \beta_{Bi} \times \widetilde{BY} - \beta_{Bi} \times BY_i + \beta_{Bi} \times \widetilde{BY}$

$= (\theta_B - 1) \times \ \beta_{Bi} \times BY_i - \left(\lambda_B \times {\theta_B}^2 - 1\right) \times \beta_{Bi} \times \widetilde{BY}$

$= \ \beta_{Bi} \times [BY_i \times (\lambda_B \times \theta_B - 1) - \left(\lambda_B \times {\theta_B}^2 - 1\right) \times \widetilde{BY}]$

As long as price mark-up of breast meat is positive, $\beta_{Bi}>0$, when $BY_{\mathrm{i}} \times (\lambda_B \times \theta_B - 1) - (\lambda_B \times {\theta_B}^2 - 1) \times \widetilde{BY} > 0, BY_{\mathrm{i}} > \widetilde{BY}\frac{(\lambda_B \times {\theta_B}^2 - 1)}{(\lambda_B \times \theta_B - 1)}$, then $\Delta P_i' > 0$. The bonus effect exceeds the evaluation effect (BE>EE), an increase in breast yield fixed standard ($\widetilde{BY}$) and the price mark-up (MK_B) increases the payment received by producer i, and vice versa. In Figure 5-4, $\widetilde{BY} \times \frac{(\lambda_B \times {\theta_B}^2 - 1)}{(\lambda_B \times \theta_B - 1)}$ corresponds to the point $\widetilde{BY}^*$, when a breast yield of a producer is greater than $\widetilde{BY}^*$, the premium he receives will be greater than the baseline scenario. Therefore, we can consider $\widetilde{BY}^* = \widetilde{BY} \times \frac{(\lambda_B \times {\theta_B}^2 - 1)}{(\lambda_B \times \theta_B - 1)}$ as a critical value, the possible consequence of increasing $\widetilde{BY}$ and MK_B is that the producers whose breast yield performance is higher than the critical value will benefit from the changes as they get a higher price than the baseline scenario while the producers whose breast yield level is lower than the critical value will be worse off.

5.3.2 Deterministic Results

By using the yield data of the 30 experimental pens, prices in the scenarios where processors have different requirements for cut-up part yield are simulated. In each scenario, the fixed standard of a particular cut-up part varies by a certain percentage while the fixed standards of other cut-up parts are kept at the baseline level. Based on the percentages of standard deviation over the mean yield level obtained in the biological experiment, which are 1.98%, 0.74% and 1.11% for breast yield, wing yield and leg yield respectively, the percentages of the changes in the deterministic analysis are set as -2%, -1%, -0.5%, +0.5%, +1% and +2%. The fixed standards after the change are presented in Table 5-4.

Table 5-4 Value of average cut-up part yields at different levels

Cut-up part	Value of fixed standard						
	-2%	-1%	-0.5%	baseline	0.5%	1%	2%
breast yield	0.2963	0.2993	0.3008	0.3023	0.3038	0.3053	0.3083
wing yield	0.1200	0.1212	0.1218	0.1224	0.1230	0.1236	0.1248
leg yield	0.3180	0.3213	0.3229	0.3245	0.3261	0.3277	0.3310

The simulation is conducted via the "What If" command by Excel 2010. Percentage changes in price over the baseline scenario are shown in Table 5-5 to 5-7 respectively. As expected, prices that paid to all 30 hypothetical producers increase when the fixed standard of breast yield and wing yield decreases, and when the fixed standard of leg yield increases. This indicates that for the 30 producers in our model, the evaluation effect exceeds the bonus effect of changing $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ by -2%, -1%,-0.5%, +0.5%, +1% and +2%. Comparing the price change induced by a 1% change of each of $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$, price appears to be most sensitive to $\widetilde{BY}$ as a 1% change in $\widetilde{BY}$ results in about -0.058% change in price, followed by $\widetilde{LY}$ with a 0.03% change in price. Price is the least sensitive for the fixed standard of wing yield compared to the other two cut-up parts as price change is only around -0.006%.

The price difference from the baseline scenario is also presented in Figures 5-5 to 5-7. The figures illustrate that varying $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ does not significantly change the shape of the price line but results in upward or downward shifts. This suggests that holding the group composition unchanged, varying the $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$

do not significantly change the distribution of payments over the baseline scenario; rather, it changes the total payment that processors need to pay. For those processors who set a stricter requirement on a specific cut-up part yield, the total payment are likely to decline, because the stricter standard downgrades the evaluation of producers' performance. However, as discussed in the last section, without decreasing the fixed standards of other quality traits or providing higher unit premiums, the producers are likely to switch to other processor who requires a lower quality.

Table 5-5 Percent change in price and total payment over baseline scenario result from varying the breast yield fixed standard

Producer	Percent change in price over baseline scenario					
	change in breast yield fixed standard					
	-2%	**-1%**	**-0.5%**	**0.5%**	**1%**	**2%**
1	0.1120%	0.0561%	0.0284%	-0.0287%	-0.0573%	-0.1166%
2	0.1115	0.0559	0.0283	-0.0286	-0.0570	-0.1161
3	0.1117	0.0560	0.0283	-0.0287	-0.0571	-0.1163
4	0.1153	0.0578	0.0293	-0.0296	-0.0590	-0.1201
5	0.1121	0.0562	0.0284	-0.0287	-0.0573	-0.1167
6	0.1148	0.0576	0.0291	-0.0294	-0.0587	-0.1195
7	0.1133	0.0568	0.0288	-0.0291	-0.0580	-0.1180
8	0.1114	0.0559	0.0283	-0.0286	-0.0570	-0.1160
9	0.1132	0.0567	0.0287	-0.0290	-0.0579	-0.1178
10	0.1122	0.0562	0.0285	-0.0288	-0.0574	-0.1168
11	0.1163	0.0583	0.0295	-0.0298	-0.0595	-0.1211
12	0.1159	0.0581	0.0294	-0.0297	-0.0593	-0.1207
13	0.1120	0.0561	0.0284	-0.0287	-0.0573	-0.1166
14	0.1188	0.0595	0.0301	-0.0304	-0.0607	-0.1234
15	0.1207	0.0605	0.0306	-0.0309	-0.0617	-0.1255
16	0.1175	0.0589	0.0298	-0.0301	-0.0600	-0.1222
17	0.1167	0.0585	0.0296	-0.0299	-0.0596	-0.1214
18	0.1146	0.0574	0.0291	-0.0294	-0.0586	-0.1192
19	0.1150	0.0577	0.0292	-0.0295	-0.0589	-0.1198
20	0.1179	0.0591	0.0299	-0.0302	-0.0603	-0.1227
21	0.1100	0.0551	0.0279	-0.0282	-0.0563	-0.1146
22	0.1196	0.0599	0.0303	-0.0306	-0.0611	-0.1243
23	0.1160	0.0581	0.0294	-0.0297	-0.0593	-0.1206
24	0.1104	0.0553	0.0280	-0.0283	-0.0565	-0.1150
25	0.1127	0.0565	0.0286	-0.0289	-0.0576	-0.1173
26	0.1175	0.0589	0.0298	-0.0301	-0.0601	-0.1223
27	0.1204	0.0604	0.0305	-0.0309	-0.0615	-0.1252
28	0.1179	0.0591	0.0299	-0.0302	-0.0603	-0.1227
29	0.1173	0.0588	0.0298	-0.0301	-0.0600	-0.1221
30	0.1154	0.0578	0.0293	-0.0296	-0.0590	-0.1200
total payment	0.1150	0.0576	0.0292	-0.0295	-0.0588	-0.1197

Table 5-6 Percent change in price and total payment over baseline scenario result from varying the wing yield fixed standard

Producer	Percent change in price over baseline scenario					
	change in wing yield fixed standard					
	-2%	**-1%**	**-0.5%**	**0.5%**	**1%**	**2%**
1	0.0116%	0.0058%	0.0030%	-0.0030%	-0.0059%	-0.0121%
2	0.0116	0.0057	0.0029	-0.0030	-0.0058	-0.0120
3	0.0116	0.0057	0.0029	-0.0030	-0.0058	-0.0121
4	0.0121	0.0060	0.0031	-0.0031	-0.0061	-0.0126
5	0.0117	0.0058	0.0030	-0.0030	-0.0059	-0.0122
6	0.0115	0.0057	0.0029	-0.0030	-0.0058	-0.0120
7	0.0116	0.0057	0.0029	-0.0030	-0.0059	-0.0121
8	0.0116	0.0057	0.0029	-0.0030	-0.0058	-0.0121
9	0.0116	0.0057	0.0029	-0.0030	-0.0058	-0.0120
10	0.0116	0.0057	0.0029	-0.0030	-0.0059	-0.0121
11	0.0121	0.0060	0.0031	-0.0031	-0.0061	-0.0126
12	0.0120	0.0060	0.0031	-0.0031	-0.0061	-0.0125
13	0.0115	0.0057	0.0029	-0.0030	-0.0058	-0.0120
14	0.0117	0.0058	0.0030	-0.0030	-0.0059	-0.0122
15	0.0120	0.0060	0.0031	-0.0031	-0.0061	-0.0125
16	0.0116	0.0058	0.0029	-0.0030	-0.0059	-0.0121
17	0.0115	0.0057	0.0029	-0.0030	-0.0058	-0.0120
18	0.0114	0.0057	0.0029	-0.0029	-0.0058	-0.0119
19	0.0121	0.0060	0.0031	-0.0031	-0.0061	-0.0126
20	0.0118	0.0059	0.0030	-0.0030	-0.0060	-0.0123
21	0.0116	0.0057	0.0029	-0.0030	-0.0058	-0.0121
22	0.0114	0.0057	0.0029	-0.0029	-0.0058	-0.0119
23	0.0115	0.0057	0.0029	-0.0029	-0.0058	-0.0119
24	0.0116	0.0057	0.0029	-0.0030	-0.0059	-0.0121
25	0.0117	0.0058	0.0030	-0.0030	-0.0059	-0.0122
26	0.0119	0.0059	0.0030	-0.0031	-0.0060	-0.0124
27	0.0120	0.0059	0.0030	-0.0031	-0.0061	-0.0125
28	0.0120	0.0060	0.0031	-0.0031	-0.0061	-0.0125
29	0.0121	0.0060	0.0031	-0.0031	-0.0061	-0.0125
30	0.0117	0.0058	0.0030	-0.0030	-0.0059	-0.0121
total payment	0.0117	0.0058	0.0030	-0.0030	-0.0059	-0.0122

Table 5-7 Percent change in price and total payment over baseline scenario result from varying the leg yield fixed standard

Producer	Percent change in price over baseline scenario					
	change in leg yield fixed standard					
	-2%	**-1%**	**-0.5%**	**0.5%**	**1%**	**2%**
1	-0.0622%	-0.0310%	-0.0158%	0.0159%	0.0316%	0.0647%
2	-0.0626	-0.0312	-0.0159	0.0160	0.0318	0.0651
3	-0.0621	-0.0309	-0.0158	0.0159	0.0315	0.0646
4	-0.0635	-0.0316	-0.0161	0.0163	0.0323	0.0661
5	-0.0619	-0.0308	-0.0157	0.0159	0.0315	0.0644
6	-0.0611	-0.0304	-0.0155	0.0157	0.0311	0.0636
7	-0.0626	-0.0312	-0.0159	0.0160	0.0318	0.0651
8	-0.0627	-0.0312	-0.0159	0.0161	0.0318	0.0652
9	-0.0623	-0.0310	-0.0158	0.0160	0.0316	0.0648
10	-0.0623	-0.0310	-0.0158	0.0160	0.0317	0.0648
11	-0.0640	-0.0319	-0.0162	0.0164	0.0325	0.0666
12	-0.0640	-0.0319	-0.0163	0.0164	0.0325	0.0667
13	-0.0626	-0.0312	-0.0159	0.0161	0.0318	0.0651
14	-0.0607	-0.0303	-0.0154	0.0156	0.0309	0.0633
15	-0.0632	-0.0315	-0.0160	0.0162	0.0321	0.0658
16	-0.0617	-0.0307	-0.0157	0.0158	0.0313	0.0642
17	-0.0618	-0.0308	-0.0157	0.0159	0.0314	0.0644
18	-0.0625	-0.0311	-0.0159	0.0160	0.0317	0.0650
19	-0.0640	-0.0319	-0.0162	0.0164	0.0325	0.0666
20	-0.0638	-0.0318	-0.0162	0.0164	0.0324	0.0664
21	-0.0630	-0.0314	-0.0160	0.0161	0.0320	0.0655
22	-0.0609	-0.0303	-0.0155	0.0156	0.0310	0.0634
23	-0.0617	-0.0308	-0.0157	0.0158	0.0314	0.0643
24	-0.0617	-0.0308	-0.0157	0.0158	0.0314	0.0643
25	-0.0608	-0.0303	-0.0154	0.0156	0.0309	0.0634
26	-0.0632	-0.0315	-0.0160	0.0162	0.0321	0.0658
27	-0.0635	-0.0316	-0.0161	0.0163	0.0323	0.0661
28	-0.0636	-0.0317	-0.0161	0.0163	0.0323	0.0662
29	-0.0630	-0.0314	-0.0160	0.0162	0.0320	0.0656
30	-0.0620	-0.0309	-0.0157	0.0159	0.0315	0.0646
total payment	-0.0625	-0.0311	-0.0159	0.0160	0.0318	0.0650

Figure 5-5 Percent change in price result from varying the breast yield fixed standard

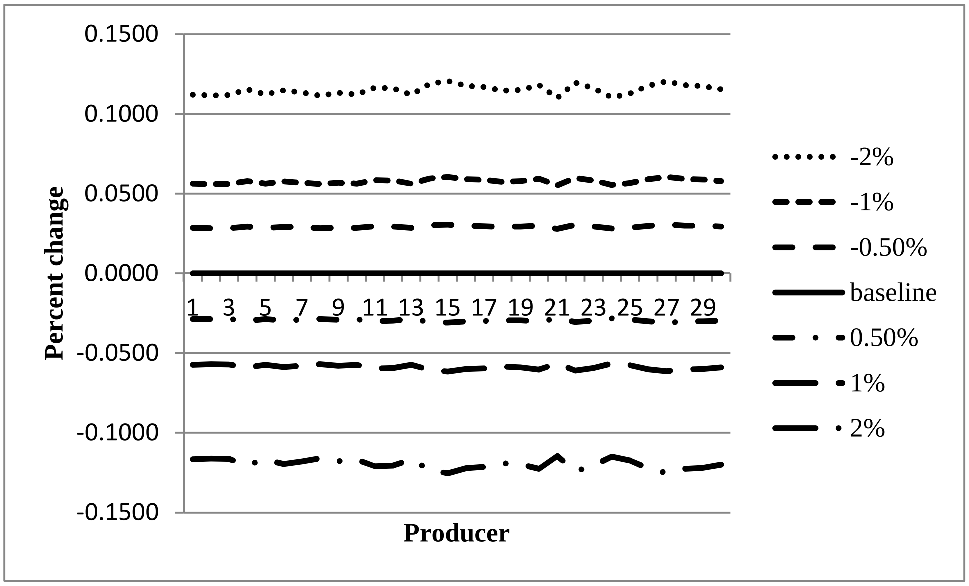


Figure 5-6 Percent change in price result from varying the wing yield fixed standard

