ABSTRACT

WENG, TENGYING. The Dynamics of the US Broiler Industry. (Under the direction of Tomislav Vukina and Xiaoyong Zheng.)

This essay studies the effect of higher concentration of US broiler industry on social welfare and effect of productivity and demand-specific factors on plants’ probability of survival, ownership change and firms’ probability of expansion. My results show that producer surplus increased when concentration increased, and decreased when concentration decreased; consumer welfare increased as a result of lower price; and social welfare changed in the same direction as producer surplus. My results also show that higher demand-specific factors will increase the probability of survival, probability of ownership change and probability of expansion. The effect of productivity is generally not significant.
The Dynamic of the US Broiler Industry

by
Tengying Weng

A dissertation submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

Economics

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2013

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I gratefully acknowledge the USDA-ERS for providing the data used in chapter 3 and chapter 4. I would also like to thank Bert Grider (UNC) for his help on using the Census data used in chapter 3 and chapter 4.

Very specific thanks go to my family, especially my dad and my mom, for their patience and support. Without them, this research would never have come to existence. I thank my brother, Tengfei, for offering encouragement throughout this research.

Finally, I wish to thank the following: Bidong Liu (for support), Tingting Liu, Luyuan Niu, Xiaomei Chen, Xingyi Su (for friendship) and friends from Zhejiang University. I also want to appreciate Christina Irvine for helping my grammar and formatting.
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CHAPTER 1: INTRODUCTION

The US broiler industry is generally considered to be the role model of industrialized agriculture in the United States. There are three characteristics which make the US broiler industry special and interesting. First, the US broiler industry is almost entirely vertically integrated, from breeding flocks and hatcheries to feed mills, transportation divisions and processing plants. The only stage which is not integrated with processors is farmers (commonly called growers). Today, more than 90% of broiler chickens are raised under contract. Because of the significant economies of scale and a large proportion of the value added in processing, processors became the natural leaders of the industry. Second, the US broiler industry has become more and more concentrated during the last couple of decades. The Herfindahl index (HHI) of poultry processing industry increased from 735 to 1224 from 1992 to 2007.\(^1\) The industry's Top-4 concentration ratio increased from 44.24% in 1992 to 58.52% in 2007, and its Top-8 concentration ratio increased from 60.30% to 72.14%.\(^2\) Finally, the total production of the US broiler industry increased dramatically from 1992 to 2007. In fact, chicken consumption surpassed beef consumption in 1993 and became the number-one meat item consumed in the United States. In Chapter 2, I will explore these aspects of the broiler industry’s history.

As mentioned above, the US broiler industry became more and more concentrated during the study period. The higher concentration in the US broiler industry could decrease the social welfare (because of higher market power) or increase social welfare (because of

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\(^1\) In the calculation of HHI, I picked the top 50 firms and left the rest of firms in the “other” category with Census data of Manufacture.

\(^2\) Top-4 and Top-8 are the top 4 firms’ market shares and top 8 firms’ market shares in the value of shipments with Census data of Manufacture.
higher efficiency). So the objective of Chapter 3 is to determine which one of the two effects dominates. In other words, are the cost reductions (synergies) through consolidation enough to offset the allocation inefficiency resulting from greater market power? The results of this analysis show that the overall social welfare increased during the HHI’s increasing period (1992-2002) while decreasing during the HHI’s decreasing period (2002 to 2007). These results show that society benefited from higher concentration in the poultry industry, while it worse off from lower concentration in the poultry industry.

The possible sources of increasing concentration of the US broiler industry are mergers and acquisitions, exits, and expansions. So one of the major objectives of Chapter 4 is to determine which plants were more likely to exit (the effects of productivity and demand-specific factor). Generally speaking, people believe that plants with higher productivity are less likely to exit. But most previous studies used revenue-based productivity as a measure of physical productivity because of the availability of data. This method could overstate the effect of physical productivity because revenue-based productivity combines with physical productivity and demand-specific factors. Chapter 4 explains the definition of demand-specific factors and why using revenue productivity could overstate the effect of physical productivity. By separately estimating the effect of physical productivity and demand-specific factors on plants’ survival, I show that higher demand-specific factors decrease the probability of exit. The effect of physical productivity on the probability of exit is generally insignificant. In addition to studying the effect of physical productivity and demand-specific factors on the probability of a plant’s exit, I also study the effect of these factors on the probability of ownership change.
Most previous studies treat plants’ ownership change as plants exit; however, I decided to separate ownership changes from exits, mainly because I believe plants that change ownership are fundamentally different from plants that completely exit from the industry. Plants that change ownership have to be good enough to attract other firms to buy them. The results of this study show that higher demand-specific factors increase the probability of an ownership change, while the effect of physical productivity on the probability of an ownership change is generally insignificant. Finally, given the fact that the poultry industry’s volume of production has almost doubled during the studied period, I also analyze the firm-level expansion in Chapter 4. The results show that firms with higher demand-specific factors have a higher probability to expand their businesses.