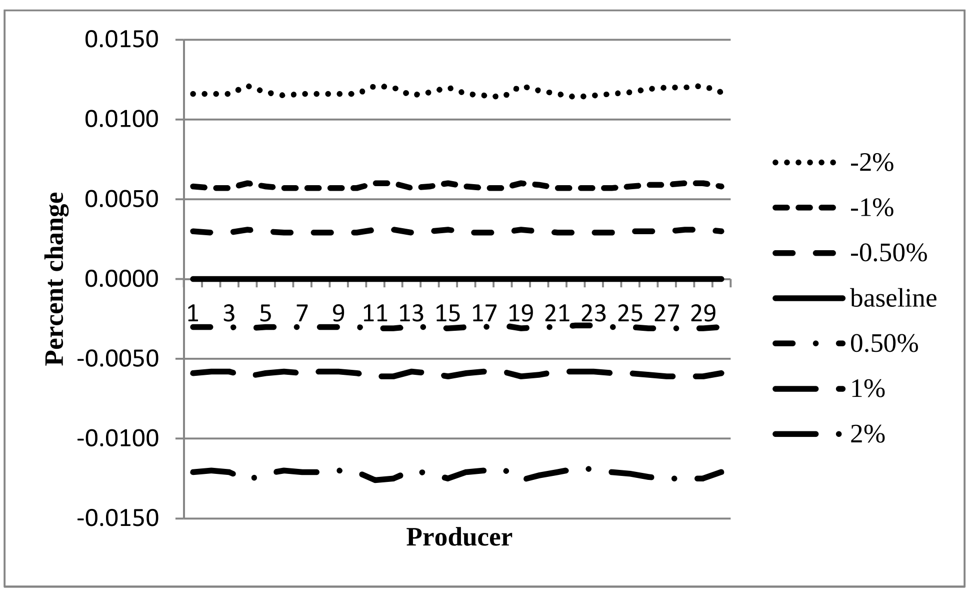
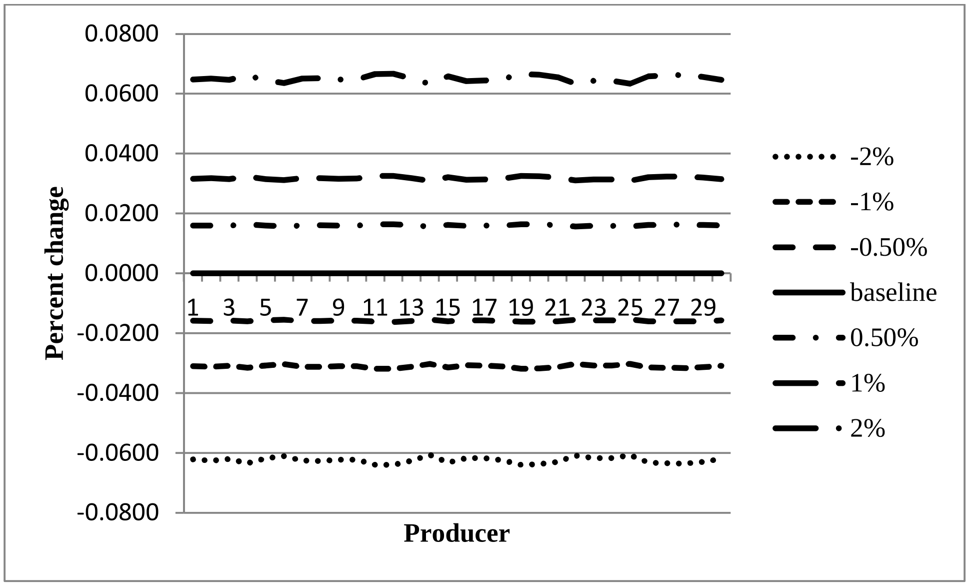


Figure 5-7 Percent change in price result from varying the leg yield fixed standard



Next, we explore the impact of relaxing the single market assumption by deterministically varying the price mark-up component (MK_B, MK_W, MK_L) of the pricing system by 1% 20%, 30% and 40%. Similar to the analysis with respect to $\widetilde{BY}, \widetilde{WY}$ and $\widetilde{LY}$, the percentage changes of MK_B, MK_W, MK_L are set according to the percentage of their standard deviations to the mean values. For comparison purposes, a 1% change in the price mark-up of each cut-up part is also considered so as to compare the impact of varying the fixed standards of the yield level. Since the impacts are symmetric by minus or plus the same ratio of price mark-up, only the result of increasing the price mark-up of each cut-up part are presented. Values of varying price mark-ups are shown in Table 5-8 and results of the deterministic analysis with respect to the three cut-up parts are presented in Table 5-9 to 5-11 and Figure 5-8 to 5-10.

As the results show, the total payments in each scenario have hardly changed after varying price mark-ups (Table 5-9 to 5-11). The change in the price mark-up only affects the distribution of payment (Figure 5-8 to 5-10). A higher price mark-up results in higher prices for the producers whose performance is above average, and lower prices for those whose performance is below average. Compared the three cut-up parts, price appear to be most sensitive to changes in the price mark-up of breast followed by leg and wing.

Compared to the deterministic analysis with respect to the fixed standards, price is relatively insensitive to cut-up part price mark-up changes. For example, the price change for producer 1 driven by a 1% increase in price mark-up of breast meat is around 0.008% while the value is 0.57% when the breast yield fixed standard increase by the same percentage. However, it should be emphasized that the change in fixed standards is subject to technological constraints as well as the biological characteristics of chicken such as body structure and genetics. Therefore, even a 1% change in yield could be considered as a significant change. Moreover, the standard deviations of the yield data and the price data suggest that price mark-up is much more flexible than yield, so that a 1% change in price mark-up could be considered as a minor change and thus has less impact on price.

Table 5-8 Value of cut-up part price mark-up at different levels

Cut-up part price mark-up	**Value of price mark-up**				
	Baseline	1%	20%	30%	40%
Breast	0.6346	0.6409	0.7615	0.8250	0.8884
Wing	0.3949	0.3988	0.4739	0.5134	0.5529
Leg	-0.2993	-0.3023	-0.3592	-0.3891	-0.4190

Table 5-9 Percent change in price and total payment result from varying the breast price mark-up

Producer	Percent change in price over baseline scenario			
	change in breast meat price mark-up			
	1%	20%	30%	40%
1	0.0008%	0.0157%	0.0235%	0.0314%
2	0.0010	0.0201	0.0301	0.0402
3	0.0009	0.0184	0.0277	0.0369
4	0.0011	0.0230	0.0345	0.0461
5	0.0008	0.0152	0.0228	0.0304
6	-0.0005	-0.0106	-0.0160	-0.0213
7	0.0001	0.0027	0.0041	0.0054
8	0.0010	0.0209	0.0314	0.0418
9	0.0002	0.0043	0.0065	0.0087
10	0.0007	0.0138	0.0206	0.0275
11	0.0007	0.0131	0.0197	0.0262
12	0.0008	0.0166	0.0250	0.0333
13	0.0008	0.0154	0.0231	0.0307
14	-0.0024	-0.0477	-0.0716	-0.0954
15	-0.0014	-0.0273	-0.0409	-0.0545
16	-0.0018	-0.0363	-0.0544	-0.0726
17	-0.0014	-0.0289	-0.0433	-0.0578
18	-0.0005	-0.0091	-0.0136	-0.0182
19	0.0013	0.0253	0.0379	0.0506
20	-0.0001	-0.0017	-0.0025	-0.0033
21	0.0017	0.0342	0.0513	0.0684
22	-0.0028	-0.0558	-0.0837	-0.1116
23	-0.0011	-0.0217	-0.0326	-0.0434
24	0.0016	0.0313	0.0469	0.0625
25	0.0005	0.0101	0.0152	0.0203
26	0.0001	0.0021	0.0032	0.0043
27	-0.0013	-0.0252	-0.0378	-0.0504
28	-0.0001	-0.0015	-0.0023	-0.0030
29	0.0002	0.0046	0.0069	0.0091
30	-0.0008	-0.0161	-0.0241	-0.0321
Total payment	0.0000	0.0002	0.0002	0.0003

Table 5-10 Percent change in price and total payment result from varying the wing price mark-up

Producer	Percent change in price over baseline scenario			
	change in wing price mark-up			
	1%	20%	30%	40%
1	0.0000%	-0.0005%	-0.0007%	-0.0010%
2	0.0000	0.0001	0.0001	0.0002
3	0.0000	0.0000	0.0001	0.0001
4	-0.0001	-0.0011	-0.0016	-0.0021
5	-0.0001	-0.0011	-0.0016	-0.0022
6	0.0000	0.0008	0.0011	0.0015
7	0.0000	-0.0001	-0.0002	-0.0002
8	0.0000	0.0000	-0.0001	-0.0001
9	0.0000	0.0003	0.0004	0.0006
10	0.0000	-0.0002	-0.0004	-0.0005
11	0.0000	-0.0010	-0.0015	-0.0019
12	0.0000	-0.0003	-0.0004	-0.0006
13	0.0000	0.0003	0.0005	0.0006
14	-0.0001	-0.0012	-0.0018	-0.0024
15	0.0000	0.0001	0.0001	0.0002
16	0.0000	0.0001	0.0001	0.0001
17	0.0001	0.0011	0.0016	0.0021
18	0.0001	0.0017	0.0026	0.0035
19	0.0000	-0.0008	-0.0011	-0.0015
20	0.0001	0.0016	0.0025	0.0033
21	0.0000	-0.0001	-0.0002	-0.0003
22	0.0001	0.0021	0.0032	0.0043
23	0.0001	0.0015	0.0022	0.0029
24	0.0000	-0.0003	-0.0005	-0.0006
25	-0.0001	-0.0014	-0.0022	-0.0029
26	0.0000	0.0008	0.0012	0.0016
27	0.0000	0.0002	0.0002	0.0003
28	0.0000	-0.0002	-0.0003	-0.0004
29	0.0000	-0.0004	-0.0006	-0.0008
30	0.0000	-0.0005	-0.0007	-0.0010
Total payment	0.0000	0.0000	0.0001	0.0001

Table 5-11 Percent change in price and total payment result from varying the leg price mark-up

Producer	Percent change in price over baseline scenario			
	change in leg price mark-up			
	1%	20%	30%	40%
1	0.0002%	0.0047%	0.0070%	0.0094%
2	0.0005	0.0092	0.0137	0.0183
3	0.0002	0.0038	0.0057	0.0076
4	-0.0002	-0.0045	-0.0068	-0.0091
5	0.0001	0.0018	0.0027	0.0036
6	-0.0004	-0.0073	-0.0110	-0.0147
7	0.0004	0.0085	0.0127	0.0170
8	0.0005	0.0102	0.0154	0.0205
9	0.0003	0.0051	0.0076	0.0102
10	0.0003	0.0061	0.0092	0.0123
11	0.0001	0.0010	0.0015	0.0021
12	0.0001	0.0012	0.0019	0.0025
13	0.0005	0.0092	0.0138	0.0184
14	-0.0006	-0.0124	-0.0186	-0.0248
15	-0.0004	-0.0087	-0.0131	-0.0174
16	-0.0001	-0.0021	-0.0031	-0.0042
17	0.0000	-0.0002	-0.0004	-0.0005
18	0.0004	0.0072	0.0109	0.0145
19	0.0000	0.0010	0.0015	0.0020
20	-0.0001	-0.0016	-0.0024	-0.0032
21	0.0007	0.0138	0.0207	0.0276
22	-0.0005	-0.0108	-0.0162	-0.0216
23	0.0000	-0.0009	-0.0014	-0.0019
24	0.0000	0.0006	0.0009	0.0013
25	-0.0005	-0.0094	-0.0142	-0.0189
26	-0.0004	-0.0081	-0.0121	-0.0162
27	-0.0003	-0.0062	-0.0092	-0.0123
28	-0.0002	-0.0040	-0.0060	-0.0079
29	-0.0005	-0.0100	-0.0150	-0.0200
30	0.0001	0.0022	0.0033	0.0044
Total payment	0.0000	0.0000	0.0000	0.0001

Figure 5-8 Percent change in price result from varying the price mark-up of breast

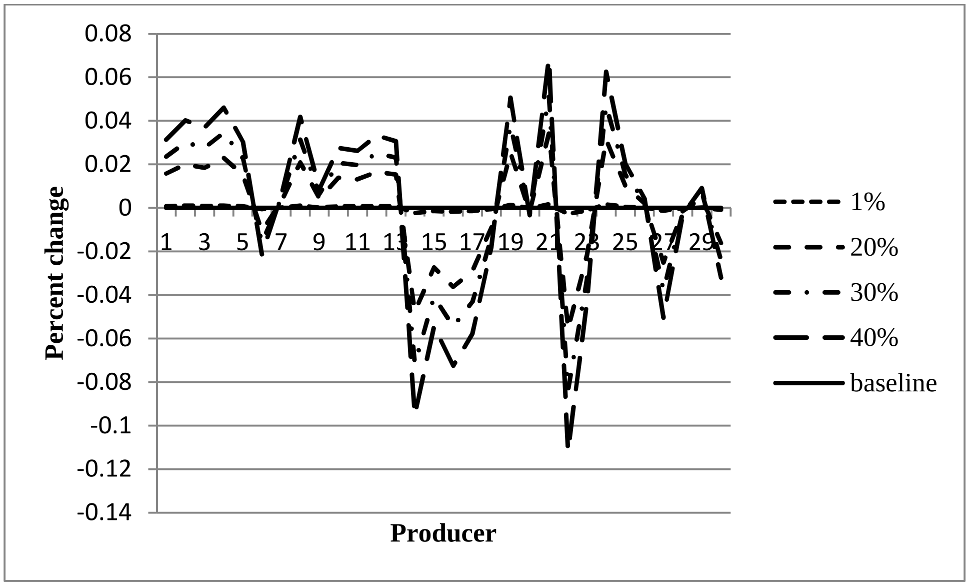


Figure 5-9 Percent change in price result from varying the price mark-up of wing

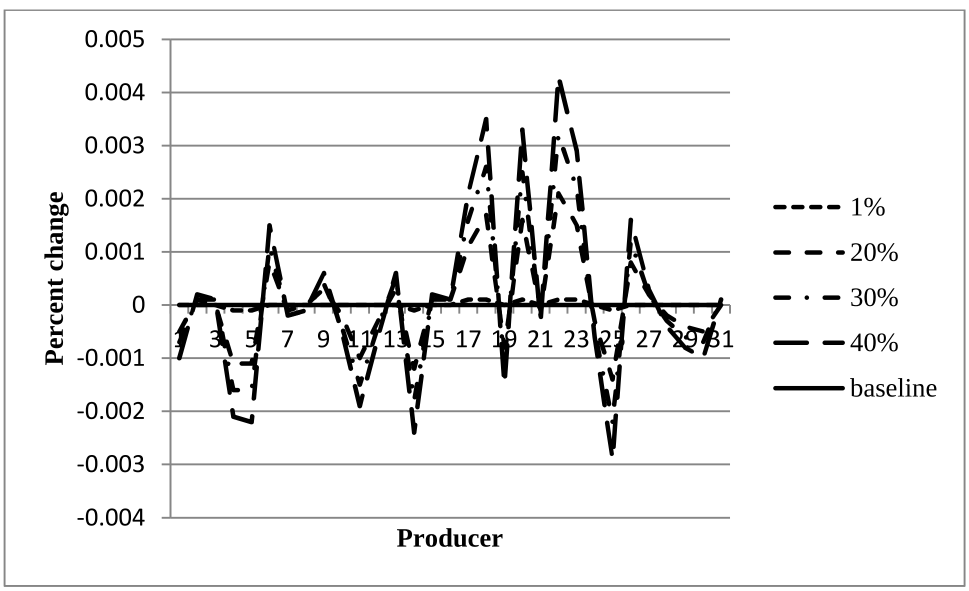
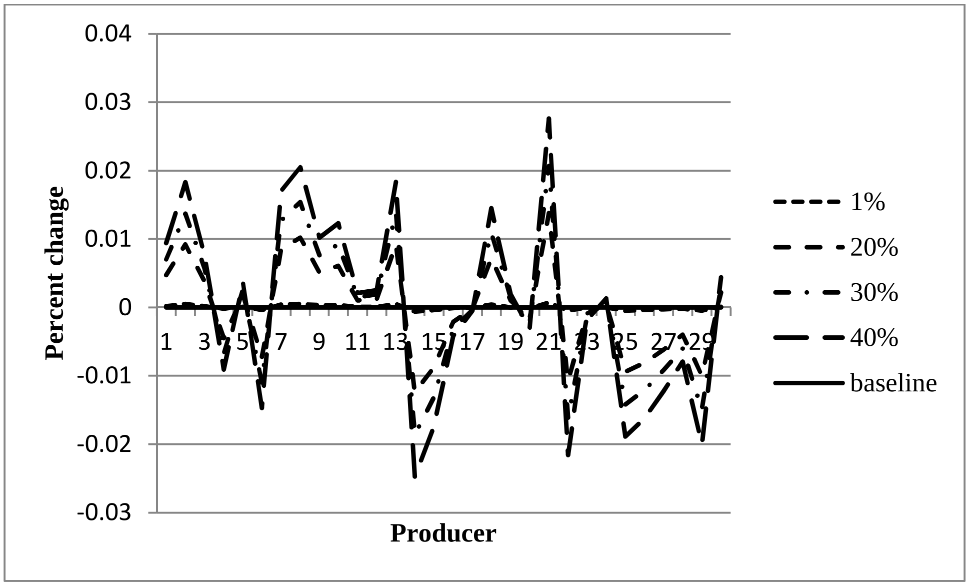


Figure 5-10 Percent change in price result from varying the price mark-up of leg



To examine the total effect of relaxing both the single processor assumption and single market assumption, we assume a 0.5% and a 1% change for $\widetilde{BY}, \widetilde{WY}$, a -0.5% and a -1% change for $\widetilde{LY}$. The higher fixed standard of breast and wing and lower fixed standard of leg indicate stricter requirements by the processor. Practically, the stricter requirements and the higher bonus should exist when the cut-up part is associated with a higher market value. Therefore, only the scenario of positive change (20%, 30% and 40%) in MK_B, MK_W, MK_L is to be investigated while a stricter requirement by processors is assumed.