Overall, our results show that the effect of physical productivity is not significant and that previous studies that used revenue productivity overstated the effect of physical productivity. Instead, demand-specific factors have significant effects on the probability of a plant’s exit, ownership change, and on firms’ expanding. Also, it is necessary to separate plants that change ownership change from plants that exit, because the results of this study show that demand-specific factors have opposite effects on the probability of exit and ownership change. By treating plants that change ownership as plants that exit the broiler industry altogether, previous studies could have possibly underestimated the effects of demand-specific factors.
CHAPTER 2: THE U.S. BROILER INDUSTRY

The broiler industry is generally considered to be the role model of industrialized agriculture in the United States. In the last century, the U.S. broiler industry has evolved from disorganized and locally-oriented business into a highly efficient, vertically integrated and horizontally concentrated industry that provides products nationwide and around the globe. This chapter presents a brief description of the U.S. broiler industry.

2.1 A Brief History

About 100 years ago, the United States chicken industry consisted of millions of small households raising flocks of dual-purpose chickens (eggs and meat) in their backyards. Mrs. Wilmer Steele of Sussex County, Delaware, is believed to be the pioneer US broiler (a chicken raised specifically for its meat) industry. In 1923, she raised a flock of 500 broilers. Her business turned out to be successful; consequently, in 1927 she was able to build a broiler house with a capacity of 25,000 broilers. By 1952, accompanied by the improvement in technology (e.g. on-line evisceration and discovery of the importance of nutrition and photoperiod (cycle of sunlight and darkness) on production), specially bred meat chickens (broilers) surpassed the farm chickens and became the number one source of chicken meat in the United States.

The further technological developments in all stages of the industry led to overproduction and hence lower prices. The substantial losses in 1959 and 1961, due to excess production and the lack of coordination between feed mills, hatcheries, farms and processors, caused a large exit of hatcheries and feed companies from the broiler industry (Martinez, 1999). From that time on, processors started to take ownership of other stages of
the industry. Because of the significant economies of scale and a large proportion of the value added in processing, processors became the natural leaders of the industry. By the 1970s, the broiler chicken industry had evolved into the fully integrated industry seen today where more than 90% of the broilers production came from integrated operations.

2.2 More Recent Developments

From 1987 to 2007, the production of broilers in the USA grew rapidly (see Figure 1). Compared to 15,413 million pounds in 1987, the total broiler production was 35,772 million pounds in 2007. Three main factors contributed to this growth: growth in population, growth in per capita consumption, and exports. Table 1 shows the contributions of those factors in 5-year intervals between 1987 and 2007. As seen from the data, the most significant contribution came from the growth in per capita consumption which was as high as almost 19% in the 1987-1992 period (see also Figure 2 which depicts the trend in the per capita broiler consumption for the 1989-2009 period). Chicken consumption surpassed beef consumption in 1993 and became the number one meat item consumed in the United States. The growth in the volume of production was accompanied by the decrease in price. As illustrated in Figure 3, broiler retail price dropped from $1.16/lb in 1987 to $0.89/lb in 2007, whereas for its substitutes, beef and pork, prices remained relatively stable.3

The growth in the broiler per capita consumption may be explained by a couple of factors. The first is the reduction in the relative price of chicken meat compared to its substitutes, beef and pork. As seen from Figure 4, the ratio of beef price to broiler price

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3 Meat prices were calculated by averaging the quarterly prices deflated by meat consumer price index from Economic Research Service of USDA.
increased from 1.8 in 1989 to 2.5 in 2007, and the ratio of pork price to broiler price increased from 1.3 in 1989 to 1.7 in 2007. The second factor is the change in consumers’ preferences away from red meats and towards the white meats, predominantly due to consumers’ health concerns. The expenditure shares of various meat categories depicted in Figure 5 illustrates the point.

Besides the higher per capita consumption and the population growth, the other contributing factor for the expansion of the broiler industry’s production came from exports. As seen in Figure 6, from 1987 to 2007 the U.S. broiler exports increased approximately 7 times, from less than 1 billion pounds to nearly 7 billion pounds. There are multiple reasons for the increase of the U.S. broiler exports, but one of the most important reasons is that the U.S. government started to support the U.S. broiler exports from 1991 onward⁴.