Recall our previous discussion about the total effect of changing fixed standard and price mark-up, the critical value can be calculated as the baseline fixed standard times $(\frac{(\lambda\times\theta^2-1)}{(\lambda\times\theta-1)})$. Holding other fixed standard unchanged, when the yield level of a particular producer is higher than this critical value, the bonus effect exceeds the evaluation effect, and the producer will benefit from the change. Given the percentage of change of the fixed standard and price mark-up, the critical values in each scenario are calculated and presented in Table 5-12. According to the results, we can expect that when the fixed standard of a particular quality trait increases by 1% (θ=1.01) and price mark-up increases by 20% (λ=1.2), only those producers whose yield level are 5.7% higher than the baseline fixed standard will benefit from the change. When the fixed standard increase by 0.5% (θ=1.05) and the price mark-up to increase to 30% higher than the baseline level (λ=1.2), producers with a yield level that is 2.13% higher than the baseline fixed standard will benefit from the changes. In general, as fixed standard decreases and price mark-up increases, more producers will be better off.

Table 5-12 Critical value for each scenario

	λ=1.2	λ=1.3	λ=1.4
θ=1.005	1.0293	1.0213	1.0173
θ=1.01	1.0572	1.0419	1.0342

The results of percent changes in prices over the baseline scenario in each scenario are presented in Table 5-13 to 5-15 and Figure 5-11 to 5-13. As Figure 5-11 to 5-13 shows, both the total payment (indicated by the vertical shift of the lines) and the distribution of prices (indicated by the vertical stretch of the lines) are affected by the changes in fixed standard and price mark-up. In all scenarios except the ones where θ = 1.005 and $\lambda = 1.4$, the changes result in declining prices for all 30 producers, which indicates that the total bonus effects are not strong enough to offset the evaluation effects in these scenarios, while fixed standards with respect to other cut-up parts stay at the baseline level. In the scenarios where θ=1.005 and $\lambda = 1.4$, 5 out of 30 producers get a higher price from the change with respect to breast meat (Table 5-13); only one producer gets a higher price in each of the scenarios where the changes are associated with wing or leg (Table 5-14 and 5-15). This result suggests that a stricter requirement on yield level should be combined with a sufficient increase in premium level, and/or with decline in fixed standard with respect to other quality traits. Otherwise the downgrading effect of a stricter requirement would be so strong that producer will be discouraged to improve yield levels.

Notice that this conclusion is based on the yield data of the 30 hypothetical producers. Therefore, it may not be generally applicable to the producers in the real market, since the variation of yield level might be greater in the real market due to differences in terms of feed ingredients, feed quality, and management methods, among other factors.

Table 5-13 Percent change in price and total payment result from varying fixed standard and the price mark-up of breast

Producer	Percent change in price and total payment over baseline scenario					
	breast yield fixed standard 0.5%			breast yield fixed standard 1%		
	Breast mark-up			Breast mark-up		
	+20%	+30%	+40%	+20%	+30%	+40%
1	-0.0188	-0.0138	-0.0088	-0.0536	-0.0515	-0.0495
2	-0.0142	-0.0070	**0.0002**	-0.0489	-0.0446	-0.0403
3	-0.0159	-0.0096	-0.0032	-0.0507	-0.0472	-0.0438
4	-0.0124	-0.0039	**0.0047**	-0.0483	-0.0428	-0.0372
5	-0.0192	-0.0145	-0.0098	-0.0541	-0.0523	-0.0504
6	-0.0459	-0.0542	-0.0624	-0.0816	-0.0929	-0.1041
7	-0.0321	-0.0337	-0.0352	-0.0674	-0.0718	-0.0763
8	-0.0133	-0.0057	**0.0019**	-0.0480	-0.0433	-0.0386
9	-0.0305	-0.0312	-0.0319	-0.0657	-0.0693	-0.0730
10	-0.0207	-0.0167	-0.0127	-0.0556	-0.0545	-0.0534
11	-0.0227	-0.0191	-0.0155	-0.0589	-0.0583	-0.0577
12	-0.0190	-0.0137	-0.0083	-0.0551	-0.0528	-0.0504
13	-0.0191	-0.0142	-0.0094	-0.0539	-0.0520	-0.0501
14	-0.0842	-0.1111	-0.1380	-0.1211	-0.1511	-0.1810
15	-0.0643	-0.0811	-0.0978	-0.1018	-0.1217	-0.1415
16	-0.0724	-0.0935	-0.1147	-0.1089	-0.1331	-0.1573
17	-0.0647	-0.0822	-0.0996	-0.1010	-0.1215	-0.1419
18	-0.0443	-0.0518	-0.0593	-0.0799	-0.0904	-0.1008
19	-0.0101	-0.0004	**0.0093**	-0.0459	-0.0392	-0.0325
20	-0.0379	-0.0418	-0.0456	-0.0746	-0.0815	-0.0884
21	0.0004	0.0146	0.0289	-0.0339	-0.0225	-0.0111
22	-0.0925	-0.1235	-0.1545	-0.1297	-0.1637	-0.1978
23	-0.0573	-0.0711	-0.0850	-0.0934	-0.1102	-0.1270
24	-0.0027	0.0101	**0.0229**	-0.0370	-0.0271	-0.0172
25	-0.0245	-0.0223	-0.0201	-0.0596	-0.0603	-0.0610
26	-0.0340	-0.0359	-0.0379	-0.0705	-0.0755	-0.0805
27	-0.0622	-0.0779	-0.0935	-0.0996	-0.1184	-0.1372
28	-0.0377	-0.0415	-0.0453	-0.0744	-0.0812	-0.0881
29	-0.0315	-0.0322	-0.0329	-0.0680	-0.0717	-0.0755
30	-0.0515	-0.0625	-0.0734	-0.0874	-0.1013	-0.1153
Total payment	-0.0352	-0.0138	-0.0409	-0.0709	-0.0768	-0.0826

Table 5-14 Percent change in price and total payment result from varying fixed standard and the price mark-up of wing

Producer	Percent change in price and total payment over baseline scenario					
	wing yield fixed standard 0.5%			wing yield fixed standard 1%		
	wing mark-up			wing mark-up		
	+20%	+30%	+40%	+20%	+30%	+40%
1	-0.0041	-0.0046	-0.0052	-0.0075	-0.0084	-0.0092
2	-0.0035	-0.0037	-0.0040	-0.0069	-0.0075	-0.0080
3	-0.0035	-0.0038	-0.0041	-0.0070	-0.0075	-0.0081
4	-0.0048	-0.0056	-0.0064	-0.0084	-0.0095	-0.0107
5	-0.0047	-0.0055	-0.0064	-0.0082	-0.0093	-0.0105
6	-0.0028	-0.0027	-0.0026	-0.0062	-0.0064	-0.0067
7	-0.0037	-0.0040	-0.0044	-0.0071	-0.0078	-0.0084
8	-0.0036	-0.0039	-0.0042	-0.0071	-0.0077	-0.0083
9	-0.0033	-0.0034	-0.0036	-0.0067	-0.0072	-0.0076
10	-0.0038	-0.0042	-0.0046	-0.0073	-0.0080	-0.0087
11	-0.0047	-0.0055	-0.0063	-0.0083	-0.0094	-0.0105
12	-0.0040	-0.0044	-0.0049	-0.0076	-0.0083	-0.0091
13	-0.0032	-0.0034	-0.0035	-0.0067	-0.0071	-0.0075
14	-0.0048	-0.0057	-0.0066	-0.0083	-0.0095	-0.0107
15	-0.0036	-0.0039	-0.0041	-0.0072	-0.0078	-0.0083
16	-0.0035	-0.0038	-0.0040	-0.0070	-0.0075	-0.0081
17	-0.0025	-0.0022	-0.0020	-0.0059	-0.0060	-0.0060
18	-0.0018	-0.0012	-0.0006	-0.0052	-0.0049	-0.0046
19	-0.0045	-0.0051	-0.0058	-0.0081	-0.0090	-0.0100
20	-0.0020	-0.0015	-0.0010	-0.0055	-0.0053	-0.0051
21	-0.0037	-0.0040	-0.0044	-0.0071	-0.0078	-0.0084
22	-0.0014	-0.0006	**0.0002**	-0.0048	-0.0043	-0.0038
23	-0.0021	-0.0016	-0.0012	-0.0055	-0.0054	-0.0052
24	-0.0039	-0.0043	-0.0048	-0.0074	-0.0081	-0.0089
25	-0.0050	-0.0061	-0.0071	-0.0086	-0.0099	-0.0112
26	-0.0029	-0.0028	-0.0027	-0.0065	-0.0067	-0.0069
27	-0.0035	-0.0038	-0.0040	-0.0071	-0.0077	-0.0082
28	-0.0039	-0.0043	-0.0048	-0.0075	-0.0082	-0.0090
29	-0.0041	-0.0046	-0.0051	-0.0077	-0.0085	-0.0093
30	-0.0041	-0.0046	-0.0051	-0.0076	-0.0084	-0.0092
Total payment	-0.0035	-0.0038	-0.0041	-0.0071	-0.0076	-0.0082

Table 5-15 Percent change in price and total payment result from varying fixed standard and the price mark-up of leg

Producer	Percent change in price and total payment over baseline scenario					
	leg yield fixed standard 0.5%			leg yield fixed standard 1%		
	leg mark-up			leg mark-up		
	+20%	+30%	+40%	+20%	+30%	+40%
1	-0.0143	-0.0135	-0.0128	-0.0337	-0.0345	-0.0354
2	-0.0099	-0.0069	-0.0039	-0.0294	-0.0280	-0.0267
3	-0.0151	-0.0148	-0.0145	-0.0345	-0.0358	-0.0371
4	-0.0239	-0.0278	-0.0317	-0.0437	-0.0492	-0.0548
5	-0.0171	-0.0178	-0.0185	-0.0364	-0.0387	-0.0410
6	-0.0259	-0.0311	-0.0363	-0.0449	-0.0518	-0.0586
7	-0.0106	-0.0079	-0.0053	-0.0301	-0.0291	-0.0280
8	-0.0089	-0.0053	-0.0018	-0.0284	-0.0265	-0.0246
9	-0.0139	-0.0129	-0.0119	-0.0333	-0.0339	-0.0346
10	-0.0128	-0.0114	-0.0099	-0.0323	-0.0324	-0.0325
11	-0.0185	-0.0196	-0.0207	-0.0385	-0.0413	-0.0440
12	-0.0183	-0.0193	-0.0203	-0.0382	-0.0409	-0.0436
13	-0.0099	-0.0069	-0.0039	-0.0294	-0.0280	-0.0266
14	-0.0310	-0.0387	-0.0464	-0.0499	-0.0592	-0.0685
15	-0.0280	-0.0339	-0.0399	-0.0477	-0.0553	-0.0629
16	-0.0209	-0.0235	-0.0261	-0.0401	-0.0443	-0.0485
17	-0.0190	-0.0207	-0.0224	-0.0383	-0.0416	-0.0449
18	-0.0117	-0.0097	-0.0076	-0.0312	-0.0308	-0.0304
19	-0.0185	-0.0197	-0.0208	-0.0385	-0.0413	-0.0441
20	-0.0210	-0.0234	-0.0258	-0.0409	-0.0449	-0.0490
21	-0.0054	-0.0001	**0.0052**	-0.0250	-0.0214	-0.0177
22	-0.0292	-0.0362	-0.0431	-0.0482	-0.0568	-0.0653
23	-0.0197	-0.0217	-0.0238	-0.0389	-0.0426	-0.0462
24	-0.0182	-0.0194	-0.0207	-0.0374	-0.0403	-0.0431
25	-0.0280	-0.0343	-0.0406	-0.0470	-0.0549	-0.0627
26	-0.0273	-0.0329	-0.0386	-0.0470	-0.0543	-0.0616
27	-0.0255	-0.0302	-0.0349	-0.0453	-0.0516	-0.0580
28	-0.0234	-0.0269	-0.0305	-0.0432	-0.0484	-0.0537
29	-0.0292	-0.0358	-0.0424	-0.0488	-0.0571	-0.0653
30	-0.0167	-0.0172	-0.0177	-0.0361	-0.0381	-0.0402
Total payment	-0.0190	-0.0206	-0.0221	-0.0385	-0.0417	-0.0449

Figure 5-11 Percent change in price result from varying fixed standard and the price mark-up of breast

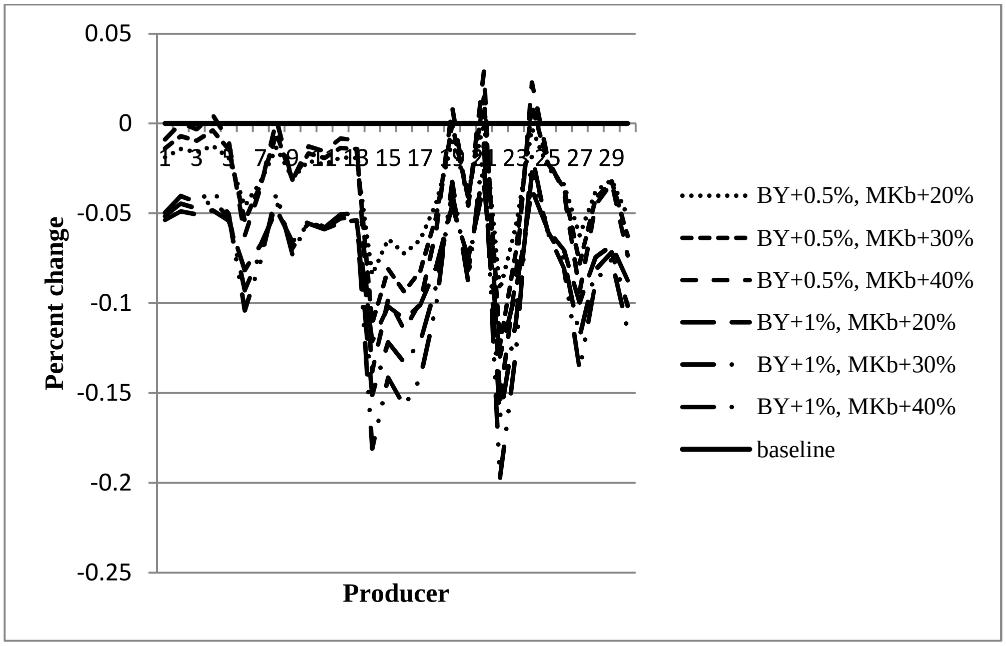


Figure 5-12 Percent change in price result from varying fixed standards and the price mark-up of wing

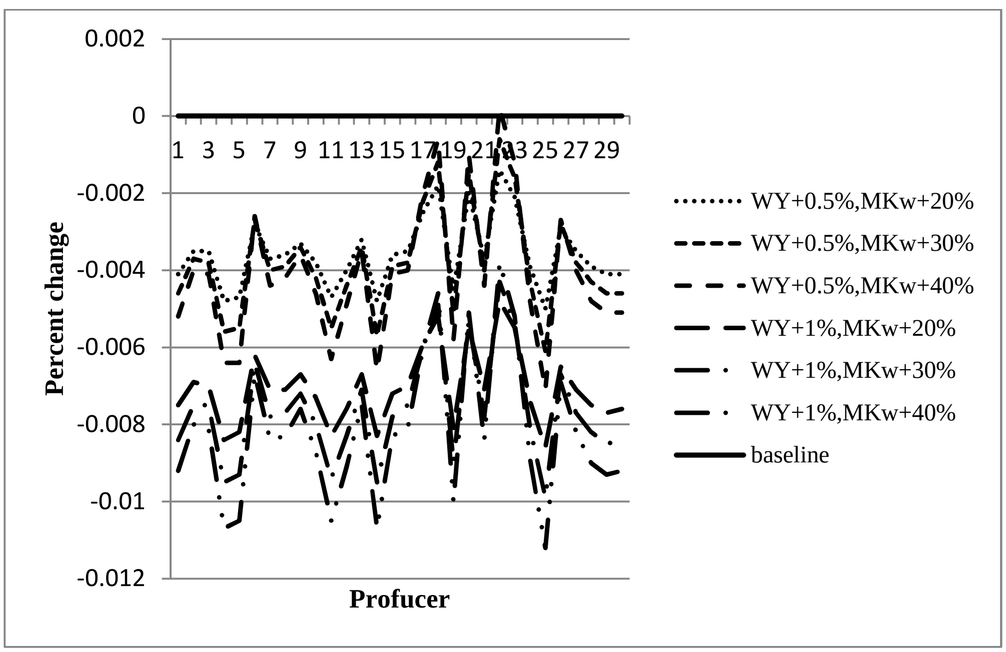
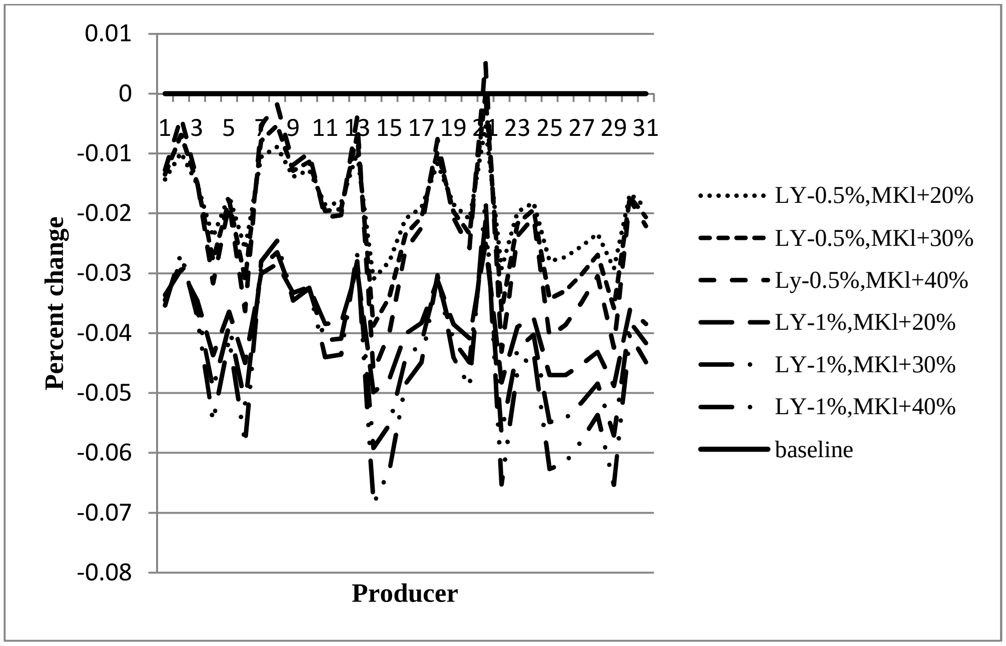


Figure 5-13 Percent change in price result from varying fixed standard and the price mark-up of leg



5.3.3 Stochastic Sensitivity Analysis

The preceding deterministic sensitivity analysis accounts for the heterogeneity in the processor, the market (with respect to mark-ups) and also for the change in price generated by different processor requirements and market values. The simulations could be used by processors and producers to predict payments in different scenarios by changing the corresponding variables in the excel sheet. However, these deterministic analyses are based on single-point estimates of variables. In other words, they are based on the best information available and could only be conducted when the precise value of the independent variables are known.

In this section, we are taking uncertainty into account by conducting stochastic analysis. We specify probability distributions for several variables in the pricing formula and use a Monte Carlo simulation analysis to obtain an empirical distribution of the payment for the producers under the novel pricing scheme. In the stochastic analysis, we will estimate the payment for each producer while keeping their performance unchanged. Moreover, we are also going to describe the distribution of the possible prices to be paid by the processors under the novel pricing scheme while performance of each producer is assumed to be stochastic.

5.3.3.1 Source of uncertainty

The uncertainty of price comes from multiple sources. First, we consider the fixed standards $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ which represent processors' requirement for cut-up part yield. This component is assumed to be constant in the baseline scenario. However, in the real world, there are various processors who specialize in different markets and therefore have different standards for quality. Moreover, $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ also indicate producers' average ability of controlling yield levels since the values of these variables are constrained by technological level. The existence of multiple processors and producers in the uncertainty of $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ in the novel pricing formula, and therefore the three variables are perceived to be stochastic in the analysis. Instead of a certain number, $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ will be assigned with a distribution, and the price formula becomes a continuously differentiable function.

Recall the formula for novel pricing scheme (equation 5.1),

$$P^i = BP_i + \beta_B \times \left(BY_i - \widetilde{BY}\right) + \beta_W \times \left(WY_i - \widetilde{WY}\right) + \beta_L \times \left(LY_i - \widetilde{LY}\right)$$

where β_B=(MK_B ×BP)× $\widetilde{BY}$, β_W=(MK_W ×BP)× $\widetilde{WY}$, β_L=(MK_L ×BP) × $\widetilde{LY}$

The impact of changes in $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ on price could be examined by taking derivatives. Take $\widetilde{BY}$ as an example: by taking the derivative of P with respect to $\widetilde{BY}$, we can decompose the response of price for the change in $\widetilde{BY}$ into a bonus effect (BE) and an evaluation effect (EE).

$$\frac{\partial P}{\partial \widetilde{BY}} = \frac{\partial P}{\partial \beta_B} \times \frac{\partial \beta_B}{\partial \widetilde{BY}} \times \left(BY_i - \widetilde{BY}\right) + \beta_B \times \frac{\partial (BY_i - \widetilde{BY})}{\partial \widetilde{BY}} \quad \text{………….…….(5.11.a)}$$

$$= MK_B \times BP \times (BY_i - \widetilde{BY}) - MK_B \times BP \times \widetilde{BY} \quad \text{…………...…….(5.11.b)}$$

$$= MK_B \times BP \times (BY_i - 2\,\widetilde{BY}) \quad \text{………..............................…..….(5.11.c)}$$

Equation 5.11 illustrates the two key impacts of changing $\widetilde{BY}$ on price. In the first part of equation (5.11.a) ($\frac{\partial P}{\partial \beta_B} \times \frac{\partial \beta_B}{\partial \widetilde{BY}} \times \left(BY_i - \widetilde{BY}\right)$), $\widetilde{BY}$ affects price P through β_B which is the variable that implies a processor' willingness to pay for a quality trait. It represents the "bonus effect" of changing $\widetilde{BY}$. Since the price mark-up of breast meat MK_B and the base price BP are positive, the direction of the bonus effect depends on the value of breast yield of the producer (5.11.c). If BY_i is greater than $\widetilde{BY}$ $\left(BY_i - \widetilde{BY} > 0\right)$, then increasing $\widetilde{BY}$ will have a positive bonus effect on producer i, the opposite being true when $BY_i - \widetilde{BY} < 0$. In the second part of equation (5.11.a), $\beta_B \times \frac{\partial (BY_i - \widetilde{BY})}{\partial \widetilde{BY}}$, $\widetilde{BY}$ affects price as there is a change in the performance evaluation of producer i, which therefore represents the "evaluation effect". Since β_B is always a positive value, the evaluation effect is always negative.

The price paid to producer i can either increase or decrease in response to an increase in $\widetilde{BY}$, depending on the strength of two effects. Specifically, when $BY_i - 2\,\widetilde{BY} > 0$(equation 5.11.c), the positive bonus effect from a higher $\widetilde{BY}$ is larger in absolute value than the negative evaluation effect. An increase in average breast yield standard will unambiguously raise the price for producer i. The opposite is true when $BY_i - 2\,\widetilde{BY} < 0$, since the negative evaluation effect will more than offset the bonus effect. Thus, the price received by producer i will decline when the producer is facing a processor with stricter requirement on breast yield.

The second component to be considered is the price mark-up of cut-up parts MK_B, MK_W and MK_L , which are important elements in the premium/ discount determination. Similar to the preceding deterministic analysis, we relax the single market assumption and now assume that producers and processors are facing multiple markets. Due to different target markets, transaction costs, varying regulations, seasonal demands and other random factors, price mark-ups are likely to be uncertain (Benabou, 1993). Thus, MK_B, MK_W and MK_L are also perceived to be stochastic in the analysis. The impact of changing price mark-ups could be examined by taking the derivative of price with respect to MK_B, MK_W and MK_L. Taking the price mark-up of breast meat for example,

$$\frac{\partial P}{\partial MK_B} = \frac{\partial P}{\partial \beta_B} \times \frac{\partial \beta_B}{\partial MK_B} = BP \times \widetilde{BY} \times (BY_i - \widetilde{BY}) \qquad (5.12)$$

Since MK_B only affects price through the premium parameter β_B, it therefore only has a bonus effect. As long as the base price BP and fixed standard $\widetilde{BY}$ are positive, the direction of the bonus effect depends on the sign of $BY_i - \widetilde{BY}$. If $BY_i > \widetilde{BY}$, which means the performance of producer i is above the fixed standard, producer i will benefit from the higher price mark-up because it results in a higher premium. In contrast, if $BY_i < \widetilde{BY}$, producer i's performance is lower than the fixed standard, such that producer i will be worse off because the higher mark-up leads to a higher discount in this case.

The last component to be considered as stochastic is the performance of each producer (BY_i, WY_i and LY_i). As discussed in the biological model, producers could control yield quality by choosing the optimum metabolizable energy level, dietary balanced protein level, pre-starter diet as well as other factors. However, under real world production conditions, producers may buy feed from different feed mills that are likely to use different feed formula. The uncertainty regarding the quality of raw material input of chicken feed results in uncertainty regarding feed quality. Moreover, the production process is also affect by exogenous factors such as weather, national disaster, diseases and so on. All these factors drive the uncertainty of producers' performance. Continuing with the example of breast yield, we can take the derivative of price with respect to BY_i which yields equation (5.13):

$$\frac{\partial P}{\partial BY_i} = \beta_B \times \frac{\partial (BY_i - \widetilde{BY})}{\partial BY_i} = \beta_B = \mathrm{MK}_B \times \mathrm{BP} \times \widetilde{\mathrm{BY}} \qquad (5.13)$$

It is apparent that BY_i only affects the performance evaluation, so it only has the evaluation effect. Since MK_B, BP, $\widetilde{BY}$ always take on positive values, the evaluation effect of BY_i is apparently positively related to price. Producers with better breast yield performance will receive a higher price, while the one unit increase in BY_i increases price by β_B unit.

5.3.3.2 Selection of the distribution

The probability distributions of the stochastic variables are constructed based on empirical data using the Distribution Fitting function of the Risk Solver Pro©. Specifically, the distributions of $\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$ are estimated based on the average yield level of the 30 producers (30 records for each cut-up part); the distributions of price mark-ups MK_B, MK_W and MK_L are based on 450 records of weekly weighted average wholesale price data from 2002 to 2010; and the distributions of producers' performance in terms of cut-up part yields are based on the yield data of the 30 pens in the experiment, collected from age 21-day to 56-day with a total sample size of 2036 for each cut-up part.

As the Risk Solver Pro© fits nearly 30 distributions to the empirical data, three goodness-of-fit tests including the Chi Squared test the Kolmogorov-Smirnoff test (Chakravarti, Laha, and Roy, 1967), and the Anderson-Darling test (Scholz and Stephens, 1974) are employed to determine which distribution fits our sample data best. The Chi-squared test is applied to binned data; it requires the data first to be grouped, so the value of the test statistic depends on how the data is binned. The Kolmogorov-Smirnov test does not require binning, but it tends to be more sensitive near the center of the distribution than at the tails. Moreover, the test requires the distribution to be fully specified. That is, if location, scale, and shape parameters are estimated from the data, the critical region of the test is no longer valid (Natrella, 2010). The Anderson-Darling test is a modification of the Kolmogorov-Smirnov test, since it gives more weight to the tails than the Kolmogorov-Smirnov test. Since the Anderson-Darling test makes use of the specific distribution in calculating critical values, a drawback of this test is that the critical values must be calculated for each distribution (Natrella, 2010).

In this study, 27 fitted distributions estimated by the program are ranked by the Anderson-Darling statistics. The first rank distributions are selected and are presented in Table 5-16. Since the critical variables for the Anderson-Darling test are only available for a few distributions, the Kolmogorov-Smirnov statistics and Chi-squared statistic as well as the *p*-value of the Chi-squared test are also presented. The results suggest that the null hypothesis, which is "the data follows the selected distribution", is not rejected in all cases.

Table 5-16 Distribution of stochastic variables

Variables	Sample size	Distribution	Anderson -darling	Kolmogorov-smirnov	Chi-squared	p-value
$\widetilde{BY}$	30	Extrem min	0.29	0.11	6.00	0.99
$\widetilde{WY}$	30	Erlang	0.33	0.11	5.20	0.99
$\widetilde{LY}$	30	Erlang	0.25	0.09	2.40	1.00
MK_B	450	Gumbel	0.68	0.03	72.93	1.00
MK_W	450	Normal	1.43	0.05	32.22	1.00
MK_L	450	Uniform	4.77	0.06	89.64	1.00
BY_i	2036	Weibull	1.29	0.02	30.90	1.00
WY_i	2036	Weibull	0.52	0.02	12.55	1.00
LY_i	2036	Normal	0.21	0.01	16.99	1.00

5.3.4 Monte Carlo simulation and results

In this section, seven Monte Carlo simulations are conducted to estimate the distribution of the live prices under the novel pricing scheme from both producers' and processors' perspectives.

The producer' perspective

From the producers' perspective, we are interested in the live price that is likely to be paid to each producer, considering that the level of their cut-up part yields is known. Therefore, in the first three simulations, the constant performance assumption is still upheld while the single processor assumption and single market assumption are relaxed. The first and second simulation assumes that the fixed standards of cut-up part yields $(\widetilde{BY}, \widetilde{WY}, \widetilde{LY})$ and price mark-up (MK_B, MK_W, MK_L) is random respectively. The third simulation assumes both fixed standards and price mark-up are random.