After the introduction of this export support program, the U.S. has made substantial increases in the volume and value of the broiler exports to various countries all around the world. For instance, the U.S. broiler exports to Russia increased from 0 in 1989 to 1.89 billion pounds in 2007. In fact, Russia surpassed Hong Kong and became the largest importing country of the U.S. broiler since 1994. As the second largest U.S. broiler importing country in 2007, mainland China increased its imports of the U.S. broiler from 0.68 million pounds in 1989 to 650 million pounds in 2007. Hong Kong also made a contribution to the growth of the U.S. broiler exports. Its import of the U.S. broiler increased from 0.21 million pounds in 1989 to 970 billion pounds in 1995 (it peaked in 1995 and then started to decline). Other countries such as Mexico and Canada increased their imports of U.S. broiler as well

⁴ http://www.nationalchickencouncil.org/about-the-industry/history/

The ratio of exports to U.S. total production also increased from 4.87% in 1987 to 18.52% in 2010 (see Figure 7). Strong reliance on exports, together with various trade barriers that effectively blocked the imports of fresh and chilled chicken meat from low cost producing countries (e.g. Brazil) was essential for industry profitability and overall success. Domestic consumers’ strong preference for white (breast) meat and the lack of demand for dark meat (leg quarters) forced the U.S. broiler industry to look to overseas markets to get rid of large quantities of leg quarters (Rabobank, 2011).

2.3 Industry Structure and Dynamics

During the same period (1992 to 2007), the broiler industry has become more and more concentrated as a result of mergers and acquisitions. The Herfindahl index (HHI) of poultry processing industry increased from 735 to 1224 from 1992 to 2007.\(^5\) The industry's Top-4 concentration ratio increased from 44.24% in 1992 to 58.52% in 2007, and Top-8 concentration ratio increased from 60.30% to 72.14%.\(^6\) For comparison purposes, the rest of the meat complex in the U.S. is even more concentrated with beef and pork industries’ concentration ratios exceeding that of the broiler industry. In 2007, the 4-firm concentration ratio for beef was about 80%, and for pork about 68% compared to only 58.52% for broilers.

\(^5\) In the calculation of HHI I picked the top 50 firms and left the rest of firms in the “other” category with Census data of Manufacture.
\(^6\) Top-4 and Top-8 are the top 4 firms’ market shares and top 8 firms’ market shares in the value of shipments with Census data of Manufacture.
Table 2 lists the most significant mergers and acquisitions that happened among the leading 25 broiler firms from 1997 to 2009. As a general tendency, most acquiring firms are large firms while most acquired firms are small firms. The exception to this is Gold Kist\textsuperscript{7} whose position was No. 3 when it was acquired by Pilgrim’s Pride\textsuperscript{8} who was then No. 2.\textsuperscript{9} 

The Pilgrim’s Pride’s case is compelling: after a series of aggressive acquisitions (Wampler Foods Inc. in 2001, ConAgra Poultry Co. in 2003, and Gold Kist in 2006), Pilgrim’s filed for Chapter 11 bankruptcy protection on December 1, 2008, because of the deterioration of poultry pricing combined with an increase in input costs and the company’s lack of liquidity to withstand the downturn\textsuperscript{10}. According to The Wall Street Journal (February 12, 2009), the company terminated the contracts with at least 300 growers in Arkansas, Florida and North Carolina because Pilgrim stopped or reduced production at processing plants in those areas.

Despite several activities in the mergers and acquisitions area in the broiler industry, the rankings of the leading players remained relatively stable during the analyzed period (see

\textsuperscript{7} While some of the statistical/econometric analyses in this research employ confidential Census microdata, the reference to this company by name is based on information that comes solely from an external trade publication Watt Poultry USA (various issues) and does not imply anything about whether that company is in (or not in) any data samples constructed using the Census microdata.

\textsuperscript{8} While some of the statistical/econometric analyses in this research employ confidential Census microdata, the reference to this company by name is based on information that comes solely from an external trade publication Watt Poultry USA (various issues) and does not imply anything about whether that company is in (or not in) any data samples constructed using the Census microdata.

\textsuperscript{9} Pilgrim’s sent an unsolicited proposal to Gold Kist offering to purchase all of the outstanding shares for $20.00 per share in cash on 18 August, 2006. The agreement was reached on 4 December 2006 at the price of $1 higher than Pilgrims’ initial offer.

\textsuperscript{10} Pilgrim’s Pride successfully emerged from bankruptcy protection on December 28, 2009 after 64% of its stake was acquired by the Brazilian conglomerate JBS earlier that year.
Table 3). Tyson\textsuperscript{11} was and remained the number one U.S. broiler company, except briefly in the 2006-2008 period when its number one position was taken over by Pilgrim’s. The other two large players are Perdue Farms and Sanderson Farms. Perdue represents an interesting case because it is the only privately-owned large company in this market segment which is dominated by publicly held companies. Table 4 shows that the production shares of most broiler companies were stable over the time period except Pilgrim. Pilgrim’s production increased from 6.40% in 1997 to 18.90% in 2009, peaking at 24.78% in 2006, because Pilgrim conducted a series of aggressive acquisitions during the time period.

2.4 Today’s Industry

The overall positive economic outlook of the U.S. broiler industry changed dramatically with the recession of 2008, and the long-term industry outlook became rather uncertain. In the last several years, the US broiler industry has been facing unprecedented challenges. The most serious challenge comes from the high cost of feed. There are several reasons for a sharp rise in prices of corn and soybeans, including increasing livestock and poultry production in emerging markets caused by increased demand for protein diets and domestic ethanol subsidies. Secondly, the US domestic market is maturing, and the international competition is intensifying. As seen in Figure 2, the U.S. per capita consumption of broilers has been decreasing since 2006 and similar trends characterize other meats. The weakening of the demand for U.S. poultry in once traditional export markets such as Russia (mainly due to increased Russia domestic production) and the stiffer competition from the low cost

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producers (such as Brazil) require the broiler companies to rethink their production strategies and perhaps reduce production.

More consolidation is probably on the way with mergers and acquisitions targeting other protein segments becoming increasingly likely. The companies that participate in all protein markets (chickens, pork and beef) simultaneously (such as JBS and Tyson) are probably the way of the future. Those who do not recognize the change in the operating environment and change their strategies may not survive and may eventually leave the industry.

Table 1: Growth in Broiler Production (%), 1987-2007

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<tbody>
<tr>
<td>Broiler production growth rate</td>
<td>35.62</td>
<td>29.36</td>
<td>17.94</td>
<td>12.16</td>
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<tr>
<td>Contributions from growth in:</td>
<td></td>
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<tr>
<td>Population</td>
<td>5.80</td>
<td>6.24</td>
<td>5.60</td>
<td>4.77</td>
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<tr>
<td>Per Capita Consumption</td>
<td>18.88</td>
<td>9.01</td>
<td>12.89</td>
<td>5.67</td>
</tr>
<tr>
<td>Other (mainly exports)</td>
<td>10.94</td>
<td>14.11</td>
<td>-0.55</td>
<td>1.72</td>
</tr>
</tbody>
</table>

Source: calculated from USDA-ERS all meat supply and disappearance data
Table 2: Major Mergers and Acquisitions among Top 25 firms, 1997-2009

<table>
<thead>
<tr>
<th>Firms</th>
<th>Action</th>
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<tbody>
<tr>
<td>Hudson Foods</td>
<td>Tyson and Hudson merged in 1998</td>
</tr>
<tr>
<td>Seaboard Farms</td>
<td>Acquired by ConAgra Poultry in 2000</td>
</tr>
<tr>
<td>Wampler Foods</td>
<td>Acquired by Pilgrim’s in 2001</td>
</tr>
<tr>
<td>BC Rogers</td>
<td>Acquired by Koch Foods in 2002</td>
</tr>
<tr>
<td>Choctaw Maid Farms</td>
<td>Acquired by Tyson in 2003</td>
</tr>
<tr>
<td>ConAgra Poultry Company</td>
<td>Acquired by Pilgrim’s in 2003</td>
</tr>
<tr>
<td>Gold Kist</td>
<td>Acquired by Pilgrim’s in 2006</td>
</tr>
</tbody>
</table>

Source: Poultry USA annual surveys

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12 While some of the statistical/econometric analyses in this research employ confidential Census microdata, the reference to this company by name is based on information that comes solely from an external trade publication Watt Poultry USA (various issues) and does not imply anything about whether that company is in (or not in) any data samples constructed using the Census microdata.
Table 3: National Rankings of Broiler Companies, 1997-2009

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<td>Tyson Foods</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Pilgrim’s Pride</td>
<td>2</td>
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<td>Koch Foods</td>
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<tr>
<td>Wayne Farms</td>
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<td>House of Raeford Farms</td>
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Source: Poultry USA annual surveys
(i) Tyson and Hudson merged in 1998
(ii) Acquired by ConAgra Poultry in 2000
(iii) Acquired by Pilgrim’s in 2003
(iv) Acquired by Pilgrim’s in 2006

13 While some of the statistical/econometric analyses in this research employ confidential Census microdata, the reference to this company by name is based on information that comes solely from an external trade publication Watt Poultry USA (various issues) and does not imply anything about whether that company is in (or not in) any data samples constructed using the Census microdata.
Figure 1: US Broiler Production (million lbs), 1987-2010

Source: USDA-ERS all meat supply and disappearance data
Figure 2: Meat Consumption per Capita (lbs), 1987-2010

Source: calculated from USDA-ERS all meat supply and disappearance data
Figure 3: Meat Real Retail Prices (dollars/lb), 1989-2009

Source: USDA-ERS all meat prices
Figure 4: Retail Prices of Beef and Pork Relative to Broilers, 1989-2009

Source: USDA-ERS all meat prices
Figure 5: Expenditure Shares of Meat on Food Expenditure (%), 1987-2009

Source: calculated from USDA-ERS all meat prices and USDA-ERS all meat supply and disappearance data
Figure 6: US Broiler Exports (million lbs), 1987-2010

Source: USDA-ERS all meat supply and disappearance data
Figure 7: US Broiler Export Ratio in Values (%), 1987-2010

Source: calculated from USDA-ERS all meat supply and disappearance data
CHAPTER 3: WELFARE EFFECTS OF THE HORIZONTAL CONSOLIDATION IN THE BROILER INDUSTRY

3.1 Introduction

The U.S. poultry industry in general, and particularly the broiler industry, is often considered the role model for the industrialization of agriculture. The poultry industry is one of the most integrated agricultural industries. It has dominated the competitive scene in the meat complex over the last 30 years, expanding its market share dramatically as it improved efficiency, maintained lower prices than its competitors, and improved its product offerings and variety. Overall, the poultry industry's vertical integration and reliance on production contracts with independent farmers undoubtedly facilitated the industry’s efficiency and responsiveness to consumers, making it a more formidable competitor in the global meat market (Tsoulouhas and Vukina 2001).