To run the simulations, the Software Risk Solver Pro© by Microsoft Excel 2010 is used. 10,000 trials are run for each simulation. Mean values of prices simulated in each case are presented in Table 5-17. The price change results from the uncertainties are presented as the percentage changes in price in Figure 5-14.

The results of all three simulations suggest that the estimated prices for the 30 producers after allowing for uncertainty are close to the prices in the baseline scenario, since the changes in price are less than ±0.005% of the baseline prices (Table 5-17). Specifically, as Figure 5-14 shows, allowing for uncertainties regarding only fixed standards $(\widetilde{BY}, \widetilde{WY}, \widetilde{LY})$ as well as uncertainty regarding both fixed standards and price mark-ups ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + MK_B, MK_W, MK_L$) result in minor decreases in prices for all producers. After accounting for uncertainty regarding only price mark-ups(MK_B, MK_W, MK_L), the prices vary around those at the baseline level. Generally speaking, for all producers, prices with uncertain processor requirements and uncertain market values of cut-up parts do not significantly differ from baseline prices. Uncertainty in terms of price mark-up results in greater variability of the pricing system, while the fixed standard uncertainty mainly affects the average price level.

Figure 5-14 Average prices for each producer estimated with different stochastic components

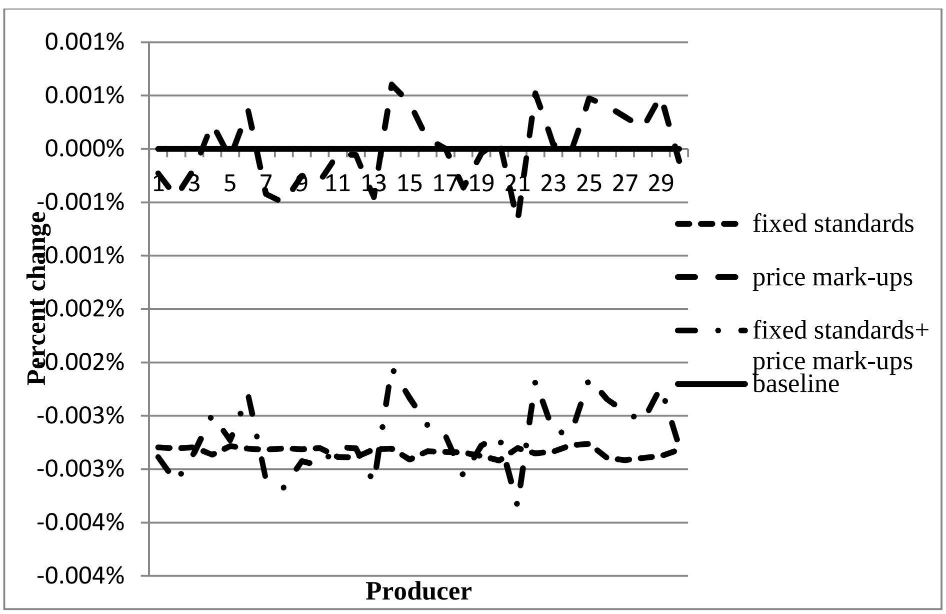


Table 5-17 Average price estimated with different set of stochastic variables at the 95% percentile

Producer	Baseline prices	Estimated prices					
		Stochastic Element(s)					
		$(\widetilde{BY}, \widetilde{WY}, \widetilde{LY})$		MK_B, MK_W, MK_L		$(\widetilde{BY}, \widetilde{WY}, \widetilde{LY})$ + MK_B, MK_W, MK_L	
		Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev
1	1.4549	1.4549	0.0017	1.4549	0.0003	1.4549	0.0018
2	1.4556	1.4556	0.0017	1.4556	0.0005	1.4556	0.0018
3	1.4551	1.4551	0.0017	1.4551	0.0004	1.4551	0.0018
4	1.4047	1.4047	0.0017	1.4047	0.0005	1.4047	0.0018
5	1.4547	1.4546	0.0017	1.4547	0.0003	1.4546	0.0018
6	1.4522	1.4522	0.0017	1.4523	0.0003	1.4522	0.0018
7	1.4543	1.4543	0.0017	1.4543	0.0002	1.4543	0.0018
8	1.4558	1.4557	0.0017	1.4558	0.0005	1.4557	0.0018
9	1.4542	1.4542	0.0017	1.4542	0.0001	1.4542	0.0018
10	1.4549	1.4549	0.0017	1.4549	0.0003	1.4549	0.0018
11	1.4044	1.4044	0.0017	1.4044	0.0003	1.4044	0.0018
12	1.4047	1.4047	0.0017	1.4047	0.0003	1.4047	0.0018
13	1.4553	1.4553	0.0017	1.4553	0.0004	1.4553	0.0018
14	1.4491	1.4490	0.0018	1.4491	0.0011	1.4490	0.0022
15	1.4010	1.4009	0.0018	1.4010	0.0006	1.4010	0.0019
16	1.4507	1.4507	0.0018	1.4507	0.0008	1.4507	0.0020
17	1.4515	1.4514	0.0018	1.4515	0.0006	1.4514	0.0020
18	1.4535	1.4535	0.0017	1.4535	0.0002	1.4534	0.0018
19	1.4053	1.4053	0.0017	1.4053	0.0005	1.4053	0.0018
20	1.4034	1.4033	0.0017	1.4034	0.0001	1.4033	0.0018
21	1.4570	1.4569	0.0017	1.4570	0.0008	1.4569	0.0019
22	1.4488	1.4488	0.0018	1.4488	0.0012	1.4488	0.0023
23	1.4520	1.4519	0.0018	1.4520	0.0005	1.4519	0.0019
24	1.4558	1.4558	0.0017	1.4558	0.0007	1.4558	0.0019
25	1.4534	1.4534	0.0017	1.4535	0.0003	1.4534	0.0018
26	1.4031	1.4031	0.0017	1.4031	0.0002	1.4031	0.0018
27	1.4013	1.4013	0.0018	1.4013	0.0005	1.4013	0.0019
28	1.4031	1.4031	0.0017	1.4031	0.0001	1.4031	0.0018
29	1.4031	1.4031	0.0017	1.4031	0.0002	1.4031	0.0018
30	1.4525	1.4524	0.0017	1.4525	0.0003	1.4524	0.0019

The processor' perspective

From the processors' prospective, we are interested in looking at the distribution of all possible prices that a processor may need to pay to multiple producers whose performances are uncertain. Therefore, the constant performance assumption is relaxed and the cut-up part yields by producers (BY_i, WY_i, LY_i) are assumed to be stochastic for the rest of the simulations which include the fourth simulation which assumes only yield level by producer i (BY_i, WY_i, LY_i) is stochastic; the fifth simulation which assumes both price mark-up and yield by producer i ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + MK_B, MK_W, MK_L$) are stochastic; the sixth simulation which assumes both fixed standards and cut-up part yields by producers i ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + BY_i, WY_i, LY_i$) are stochastic; and finally the seventh simulation which assumes all three sets of variables ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + BY_i, WY_i, LY_i + MK_B, MK_W, MK_L$) are stochastic. Since these four simulations are not producer specific, the base price (which is a discrete variable based on average weight of the birds from the same pen) is set to be a constant value equals to \$1.4535 per kg. Therefore, prices in these four simulations are only influenced by the premium/ discount component of the price formula.

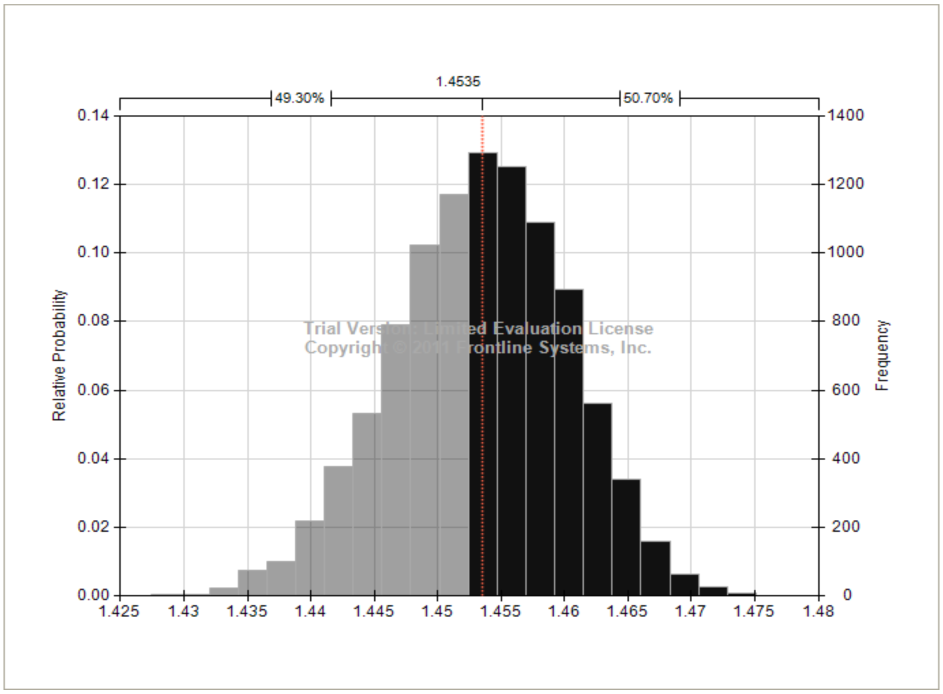
In total, 10,000 trials are run for each simulation. The means of simulated prices as well as the prices simulated at the 5% and 95% percentile in each simulation are presented in Table 5-18. The price distributions of the fourth to seventh Monte Carlo simulations are presented in Figure 5-15, 5-17, 5-19 and 5-20 respectively.

Regarding the price sensitivity to stochastic variables, the Pearson product-moment correlation coefficient is employed to measure the strength of linear dependence between price and each uncertain variable. The value of the Pearson product-moment correlation coefficient ranges from -1 and +1. A positive value indicates the positive correlation between price and the stochastic variable, while a negative value indicates the negative correlation. A higher absolute value of the correlation coefficient indicates a stronger relationship between the two variables. The Pearson product-moment correlation coefficients in each scenario are presented in a tornado chart following each price distribution figure.

Table 5-18 Prices estimated in the fourth to seventh Monte Carlo simulations ($/kg)

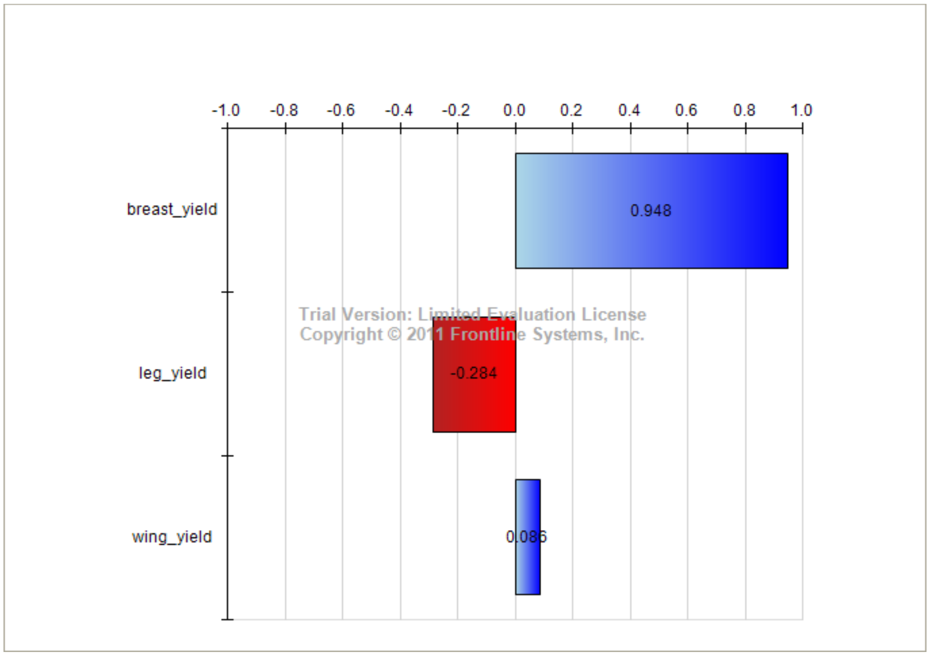
Stochastic Elements	5%	mean	95%
$\boldsymbol{BY_i, WY_i, LY_i}$	1.4413	1.4533	1.4644
$\boldsymbol{\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + MK_B, MK_W, MK_L}$	1.4412	1.4534	1.4644
$\boldsymbol{\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + BY_i, WY_i, LY_i}$	1.4423	1.4533	1.4623
$\boldsymbol{\widetilde{BY}, \widetilde{WY}, \widetilde{LY} + BY_i, WY_i, LY_i + MK_B, MK_W, MK_L}$	1.4410	1.4534	1.4648

Figure 5-15 Distribution of prices when yield is assumed to be stochastic



Source: own calculations (permission for the use of the graph obtained from Frontline Systems, Inc.)

Figure 5-16 Price sensitivity to producers' performance in yields



Source: own calculations (permission for the use of the graph obtained from Frontline Systems, Inc.)

In the fourth Monte Carlo simulation, where only cut-up part yields of producers are assumed stochastic, the estimated mean live price is $1.4533 per kg which is slightly lower than the base price. Looking at the price distribution shown in Figure 5-15, there is a 50.70% chance that a premium will be applied (estimated price >base price), and a 49.30% chance of a discount being applied.

As Figure 5-16 shows, breast yield and wing yield of producer are positively related to live price, while leg yield is negatively related. Among the three cut-up parts, beast yield has the greatest impact on price followed by leg yield and wing yield. This is driven by the fact that the absolute value of price mark-up of breast is the highest among the three cut-up parts, and the proportion of breast meat account for around 30% of whole bird. These result implies that while the price mark-up (MK_B, MK_W, MK_L) and the fixed standards of cut-up part yields ($\widetilde{BY}, \widetilde{WY}, \widetilde{LY}$) are held at the baseline level, the producer will most effectively increase the live price by improving his performance in breast yield, followed by leg yield and wing yield.