The broiler industry is entirely vertically integrated, from breeding flocks and hatcheries to feed mills, transportation divisions and processing plants. The finishing stage of production is organized almost entirely through contracts with independent growers. A large proportion of the value added in processing is the main reason the processors became the coordinators of the industry, whereas the significant economies of scale in processing have led to a significant industry concentration.

This concentration coupled with restructuring occurred either through the replacing of existing plants with fewer, larger, more efficient ones, or through reorganization and

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14 Any opinions and conclusions expressed herein are those of the author(s) and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.
consolidation of assets of existing firms into more efficient configuration, or both. The concentration and restructuring in the poultry industry could have two impacts: (a) social welfare would decrease because higher concentrated industry means higher market power (b) social welfare would increase because the industry restructuring may improve cost efficiency. The objective of the chapter is to determine which one of the two effects dominates. In other words, are the cost reductions (synergies) through consolidation enough to offset the allocation inefficiency resulting from greater market power?

The results of this paper show that Herfindahl-Hirschman Index (HHI) increased in the periods between 1992-1997 and 1997-2002, and decreased in the period 2002-2007. Consumer surplus increased in all three periods. Producer surplus is positively correlated with HHI; that is, producer surplus increases when HHI increases and decreases when HHI is decreases. The overall social welfare increased during the HHI increased period (1992-2002), while decreasing during the HHI decreasing period (2002 to 2007), which means the society benefited from higher concentration in the poultry industry.

The rest of this chapter is organized as follows. Section 2 reviews the relevant literature, both theoretical and empirical. The empirical methodology is detailed in Section 3. Section 4 describes the data. Results are reported and discussed in Section 5 and the final Section concludes the chapter.

3.2 Literature review

3.2.1 Theoretical Literature

The theoretical literature in this area starts with Williamson (1968) who first modeled the market power and cost efficiency tradeoff and derived a simple partial equilibrium formula
for computing the average cost reduction necessary to neutralize the allocation inefficiency of post consolidation rise in output price. Williamson (1968) argued that if the post-merger price decreased, the social welfare would certainly increase. This is because when the price decreases, the total output should increase, and the consumer surplus would certainly increase. On the other hand, because merged firms produce more with lower average cost (because mergers shift the merged firm’s average cost and marginal cost function down), the non-merged firms produce less with the lower average cost (the non-merged firms’ average cost and marginal cost functions do not shift; this change is along the average cost curve). As a result, the model predicts that the industry average cost will decrease, and the overall industry production will increase, which consequently increases the producer surplus. In the case of an increase in the post-merger price, the results are ambiguous. The welfare tradeoff model applies most easily to the case of two firms that merge into a monopoly. The analysis recognizes that in the case of a demand curve that is relatively elastic, the efficiency gains from a cost-reducing merger (toward monopoly) could easily outweigh the incremental deadweight loss from the post-merger monopoly pricing. Williamson (1968) provided the core theoretical basis used today for taking efficiencies into account in horizontal merger analysis.

The Department of Justice’s “Merger Guidelines” (1984) takes Williamson’s trade-off explicitly into account. The main focus is on market concentration typically measured by the HHI. The HHI is calculated by summing the squares of the individual market shares of all the participants. Compared to the top-4 firms’ concentration ratio, the HHI reflect both the distribution of top 4 firms and the firms outside top-4. In the Guidelines (1984), only mergers
that will not result in a highly concentrated market (HHI greater than 1000) or increase concentration by very much (less than 100 points or 50 points) will be permitted without further investigation. For the mergers which cross the threshold, the Department of Justice is likely to challenge them. The Department will not challenge the merger if it produces significant cognizable efficiencies which cannot be achieved by the parties through other means. “Cognizable efficiencies include, but are not limited to, achieving economies of scale, better integration of production facilities, plant specialization, lower transportation cost, and similar efficiencies relating to specific manufacturing, servicing, or distribution operations of the merging firms” (Guidelines 1984). When these cognizable efficiencies are large enough to offset the price increase as a result of market power increased by the potential merger, the merger is likely to be permitted.

Because the Guidelines (1984) focus on whether output price increases or decreases, recent papers focus on the effect of mergers on price. The measured effect is unilateral because researchers assume that non-merging rivals do not alter their strategies either pre-merger or post-merger. In this case, if the price does not increase after the merger, social welfare will definitely increase. In other words, no increase in price is the sufficient condition for social welfare to increase.

Farrell and Shapiro (1990) derived the necessary condition to maintain the price before and after the merger. They show that the post-merger price will decrease if and only if the price cost margin of the merged firm is larger than the sum of the price cost margins of the pre-merge firms when the merged firm produces at the level of total production of the pre-merged firms. In other words, the merger will increase the price unless the marginal cost
decreases significantly to offset the effect of higher post-merger market power. Farrell and Shapiro (1990) also relate the marginal cost of the merged firm to the share of the pre-merger firms, demand elasticity and pre-merger price. They showed that larger pre-merger firms and lower demand elasticity require more cost reduction to prevent price from increasing after merger. This result is reflected in the Horizontal Merger Guidelines (1997) which recognizes that the greater the potential adverse competitive effect of a merger (as indicated by the increase in the HHI and post-merger HHI), the greater must be the cognizable efficiencies in order for the merger not to have an anticompetitive effect in the relevant market.

Farrel and Shapiro (1990) further extend their model to general cost and demand functions. They argue that because it is hard to compare pre- and post-merger allocations directly, they studied the merger effect on the welfare of non-merging firms and consumers, which they called external welfare effects. Because the profit of merged firm should increase after merger (otherwise the firms would have not merged to begin with), if the welfare of non-merging firms and consumers increase as a result of the merger, social welfare will increase for sure. Farrel and Shapiro (1990) also showed that if the market share of the new firm is less than the sum of the market shares of the other firms in the industry weighted by their respective conjectural variation terms, external welfare effects will be positive.

Werden and Froeb (1998) derived the ratio of marginal cost reduction to pre-merger price needed to prevent the price from increasing after a merger as a function of the pre-merge market shares and demand elasticity. Their result is quite similar to Farrell and Shapiro (1990) and says that the higher the market shares and the lower the demand elasticity
(in absolute value), the more reduction in marginal cost is required to prevent the post-merger price from increasing.

As said earlier, having no increase in the post-merger output price is a sufficient condition for social welfare to increase. However, the social welfare could increase even when the post-merger price goes up if the increase in producer surplus dominates, i.e. when cost synergies are substantial. Although the studies by Farrell and Shapiro (1990) and its extensions are widely accepted by economists, the Horizontal Merger Guidelines (2010) are still in favor of protecting competition and consumer surplus.

### 3.2.2 Empirical Literature

Different consequences of mergers and acquisitions have been studied empirically. Some authors study the effects of mergers on the partners’ profitability (Cosh, Hughes & Singh, 1979; Kumar, 1985; Meek, 1977; Ravenscraft and Scherer, 1987; Utton, 1974). Others study the relationship between ownership change and the stock market performance (Alberts & Varaiya, 1989; Hughes, 1993; Mueller, 1989; Roll, 1986). Other studies are concerned with productivity and prices. Since the literature in this field is huge, this review will focus only on the empirical studies in food and beverage and meat packing industries.

The first group of studies looks into the effect of mergers and acquisitions on productivity. The main finding of this literature is that mergers and acquisitions will increase productivity, as shown by Lichtenberg and Siegel (1992) and McGuckin and Nguyen (1995), among others. On the other hand, Nguyen and Ollinger (2006) argue that Lichtenberg and Siegel’s (1992) and McGuckin and Nguyen’s (1995) results may not hold for more narrowly defined industries. So they study the productivity of meat processing plants (meat packing
industry, sausages and other prepared meat product industry as well as the poultry slaughtering and processing industry) before and after mergers using 1977-82 and 1982-97 periods. Their results show that smaller acquired plants in the meat packing industry, sausages and other prepared meat product industry and larger plants in the poultry slaughtering and processing industry in 1977-87 improved their productivity growth after merger. But for smaller plants of the poultry processing industry during 1982-87 and all plants of poultry processing industry during 1987-92, there was no improvement in productivity.

Other researchers studied the effect of mergers and acquisitions on employment and wages with different results obtained by using different data. Brown and Medoff (1988), using a sample of firms in Michigan, found that mergers and acquisitions have little effect on employment and wages. But Lichtenberg and Seigel (1992) found that mergers and acquisitions of manufacturing plants led to reduction in both employment and wages at central offices but had little effect at production establishments. Further, McGuckin and Nguyen (1998) showed that the change in ownership increased the wages of employees of acquired plants by 12% and employment by 16% in food industry over 1977-82. Nguyen and Ollinger (2007) showed that mergers and acquisitions increased wages in the meat packing and prepared meat product industries over 1977-87 but not during 1982-92, and it resulted in increased employment in all three meat and poultry industry over 1977-87 period, but only in poultry for 1982-92.