Figure 5-17 Distribution of prices when yield and price mark-up are assumed to be stochastic

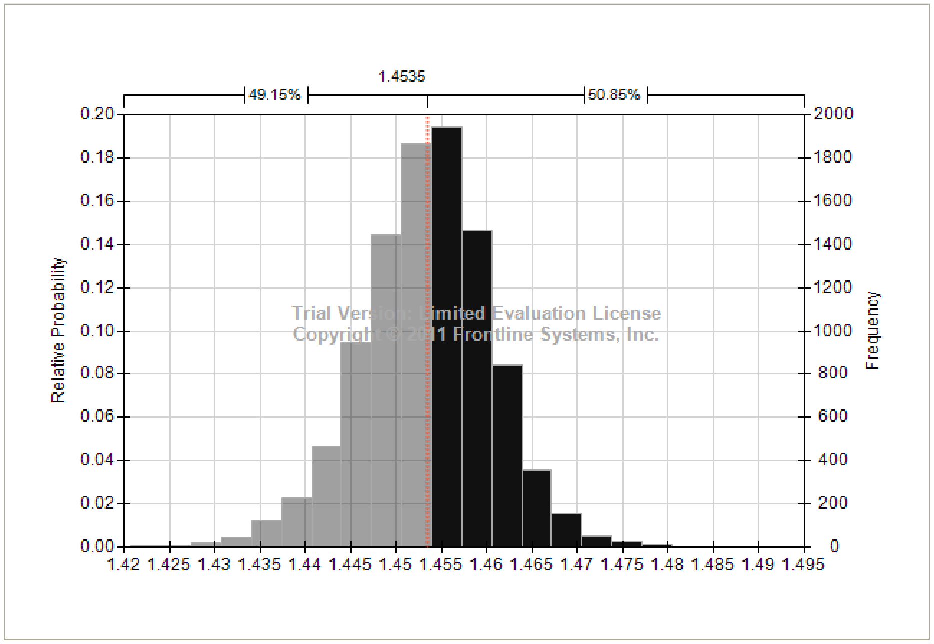


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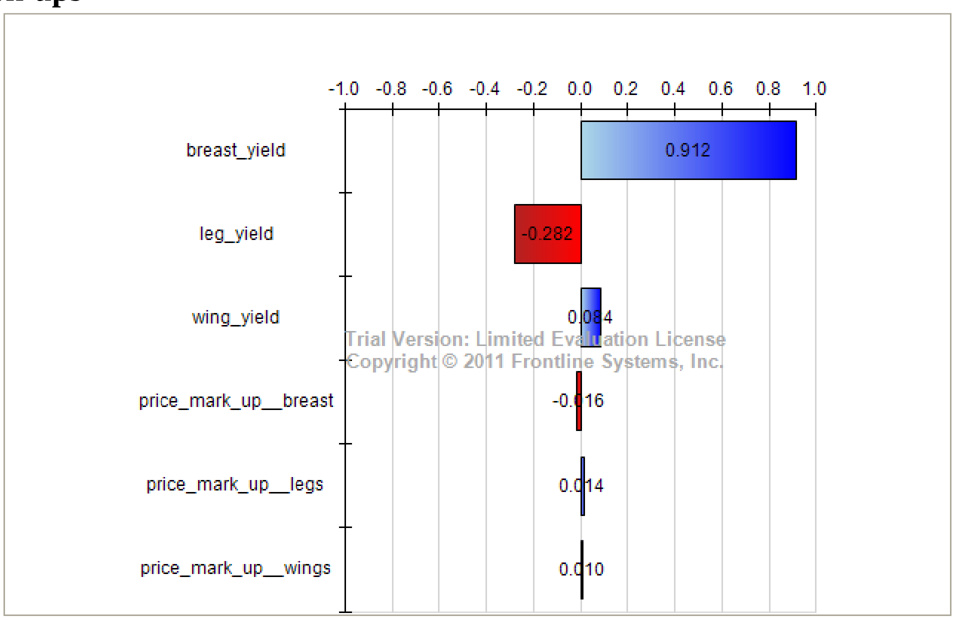
Figure 5-18 Price sensitivity to producers' performance in yields and price mark-ups



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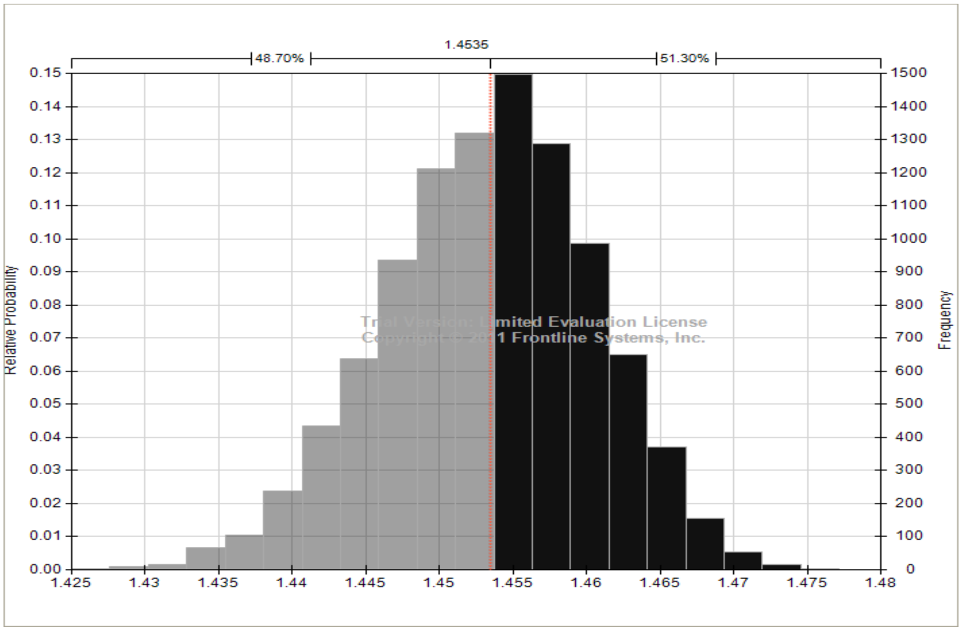
In the fifth Monte Carlo simulation, both cut-up part yields and price mark-ups are assumed to be stochastic. The mean price in this scenario is estimated at $1.4534 per kg; slightly lower than the base price $1.4535. The probability of the processor paying a price premium is 50.85% and the probability of paying a discount is 49.12%.

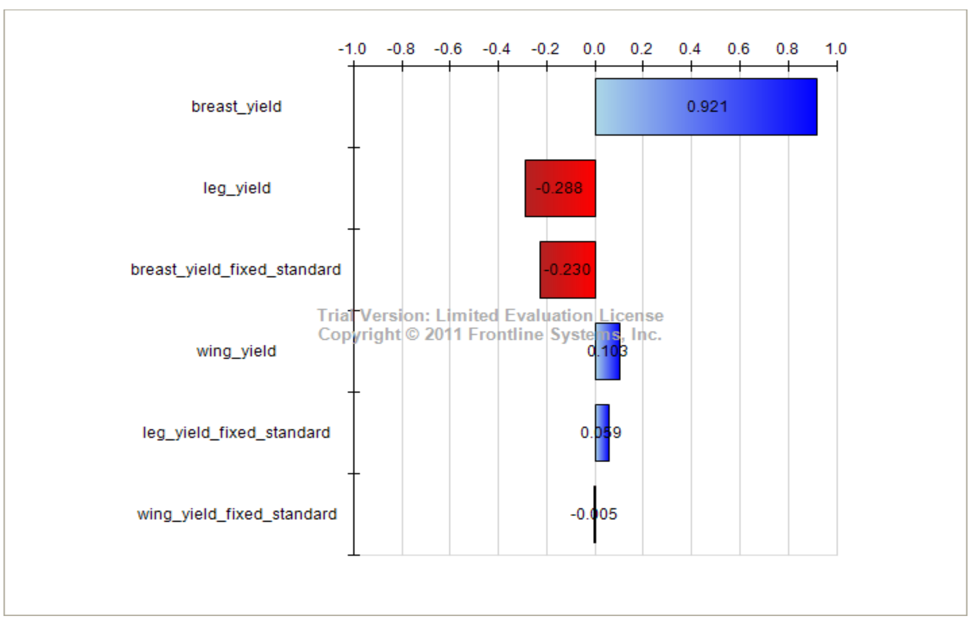
As discussed in the previous section, cut-up part yield affects price through the evaluation effect and price mark-up affects price through the bonus effect. The sensitivity analysis results shown in Figure 5-18 suggest that the evaluation effect driven by cut-up part yield has a greater impact than the bonus effect driven by price mark-up. Breast yield has the greatest impact on price compared to the other five stochastic variables in the simulation. The impacts of uncertain price mark-ups are significantly weaker than the uncertain cut-up part yield as the Pearson product-moment correlation coefficients of all price mark-ups are less than 0.02. Among the price mark-ups of the three cut-up parts, the price mark-up of breast has the greatest impact followed by the price mark-up of leg and wing.

Figure 5-19 Distribution of prices when producers' performance in yields and fixed stands are assumed to be stochastic



Source: own calculations (permission for the use of the graph obtained from Frontline Systems, Inc.)

Figure 5-20 Price sensitivity to producers' performance in yields and fixed standards



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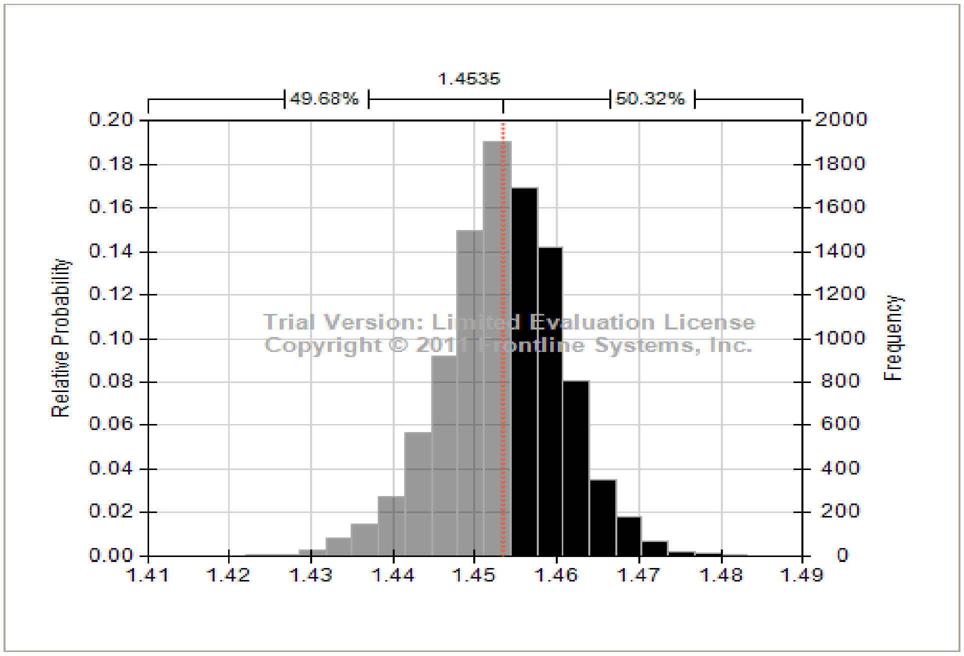
In sixth Monte Carlo simulation, both individual producer's cut-up part yields and the fixed standards of cut-up part yields are assumed to be stochastic. The mean live price is estimated at $1.4533 per kg. As the price distribution shows in Figure 5.19, processors have a 51.30% probability of paying a price higher than the base price and a 48.70% probability of paying less.

Regarding price sensitivity, Figure 5-20 shows that the individual producer breast yield is still the dominant element in the price determination followed by leg yield. Looking at the three fixed standards, breast yield standard has the greatest impact on price, while impacts of the other two fixed standards are very weak. Leg yield fixed standard appears to be positively related to price, while the wing yield and breast yield fixed standards appears to be negatively related. Recall that changing the fixed standard has both an evaluation effect and a bonus effect; and the directions of the two effects' impact on price are opposite. The result of this Monte Carlo simulation suggests that the evaluation effects of changing the fixed standards of all three cut up part exceed the bonus effects.

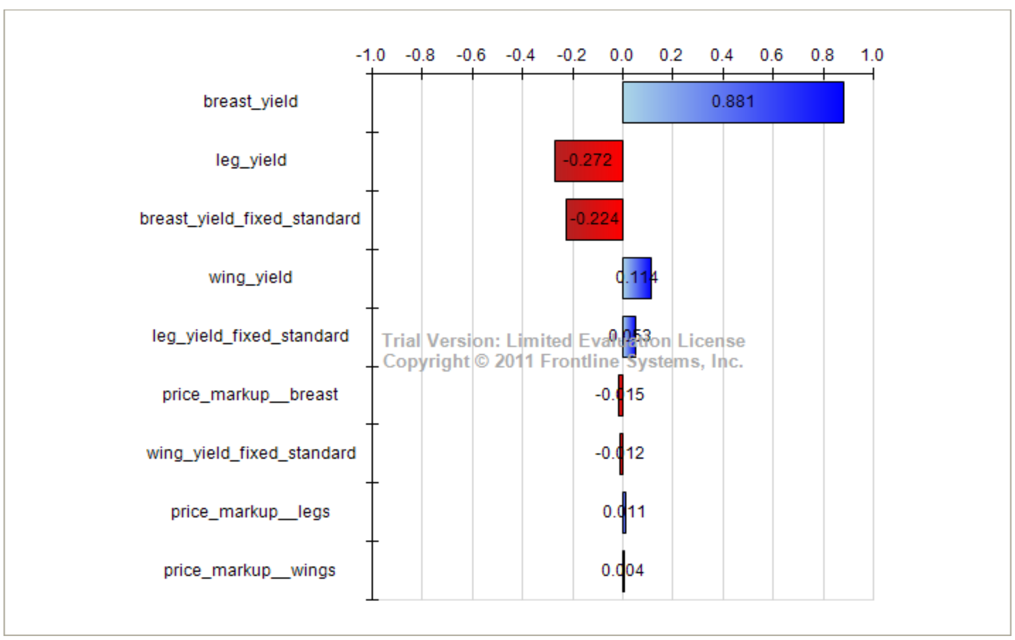
Generally speaking, the results of the sixth simulation imply that when both cut-up part yield by producers and the fixed standard of each cut-up part yield are stochastic, it can be expected that the producer could most effectively increase price by improving breast yield; processors' stricter requirement on yield levels will result in a decline in price; and price will be more sensitive to the fixed standard of breast yield than the fixed standards of the other two quality traits.

Figure 5-21 Distribution of prices when producers' performance in yields, price mark-ups and fixed standards assumed to be stochastic



Source: own calculations (permission for the use of the graph obtained from Frontline Systems, Inc.)

Figure 5-22 Price sensitivity to producers' performance in yields, price mark-ups and fixed standards



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Finally, a Monte Carlo simulation with all three stochastic elements is conducted. The mean of prices simulated from the 10,000 trials is $1.4534 per kg with a 50.32% chance greater than the base price and 49.68% chance of being lower. Two of the cut-up part yield variables, breast yield and leg yield, have the greatest impact on price among the nine stochastic variables. Consistent with the discussion in section 5.3.1, producers' performance in all cut-up part yields are positively related to price in all three cut-up parts. Fixed standards that represent processors requirements also have a significant impact on price in this scenario. Fixed standards of breast yield and leg yield rank as the third and fifth important variable in terms of the impact on price. For all three average yield variables, the strictness of processor's requirements is negatively related to price, which means that the evaluation effect of these elements exceeds the bonus effect and leads to the negative correlation between processor requirements and prices. Similar to the fifth simulation, price mark-up is the element with least influence on price. In general, stochastic variables that relate to breast have the greatest impact while those related to wing have the least. This is possibly due to the relative proportion of the cut-up part, since the cut-up part with a higher proportion also has a higher weight in the price formula and thus has a greater impact on price.

According to the results of the four Monte Carlo simulations conducted from a processor's perspective, the probability of paying a premium or discount are both around 50% in all simulations. As a result, the means of the simulated prices in these four simulations are close to the based price (difference $\leq$0.005%). Further, price with uncertainty is most sensitive to producers' performance in cut-up part yield especially breast yield. A processor's requirement, which is reflected in the fixed standards, also affects live price through the bonus effect and the evaluation effect. The price mark-up of cut-up parts is the element with the least influence on price.

5.4 Summary

In chapter five, prices were simulated under a novel pricing scheme, and the sensitivity to the key components in the pricing formula was subsequently examined.

First, employing the yield data obtained from a biological experiment, prices paid to thirty hypothetical producers under the current pricing scheme and the novel pricing scheme are simulated as the baseline scenario under the single processor assumption, the single market assumption and the constant producer performance assumption. While the price in a certain production period under the current pricing scheme is essentially determined by the average weight of the chicken, price under the novel pricing scheme is based on the average weight as well as cut-up part yields of each producer. The results of the baseline simulation suggest that the novel pricing scheme would shift price risk towards the producers, since it results in greater variation of prices paid to producers without causing a significant change in total payments by processors.