Yet other studies focused on the effect of mergers and acquisitions on input price, output prices and input and output margins. In general, researchers found that higher concentration
lead to lower input prices (Wald, 1981; Menkhaus et al., 1981; Hayenga, Deiter and Montoya, 1986; Menkhaus, Whipple and Ward, 1990; Ward, 1992). On the other hand, the results for the effect of higher concentration on margins vary. Schroeter and Azzam (1990) and Brester and Musick (1995) found higher industry concentration was associated with the higher farm-to-wholesale marketing margins in the beef and pork packing industries and higher farm-to-retail margins in the lamb industry. Matthews (1999) used monthly data from 1979 to 1996 and found no significant association between increased concentration and farm-wholesale marketing margins. Ward and Stevens (2000) also found little aggregate effect in the beef industry price linkages resulting from increased packer concentration.

Finally, the Williamson welfare tradeoff due to consolidation in the beef packing industry was studied by Azzam and Schroeter (1995). The objective was to determine what cost reductions are necessary to offset the anticompetitive effects of market power resulting from consolidation in a regional oligopolistic industry. He found that the unit costs would have to decrease by 0.29% to neutralize the effects of a 50% increase in concentration, and would have to decrease by 2.94% to offset the effects of a cartelization of the buyers’ side of the cattle market.

3.3 Empirical Methodology

3.3.1 Producer Surplus

3.3.1.1 Cost Function Estimation

In order to calculate the producer surplus, I first estimate the cost function for the U.S. broiler industry. We use the generalized Leontief cost function, first introduced by Diewert and Wales (1984):
(1). \[ C_n = \sum_i \beta_i w_{in} + \sum_i \sum_j \beta_{ij} w_{in}^{1/2} w_{jn}^{1/2} y_n + \sum_i \delta_i w_{in} y_n^2, \]

where \( C_n \) is output cost for plant \( n \), \( w_{in} \) is price of input \( i \) for plant \( n \), and \( y_n \) is the output quantity for plant \( n \). \( \beta \)'s and \( \delta \)'s are the parameters to be estimated. With the generalized Leontief cost function, homotheticity is satisfied by construction. I impose the restriction \( \beta_{ij} = \beta_{ji} \) such that the symmetry condition is also satisfied. When \( \beta_i = 0, \forall i \) and \( \delta_i = 0, \forall i \), the underlying production function from which (1) is derived has the property of constant returns to scale (CRS).

Applying Shephard’s Lemma to (1) gives the input demand functions,

(2). \[ \frac{\partial c_n}{\partial w_i} = x_{in} = \beta_i + \sum_j \beta_{ij} w_{in}^{-1/2} w_{jn}^{1/2} y_n + \delta_i y_n^2 \text{ for all } i, \]

where \( x_{in} \) is the quantity demanded of input \( i \) for plant \( n \). In order to convert the theoretical model (2) to an empirical model, I append errors to (2):

(3). \[ X_{in} = \beta_i + \sum_j \beta_{ij} w_{in}^{-1/2} w_{jn}^{1/2} y_n + \delta_i y_n^2 + \epsilon_{in} \text{ for } i = 1, 2, 3, 4, \]

where \( \epsilon_{in} \)'s are error terms. The equation system is then estimated by iterated seemingly unrelated regression (ITSUR). The following paragraphs show how ITSUR estimate parameters. We now rewrite (3) in terms of matrix to make the explanation easier to understand:

(4). \[ Y_n = X_n \beta + \varphi_n. \]
where $Y_n = \begin{bmatrix} x_{1n} \\ x_{2n} \\ x_{3n} \\ x_{4n} \end{bmatrix}$, $\beta$ is a $18 \times 1$ parameter vector, $X_n$ is $4 \times 18$ matrix of independent variables, $\varphi_n = \begin{bmatrix} \varepsilon_{1n} \\ \varepsilon_{2n} \\ \varepsilon_{3n} \\ \varepsilon_{4n} \end{bmatrix}$. In ITSUR, $\varepsilon_{1n}$, $\varepsilon_{2n}$, $\varepsilon_{3n}$ and $\varepsilon_{4n}$ are assumed to be correlated. But $\varphi_n$ and $\varphi_s$ are independent with each other for $n \neq s$. Parameters are then estimated by feasible generalized least squares. Because the variance-covariance matrix of $\varepsilon s$ (name it $\Sigma$) is unknown, we need to estimate the parameters by iteration. In the first step, we run ordinary least squares for (4). The residuals from this regression are used to estimate elements of $\Sigma$. In the second step, we run the generalized least squares regression for (4) to get the second estimation of $\beta$. The residuals from this second regression can be used to form the second estimator of $\Sigma$. The estimation runs iteratively until the convergence is achieved. In order to account for changes in the cost function across time, we estimate the equation system (4) for each census year separately. We assume that the changes in cost function parameters across different years are caused by changes in industry concentration. After estimate parameters, from equation (3), we can calculate the input demand elasticities by formulas below:

\begin{equation}
\text{e}_{lin} = -\frac{1}{2} \sum_{j \neq i} \hat{\beta}_{ij} w_{in} \frac{y_n}{w_{jn}^{2}} \frac{y_{n}}{y_{n}} \frac{w_{in}}{w_{jn}^{2}} \frac{w_{jn}}{w_{jn}^{2}} + \frac{\delta_{i} y_{n}^{2}}{y_{n}^{2}} + \frac{\delta_{i} y_{n}^{2}}{y_{n}^{2}}
\end{equation}