Second, deterministic sensitivity analyses were conducted to simulate prices given different levels of fixed standards and price mark-ups. Three scenarios have been considered, including scenario one where fixed standards of each cut-up part vary by ±0.5%, ±1% and ±2%; scenario two where the price mark-up of each cut-up part varies by 1%, 20%, 30% and 40%; and scenario three where the fixed standard and the price mark-up of each cut-up part change simultaneously. The impact of changing the fixed standard was decomposed into a bonus effect and an evaluation effect, while the impact of changing the price mark-up was only reflected in its bonus effect. The deterministic results reveal that under the novel pricing scheme, changing the fixed standards results in an upward or downward shift in average price level, where the shift caused by the breast yield fixed standard is the most significant, followed by leg and wing fixed standards. In comparison, changing price mark-ups has a much smaller impact on price, and it mainly results in the change of the price distribution. When the two elements with respect to a specific cut-up part change simultaneously, the evaluation effect of changing the fixed standard appears to be stronger than the total bonus effect of changing fixed standard and price mark-up in the majority of cases of the simulations. This implies that a processor, who requires a higher yield level with respect to a specific cut-up part, should provide a sufficiently high premium or lower the fixed standard of other cut-up parts.

Finally, stochastic sensitivity analysis via Monte Carlo simulation is conducted in order to investigate the price distribution and the impact of key components from both producers' and processors' perspective when uncertainty is taken into account. From the perspective of a producer, supposing that the yield level of each producer is known, we conducted three simulations, assuming that 1) fixed standards are uncertain; 2) price mark-ups are uncertain and 3) both elements are uncertain. The results suggest that the uncertainty of these two elements do not cause significant changes in the average price level compared to the baseline scenario. In general, uncertain price mark-up results in greater variability of the pricing system, while the uncertain fixed standard mainly affects the overall price level. From the perspective of a processor, we are more interested in the distribution of prices that a processor may need to pay to producers under the novel pricing scheme. Supposing that the yield performances of producers are uncertain, four Monte Carlo simulations with different stochastic elements or combinations of elements were conducted. The results of all four scenarios suggest that the probability of paying a premium or discount is around 50%. The means of the prices estimated in the four scenarios do not significantly differ from the baseline scenario. Regarding price sensitivity, price appears to be most sensitive to producers' performance in terms of breast yield and leg yield. Fixed standards that represent processors' requirements on cut-up part yields also affect prices where the breast yield and wing yield fixed standard is positively related to price, and the leg yield fixed standard is negatively related. Price mark-ups of the three cut-up parts have relatively less impact on prices.

Chapter 6 Conclusions, limitations and potential extensions

6.1 Conclusions

The Canadian chicken industry is characterized by a supply management system under which the production level and price of live chicken is predetermined in every production period. Whereas the production level is set according to an estimate of the market demand of each province, and price is based on average production cost and average body weight of birds, the supply management system ensures consistent supply for processors and stable income for producers. However, many earlier studies have suggested that a compensation scheme which rewards producers for better quality is currently lacking in the Canadian system, such that the current scheme discourages producers from improving product quality and from adopting advanced production technologies (e.g. Funk, 1978; Panter, 2006).

In contrast to the Canadian chicken industry, the majority of U.S. chicken is produced under production contracts. Relative performance is the most common form of performance evaluation method employed in the U.S. broiler market. Average feed conversion ratio or average settlement cost of the same group of producers in a given production period is used as a benchmark to measure producers' performance. Producers whose performances are above average receive bonuses while producers below average receive discounts. Compared to the Canadian system, U.S. producers have less control over production due to the industry being vertically integrated. Price is less predictable under the U.S. scheme, as it depends on the performance of other producers in the group. However, one of the advantages of the U.S. pricing scheme is that it provides incentives for better performance, so that producers are encouraged to improve feed conversion ratios and cost efficiency.

This study aims to contribute to the design of a Canadian pricing scheme that rewards producers for better performance with regard to quality. We explore in which ways a quality-based pricing scheme could be adopted by the Canadian poultry industry, and analyze the potential impact of such a compensation scheme with real data. The analysis aims to answer the following questions:

1. Which quality traits could be integrated into the pricing system, considering their biological growth trajectories and overall market significance?
2. What is an appropriate form of such a pricing scheme (in terms of incentives for quality), maintaining the basic structure of Canadian supply management? How to quantify the price premiums/discounts for each quality trait?
3. To what extent does the novel pricing scheme affect the chicken producers and processors?

To answer the first question, a biological model is established based on data obtained from a biological experiment. The results suggest that there is substantial heterogeneity in terms of chicken quality, since cut-up part yield levels vary for birds which fall into the same weight range in the experiment. It is therefore likely that the current Canadian pricing scheme, in which price is based on average weight, is inefficient. The OLS regression on yield and dietary data suggests that cut-up part yield of a chicken, especially breast yield and leg yield, can be affected by the dietary balanced protein, metabolizable energy levels, age of bird and other factors. This indicates that a producer could influence cut-up part yields by controlling feed ingredients as well as management methods. Therefore, yield levels of the three key cut-up parts (after considering their market evaluation), which include breast, wing and leg quarter, are selected as the three quality traits to be integrated into the pricing scheme.

To design a pricing scheme under which producers could be compensated based on their performance in terms of the three quality traits, we first reviewed pricing schemes that are commonly used in agricultural sectors in North America, including absolute performance pricing schemes, relative performance pricing schemes, formula based pricing schemes, and bargaining pricing schemes. After comparing the advantages and disadvantages of these pricing schemes and considering the continued purpose of supply management of ensuring consistent supply and stable price, a formula-based absolute performance pricing scheme is developed under the assumption of maintaining supply management, such that production level is predetermined by production quota.

The implementation of the novel pricing scheme follows a two-step mechanism. In step one, a base price is determined based on the average production cost plus producer margin as well as the average weight of the chicken in same truckload delivered by a particular producer. This is consistent with the current pricing scheme, which ensures that the average total cost of production can be covered. In step two, a premium or a discount is determined based on a producer's yield performance in terms of breast yield, wing yield and leg yield.

Producer's performance in each cut-up part yield is evaluated by a fixed standard. Each fixed standard represents a processor' requirement on yield level of the corresponding cut-up part. Producers whose performance is above the fixed standard receive a premium, and producers whose performance is below the fixed standard receive a discount. The magnitude of the unit premium/discount is based on the historical price mark-up of the corresponding cut-up part over the price of fresh whole chicken at the wholesale level, considering that this was the only accessible data which also most likely represents the value of a cut-up part to a satisfactory level of approximation.

The proposed novel pricing scheme is applied to yield data obtained from a Canadian biological experiment. Based on this experimental data, 30 representative producers are identified, and the prices received by these producers as well as the total price paid by a representative processor are simulated. The results of the baseline scenario, which assumes a single processor, a single market and constant performance, suggests that every producer gets both a discount and a premium according to performances in different cut-up part yields. As a result, the greater variability that would be associated with the reformed pricing scheme is diminished to some extent, because of the offsetting effect of discounts and premiums. In general, the proposed pricing scheme results in greater variability in the distribution of prices received by the 30 producers, without changing the average price paid by processors. This implies that the proposed pricing scheme may result in greater price risk to producers. However, due to the small magnitude of the price change resulting from the proposed pricing scheme, the increase in price risk does not significantly influence producer's income.

In order to further examine the impact of the novel pricing scheme as well as the sensitivity of price to the key components of the price formula, the baseline assumptions are relaxed and both deterministic and stochastic sensitivity analyses were conducted following Bond et al. (2005) and Alston et al. (2002). In the deterministic sensitivity analysis, fixed standard and price mark-up of each cut-up part deterministically changes by a certain percentage. The results of the deterministic analysis suggest that the changes of fixed standards mainly result in shifts in the average price level, while the changes of price mark-ups mainly result in greater price variation. In the case where the fixed standard and the price mark-up with respect to a certain cut-up part change simultaneously, the evaluation effect of changing the fixed standard appears to be stronger than the bonus effect caused by changing both fixed standard and price mark-up, which results in a price decline for most of the 30 producers in our experiment. This implies that a stricter requirement on yield levels should be combined with a sufficient increase in premium levels, and/or with lower fixed standards with respect to other quality traits.

The stochastic sensitivity analysis is conducted from both producer's and producer's perspective by Monte Carlo simulations. From the producers' perspective, price paid to each hypothetical producer was simulated while yield level of individual quality traits was assumed to be known and the fixed standard and price mark-up were assumed to be stochastic. The results suggest that the uncertainty in terms of fixed standards causes a minor shift in average price level while uncertainty in terms of price mark-up results in a greater variability of price. In general, the simulated prices for each producer - after allowing for uncertainty with respect to fixed standard and price mark-up - do not significantly differ from the baseline prices.

From a processor's perspective, the incentive-compatible prices for producers that processors may need to pay were simulated, assuming that the yield performance of each producer is stochastic while abstracting from demand and effort complementarity (section 4.3.3). The price distributions estimated in the four simulations indicate a 50/50 percent chance of a processor having to pay premiums or discounts. Consequently, the sums of premiums or discounts paid by processors are closed to zero, and the average price paid by the processor was estimated to be very close to the base price. The average price the processors need to pay under the novel pricing scheme is expect to remain at the same level as under the current pricing scheme, as long as the total premiums and discounts offset each other. Moreover, the results suggest that price is most sensitive to producers' performance, especially the performance in terms of breast yield and leg yield. This implies that a producer could most effectively increase price (and thus revenue) by improving performance in terms of breast yield.

Given the above results, one implication for the industry is that the current pricing scheme based on cost and weight may not be the most effective compensation scheme from the perspective of the Canadian chicken industry as a whole. A reformed pricing scheme that takes quality explicitly into account could provide more incentives for quality improvement. Cut-up part yield levels could be used as an indicator of quality and thus as the basis for determining monetary incentives. An absolute performance evaluation method based on a fixed standard could be employed by the industry. Such a quality-based pricing scheme may result in greater variability in price, since the price is affected by producer's performance, processor's requirements for quality traits and the market value of those quality traits. To enhance the effectiveness of a performance scheme in terms of the influence of quality on price and on producers' yield performance, the industry could consider reallocating the weight of each key component of the pricing scheme as proposed above.

6.2 Limitations

Several limitations of this study relate to the nature of the data employed. Considering the absence of production and processing cost data, the analysis does not provide insights with respect to possible changes in cost that may be associated with the reform of the pricing scheme. At the production level, the novel pricing scheme may induce producers to adjust their production decisions, resulting in changes in production cost. At the processing level, cost might increase as the novel pricing scheme may require extra labour, processing facilities and time to measure quality traits. However, due to absence of adequate cost data, these possible cost changes have not been analysed in the study. Similarly, an analysis of the relationship between the costs of producer efforts as they relate to each of the three quality traits is missing, resulting in the inability to make predictions regarding the extent of effort complementarity. For the same reason, the analysis on producer's and processor's surplus which could have been used to illustrate the impact on the two parties' welfare is not presented.

Another limitation of the study originates from the fact that the premium/discount component of the novel pricing scheme is only based on yield, instead of taking the value related to cut-up part size into account. The size or weight of a cut-up part is typically a more actuate indicator than yield level for the evaluation of producers' performance related to cut-up part quality, since processors' and consumers' preferences are more directly reflected in cut-up part size instead of yield. For example, processors such as KFC or Swiss Chalet appear to have strict requirements regarding size of wing and drumstick (Thompson, 2010). However, since disaggregate price data across different weight categories for which the premium of cut-up part size could be estimated was not available, the proposed pricing scheme only accounts for cut-up part yield.

A further potential limitation of this study is that the prices which were employed in the Monte Carlo simulations are not retail prices, but aggregate wholesale prices, abstracting from market (region) specific price variations. Considering the lack of quality-trait specific retail (demand) data, no inference could be done with regard to retail demand complementarity between the three quality traits (elasticity of demand for the quality traits), which would have been desirable for projections about the efficiency of a more high or low-powered incentive scheme. On the other hand, the use of wholesale price data could also be considered as a strength of the analysis, if the actual pricing decisions in the Canadian poultry sector are driven by this sector, and less by the retail sector.

Furthermore, the distribution of stochastic fixed standards and producer yield levels of each cut-up part are based on experimental data instead of real production data from actual farms. Moreover, the sample size (30) for the price fixed standards is relatively small. As a result, the conclusions with respect to price distribution and sensitivity may be affected by the assumptions of the distributions of the underlying stochastic variables.

6.3 Potential extensions

Although this study has started to explore the form and impact of a quality-based pricing scheme for the Canadian poultry industry, much research remains to be done. Cost data on the production and processing level could be collected for further studies on issues related to the relationship between price premiums and production efforts, and producers' and processors' welfare results from a quality-based pricing scheme. If disaggregate retail or wholesale price and demand data on cut-up parts in different weight categories is available, the pricing scheme could be further developed into a scheme where the premium/ discount is set as a distribution based on size of the cut-up part on an individual basis while assessing changes in weights of key performance components, and the relative efficiency of a more high or low-powered incentive scheme that accounts for effort allocation underling each of the quality traits compensated for.

References

Abbassi, A., and Gervais, J. P. (2010). Evaluating reforms in Canadian chicken marketing mechanisms using a linear-quadratic inventory model. *Journal of Agricultural and Food Industrial Organization, 8*(1), 1.

Agriculture and Agri-Food Canada (2011). *Poultry Marketplace-Per capita poultry consumption comparison with other animal protein sources.* Retrieved September 28, 2011, from http://www.agr.gc.ca/poultry-volaille/consm_eng.htm

Agriculture and Agri-Food Canada (2011). *Poultry Market Place.* Retrieved September 28, 2011, from http://www.agr.gc.ca/poultry/index_eng.htm

Agriculture and Agri-food Canada (2007). *Profile of the Canadian chicken Industry*. Retrieved September 28, 2011, from http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1184610941693&lang=eng

Alberta Chicken Producer (n.d.). *About us.* Retrieved June 10, 2011, from http://www.chicken.ab.ca/about-us

Government of Alberta (2007). *The Alberta Broiler Chicken Industry*. Retrieved April 20, 2011, from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/pou3598

Alston, J.M., Hyde, J., Marra, M.C., & Mitchell, P.D. (2002). An ex ante analysis of the benefits from the adoption of corn rootworm resistant transgenic corn technology. *AgBioForum*, 5(3), 71-84.

Beck, R., Hoskins, C., and Mumey, G. (1994). The social welfare loss from egg and poultry marketing boards, revisited. *Canadian Journal of Agricultural Economics, 42*(2), 149-158.

Benabou, R., and Gertner, R. (1993). Search with learning from prices: Does increased inflationary uncertainty lead to higher markups? *The Review of Economic Studies, 60*(1), 69.

Bond, C. A., Carter, C. A., and Farzin, Y. H. (2005). Economic and environmental impacts of adoption of genetically modified rice in California. *Research Report #350. University of California, Agricultural and Natural Resources.*

Cai, R. (2002). The development of the "company plus farmer" model in the poultry sector. *China Poultry, 24*(23)

Canadian Poultry and Egg Processors Council (2011). *Chicken Processing Members of CPEPC.* Retrieved Jan 10, 2011, from http://www.cpepc.ca/chicken.html

Chakravarti, I. M., Laha, R. G., and Roy, J. (1967). *Handbook of methods of applied statistics: Techniques of computation, descriptive methods, and statistical inference.* Vol. I, John Wiley & Sons, New York.Chicken Farmers of Canada, (2011).

Chicken Farmers of Canada (n.d.). *The Journey of Chicken*. Retrieved June 7, 2010, from http://chicken.ca/on-the-farm/from_the_farm_to_you/the-journey-of-chicken/

China - Poultry and Products Semi-Annual Report 2011. (n.d.). Retrieved September 28, 2011, from http://www.themeatsite.com/articles/1254/china-poultry-and-products-semiannual-report-2011

Coffin, H. G., Douglas, M., Macdonald, and Romain, R. (1989). *Performance of the Canadian poultry system under supply management.* Joint publication of the Dept. of Agricultural Economics, Macdonald College of McGill University and le Dép. d'économie rurale, Université Laval.

Cranfield, J., Cousineau, L., Swidinsky, M., Lai, H., Goddard, E., and Rude, J. (1995). Oligopoly power in the Canadian food processing industry–further results. *Working paper, Department of Agricultural Economics and Business, University of Guelph.*

Farm Credit Canada (2009). *Poultry Fact.* Retrieved September 28, 2011 from http://www.fcc-fac.ca/en/learningcentre/knowledge/doc/Poultry_facts_e.pdf

FAO (n.d.). *Agreement of participation in integrated production of poultry*. Retrieved May 13, 2011, from http://typo3.fao.org/fileadmin/user_upload/contract_farming/samples/23_Sample_contract 1_of_poultry_in_Brazil.pdf

FAOSTAT, FAO Statistical Database. *Food and agricultural commodities production*. Retrieved September 28, 2011, from http://faostat.fao.org/site/339/default.aspx

Fisher, C. Boorman, K. N. (1986). In C. Fisher K. N. B. (Ed.), *Nutrient requirements of poultry and nutritional research*. 9-39. Butterworths: Oxford.

Fulton, M., and Tang, Y. (1999). Testing the competitiveness of a multistage food marketing system: The canadian chicken industry. *Canadian Journal of Agricultural Economics 47*(3), 225-250.

Funk, T., Rice, M. (1978). Effects of marketing boards on the agribusiness sector. *American Journal of Agricultural Economics, 60*(5), 894-898.

Gervais, J. P., and Devadoss, S. (2006). Estimating bargaining strengths of Canadian chicken producers and processors using a bilateral monopoly framework. *Agribusiness, 22*(2), 159-173.

Gervais, J. P., Guillemette, K., and Romain, R. (2007). Output and price determination in the Canadian chicken industry: Which should come first? *Canadian Journal of Agricultural Economics, 55*(2), 255-273.

Jim Harkness (2008). *Chinese agribusiness: a visit to Chennong Corporation 2008*. Retrieved August 20, 2011, from http://iatp.typepad.com/thinkforward/2008/01/chinese-agribus.html

Ke, B. and Han,Y. (2007). Poultry sector in China: structural changes during the past decade and future trends. *International Conference:"Poultry in the 21st Century–Avian Influenza and Beyond". FAO, Bangkok.*

Kirkwood, Karen. Personal communication, May 14, 2010.

Knoeber, C. R. (1989). A real game of chicken: Contracts, tournaments, and the production of broilers. *Journal of Law, Economics, and Organization*, *5*(2), 271.

Knoeber, C. R., and Thurman, W. N. (1995). "Don't count your chickens...": Risk and risk shifting in the broiler industry. *American Journal of Agricultural Economics, 77*(3), 486.

Lermer, G., and Stanbury, W. (1985). Measuring the cost of redistributing income by means of direct regulation. *Canadian Journal of Economics, 18*(1), 190-207.

Levy, A., and Vukina, T. (2004). The league composition effect in tournaments with heterogeneous players: An empirical analysis of broiler contracts. *Journal of Labor Economics,* 353-377.

Liu, H. (2005). The competitiveness of Canada's poultry processing industry. *Agriculture and Rural Working Paper Series, Statistics Canada, Agriculture Division.* Retrieved on Nov 14, 2011, from http://publications.gc.ca/collections/Collection/Statcan/21-601-MIE/21-601-MIE2005075.pdf

MacDonald, J., and Korb, P. (2006). The growing use of contracts to govern US farm production. *Economic Research Service, U.S. Department of Agriculture. Paper presented at the 2006 Annual Conference of the International Society for New Institutional Economics, Boulder, CO, September 23, 2006.*

MacDonald, J. M. (2008). Report summary: Economic organization of US broiler production. Economic. *Information Bulletin No. 38*. Economic Research Service, US Department of Agriculture.

Martin, L., and Holliday, D. C. (1977). The output decision process of canadian broiler marketing boards. *Canadian Journal of Agricultural Economics/Revue Canadienne d'Agroeconomie*, *25*(2), 45-60.

Martin, L., Warley, T. (1978). The role of marketing boards in stabilizing commodity markets. *American Journal of Agricultural Economics*, *60*(5), 878-84.

Martin, L., Westgren, R., Schrader, L., Cousineau, L., LeRoc'h, N., Paguaga, R., et al. (1993). Alternative business linkages: The case of the poultry industry. *George*

Morris Centre Food Industry Research Group, Guelph, Ontario, Working Paper, 10, 93.

Martin, L. L. (1997). Production contracts, risk shifting, and relative performance payments in the pork industry. *Journal of Agricultural and Applied Economics29*(2), 267–278.

Martinez, S. W. (2002). Vertical coordination of marketing systems: Lessons from the poultry, egg, and pork industries. *Agricultural Economics Report, 807.*

Moschini, G. (1988). A Model of Production with supply management for the Canadian agricultural sector. *American Journal of Agricultural Economics 70*(2), 318-329.

Natrella, M. (2010). *NIST/SEMATECH e-handbook of statistical methods.* Retrieved November 1, 2011, from http://www.itl.nist.gov/div898/handbook/

Panter, C. A. (2006). *Canadian Demand for Chicken Disaggregated by Cut and Product.* Unpublished master's thesis, Department of Rural Economy, University of Alberta.

Romero, L., Zuidhof, M., Renema, R., Robinson, F., and Naeima, A. (2009). Nonlinear mixed models to study metabolizable energy utilization in broiler breeder hens. Poultry Science, 88(6), 1310.

Schmitz, A. (1983). Supply management in canadian agriculture: An assessment of the economic effects. *Canadian Journal of Agricultural Economics, 31*(2), 135-152.

Schmitz, A., and Schmitz, T. G. (1994). Supply management: The past and future. *Canadian Journal of Agricultural Economics, 42*(2), 125-148.

Schmitz, A. (1995). Supply management and GATT: The role of rent Seeking1. *Canadian Journal of Agricultural Economics, 43*(4), 581-586.

Scholz, F., and Stephens, M. (1987). K-sample anderson-darling tests. *Journal of the American Statistical Association*, 918-924.

Shleifer, A., (1985). A theory of yardstick competition. *The RAND Journal of Economics, 16* (3), 319 -327

Slade, M. (1996). Multitask agency and contract choice: An empirical exploration. *International Economic Review* 37: 465–486.

Smith, E., and Pesti, G. (1998). Influence of broiler strain cross and dietary protein on the performance of broilers. *Poultry Science, 77*(2), 276-281.

Statistics Canada (2011). *Table 30018. Production, disposition and farm value of poultry meat, annually*. Retrieved September 28, 2011, from http://dc.chass.utoronto.ca/cgi-bin/cansimdim/c2_getArray.pl

Taylor, C. R., and Domina, D. (2002). Restoring economic health to contract poultry production. *Agricultural and Resource Policy Forum, Auburn University College of Agriculture*. Retrieved May 10, 2010, from http://www.dominalaw.com/ew_library_file/Restoring%20Economic%20Health%20to%20Contract%20Poultry%20Production.pdf

Thompson, Kevin (2010). *Canadian Poultry and Egg Processors Council*. Personal communication. August 2010.

Troughton, J.M., (1989). The role of marketing boards in the industrialization of the Canadian agricultural system, *Journal of Rural Studies, 5*(4), 367-383.

Tsoulouhas, T., Vukina, T. (1999). Integrator contracts with many agents and bankruptcy. *American Journal of Agricultural Economics*, 61-74.

Upton, M. (2008). Scale and structures of the poultry sector and factors inducing change: Intercountry differences and expected trends. *International Conference:"Poultry in the 21st Century–Avian Influenza and Beyond". FAO, Bangkok.*

Veeman, M. M. (1982). Social costs of Supply-Restricting marketing boards. *Canadian Journal of Agricultural Economics, 30*(1), 21-36.

Vukina, T. (2001). Vertical integration and contracting in the US poultry sector. *Journal of Food Distribu*tion Research, 32(2), 29-38.

Willwerth, A. (2009) *Benefits to poultry value chain participants of providing new producer incentives for improved quality.* MSc Thesis draft, Department of Rural Economy, University of Alberta.

Zheng, X., and Vukina, T. (2007). Efficiency gains from organizational innovation: Comparing ordinal and cardinal tournament games in broiler contracts. *International Journal of Industrial Organization, 25*(4), 843-859.

Zuidhof, M. (2009). *Nonlinear analysis of nutritional effects on broiler performance.* Unpublished manuscript.

Appendix 1

Ontario live price formula breakout and explanation

(Accessed through the Alberta Chicken Producers on June 7, 2010)

<u>FEED COMPONENT</u>

- Feed cost totals of Live Price as a %.

  8 week average is 43.44%

  16 week average is 43.88%

  24 week average is 44.35%

  48 week average is 45.46%

- Feed prices are provided by the Ontario Agri Business Association (OABA) to Chicken Farmers of Canada on a weekly basis.

  OABA provides a weighted average of 4 independent (not associated or owned by a processor or producer) feed mills on a weekly basis. The weighted averages are based on weight (tonne) not sales ($). The 4 feed mills represent approx 40% market share in volume of the chicken feed sold each week.

- Chicken Farmers of Ontario (CFO) take 8 weeks of data and measure the change between the previous period to determine if a change in Live Price is required.

  Formula: ($5/tonne = 1 cent/kg change in Live Price)

Previous Period Feed ($/tonne)-Current Period Feed ($/tonne) = change in $/tonne

Change in $/tonne divided by $5.00 = change in Live Price

Example:

A-97: $301.11/tonne

A-98: $289.92/tonne

Change: -$11.19/tonne

Change in Live Price: -2.24 cents/kg (11.19/5.00 = 2.238)

Note: A-98 feed prices = 4 weeks of A-96 and 4 weeks of A-97 = 8 week average or weeks of Mar 1 to April 19th, 2010 etc.

<u>CHICK COMPONENT</u>

- Chick cost totals of Live Price as a %.

  8 week average is 23.71%

  16 week average is 23.53%

  24 week average is 23.39%

  48 week average is 23.04%

- Chick prices are provided by the Ontario Broiler and Hatching Egg and Chick Commission (OBHECC) to Chicken Farmers of Ontario (CFO) by

A-Period. OBHECC cost of production formula is proprietary and is not known by CFO.

- OBHECC provides broiler chick prices for male, female, random mix and sex mixed. CFO used the sex mixed chick price in the Live Price formula.
- CFO build into the beginning a 2.5 cents per chick cost for vaccines. Since then only the change in chick price is measured.

Formula: (1 cent/chick = 0.5 cent/ kg change in Live Price)

Previous Period per Chick Price -Current Period Feed per Chick Price = change in cent/kg.

Change in cents per chick divided by 2 = change in Live Price

Example:

A-97: 60.80 cents/chick

A-98: 60.71 cents/chick

Change: -0.09 cents/chick

Change in Live Price: -0.05cents (0.09/2.00 = 0.045)

PRODUCER MARGIN COMPONENT

- Producer margin cost totals of Live Price as a %.

  8 week average is 32.85%

  16 week average is 32.58%

  24 week average is 32.26%

  48 week average is 31.50%

- The Producer Margin BASE was established from 1990 costs. A 3rd party independent consultant PricewaterhouseCoopers was hired to conduct the 1990 cost of production study on producer margins. The PricewaterhouseCoopers COP 1992 study can be obtained at the CFC office. The study lays out the COP components that are in the producer margin for the Ontario live price. FPCC also had a 1998 study on Cost of Production Guidelines which is a helpful document. Meyers Norris Penny has been hired by CFO to work on updating the base to 2006 costs. Currently the 1990 cost base is still being used, but the 2006 cost study should be released soon.
- CFO adjusts the producer margin, once every six quota periods (48 weeks) to include changes in the costs of production excluding feed and chick costs which are done every A-Period (8 weeks).
- CFO updates the 1990 cost of production (base) using Statistics Canada on the COP components identified in the 1992 PricewaterhouseCoopers study. Average prices of the recent six quota periods are measured against the

previous six quota periods and the difference is applied to the producer margin in the previous six quota periods. Last producer margin update was in A-94, the next update will occur in A-100.

Formula: (adjusted every 6 periods (48 wks) only)

Current 6 Period Producer Margin – Previous 6 Period Producer Margin = change in cent/kg.

Example:

Current Producer Margin: 44.94 cents/kg

Previous Producer Margin: 44.31 cents/chick

Change: 0.63 cents/kg

Change in Live Price: +0.006 cents (0.63/100= 0.0063)

Appendix 2

Introduction of the chicken industry in Brazil and China

Brazil is the world's largest chicken exporter since 2004 (Valdes, 2006). Similar to the U.S. system, the poultry sector in Brazil is vertically integrated. Production contracts are commonly used in the Brazilian poultry industry. According to the Upton (2007), about 95% of poultry meat is produced under contract to the large integrator companies. Integrators are often the large processing firms in the country. They provide a) chicks, feeds and medicines; b) the provision of technical, managerial and veterinary support; and c) transport for the delivery of feeds and the collection of finished broilers. The contracted grower provides: a) the capital invested in buildings and equipment; b) the day-to-day management; and c) electricity and water services. Similar to the payment scheme used in the United States, the payment scheme used in the Brazil poultry industry consists of two components: 1) a predetermined base price per kg live weight of harvested birds; 2) a bonus for improved performance, usually related to low mortality and good feed conversion ratio. In some cases, a penalty may be incurred for poor performance (Upton, 2007).

According to a sample contract of integrated poultry production in Brazil provided by the FAO, a system that take into account the death rate (%), feed conversion, daily weight gain, loading time during broiler delivery, and quality of management and injuries(%) is employed. Growers receive a score based on their performance in these six aspects, where each point corresponds to Brazilian New Cruzeiros 0.036 in the sample contract. Then the final price/kg corresponds to the total points obtained by the producer times the base price negotiated prior to the growing cycle. According to the sample contract, a minimum level of points (e.g. 80 points) is also included in the contract.

China is also an important player in the global poultry industry. Being the second largest chicken producing country in the world, China's poultry sector experienced vigorous growth from 1985 to 2005. The significant development of the Chinese poultry industry was not only driven by the strong domestic demand but also supported by the improvement in production technology and the development of vertical integration in the industry (Ke and Han, 2007). The predominated form of vertical integration in the past two decades is called '*company plus contracted household farm*' system. Under this system, processing firms directly cooperate with individual farmers via production contracts. Usually, a processing firm sells inputs (chicks, feed, and medicine) to farmers on credit, and guarantees a minimum payment which is also called a "floor price". If the market price at harvest time is higher than the floor price, the company will pay a proportion (for example 80 percent) of the higher price; and if the market price is lower than the floor price, the company still pays the floor price. Such a system intended to guarantee minimum profitability for the farmers and ensure steady supply for processors. However, the constraining power of such kind of contract or agreement is weak, in that both farmer and processors frequently break the contracts when the market price differs from the agreed floor price (Harkness, 2008). Moreover, as the contract is typically signed between a large integrator company and many small-scale regionally scattered household farms with a quality standard lacking in the system, it is difficult for the integrator company to have an effective central management of all producers and control for the quality of the chicken (Cai, 2002).

Another production system emerging in the Chinese poultry sector is called the '*company plus production base (company's own farms) plus contracted household farms*' system. Similar to the '*company plus farmer*' model, the integrator company also cooperates with farmers via production contracts (or the farmer becomes a shareholder of the company). What differs from the '*company plus farmer*' is that a company agent called '*production base*' is involved in the supply chain. The production base acts as both the agent of the company and the representative of contracted farms. On the one hand, the agent manages and supervises the contracted farmers in terms of production efficiency and product qualities. As a result, this '*company plus base plus farmer'* system helps to increase a company's control over production quality. On the other hand, the existence of the agent helps farmers in preventing the integrator company from breaking contracts. Therefore, this 'company plus base plus farmer' system reduces the farmers' risk.