\begin{equation}
\text{e}_{ijn} = \frac{1}{2} \hat{\beta}_{ij} w_{in} \frac{y_{n}}{w_{jn}^{2}} \frac{y_{n}}{y_{n}} \frac{w_{jn}}{w_{jn}^{2}} \frac{w_{jn}}{w_{jn}^{2}} + \frac{\delta_{i} y_{n}^{2}}{y_{n}^{2}} + \frac{\delta_{i} y_{n}^{2}}{y_{n}^{2}} \text{ for } j \neq i,
\end{equation}

where $e_{li}$ is own price elasticity for input $i$, $e_{lj}$ is cross price elasticity for input $i$ with respect to price of input $j$, $\hat{\beta}_{ij}$, $\hat{\beta}_{i}$ and $\hat{\delta}_{i}$ are the estimator for parameter $\beta_{ij}$, $\beta_{i}$ and $\delta_{i}$ respectively.
From equations (5) and (6), we can see that $e_{ij}$ and $e_{il}$ will change with different $w_{tn}$s, $y_n$ s and $x_i$s. So we substitute the industry averages of input prices, output quantities into the equations to get the elasticities:

\[
e_{il} = -\frac{1}{2} \sum_{j \neq l} \frac{\beta_{ij} \overline{w}_l - \frac{3}{2} w_j \overline{y}_j - \frac{1}{2} \overline{w}_l - \frac{1}{2} \delta_{ij} \overline{y}_j^2}{\beta_l + \sum_j \beta_{ij} \overline{w}_l - \frac{3}{2} w_j \overline{y}_j + \delta_{ij} \overline{y}_j^2}
\]

\[
e_{ij} = \frac{1}{2} \beta_{ij} \overline{w}_l - \frac{1}{2} w_j - \frac{1}{2} \overline{w}_l - \frac{1}{2} \delta_{ij} \overline{y}_j^2 \frac{w_j}{\beta_l + \sum_j \beta_{ij} \overline{w}_l - \frac{3}{2} w_j \overline{y}_j + \delta_{ij} \overline{y}_j^2} \text{ for } j \neq i,
\]

where $\overline{w}_l$, $\overline{y}$ are industry average of input prices and output quantity.

### 3.3.1.2 Producer Surplus

With the cost function estimated out, we can compute the producer surplus for each plant $n$ in each census year $t$ as follows:

\[
PS_{tn} = TR_{tn} - \int_0^{y_{tn}} MC_{tn}(y) \, dy,
\]

where $PS$ denotes the producer surplus, $TR$ is the total revenue and $MC(\cdot)$ is the marginal cost function. $MC(\cdot)$ can be obtained by taking the partial derivative of (1) with respect to the output quantity and takes the following form,

\[
MC(y_n) = \sum_i \sum_j \beta_{ij} w_{tn}^{1/2} w_{jn}^{1/2} + 2 \sum_i \delta_i w_{tn} y_n.
\]

Using (10), (9) can be rewritten as,

\[
PS_{tn} = TR_{tn} - \sum_i \sum_j \beta_{ij} w_{tni}^{1/2} w_{tnj}^{1/2} y_{tn} - \sum_i \delta_{it} w_{tni} y_{tn}^2,
\]

where $w_{tni}$ is the price of input $i$ for plant $n$ in year $t$ and the parameters have a subscript $t$ because as mentioned above, we estimate the cost function for each census year separately.

Finally, we get the total producer surplus for the industry in census year $t$ by summing $PS_{tn}$.
across all plants in that year, that is, \( PS_t = \sum_{n=1}^{N_t} PS_{tn} \), where \( N_t \) is the number of plants in census year \( t \).

With the method above, we implicitly assume that the changes in producer surplus across different census years are caused only by changes in industry concentration. Industry concentration could affect the producer surplus in many different ways: First, in the output market, broiler processing firms could have higher oligopoly power could charge higher prices to consumers. Second, in the input markets, broiler processing firms having higher oligopsony power to procure inputs at a lower price (that is, lower \( w_l \) in (1)). Third, larger firms could have higher incentives and more funding for research and development in technological improvements which could potentially lower the marginal cost. There are other factors that could potentially cause changes in the producer surplus across different census years, not including them in this analysis. For example, changes in the supply and demand conditions in the grain market can cause changes in the feed price (hence changes in \( w_l \) for materials in (1)) and hence the cost and the producer surplus. While a higher concentration rate of broiler processing firms would increase their ability to negotiate the price of live chicken, this not not likely to be the case with other input markets. One way to address this problem is to fix prices for labor, energy and capital, while allowing prices for material to (live chicken) to vary. In our results, we include both version of producer surplus.
3.3.2 Consumer Welfare\textsuperscript{15}

3.3.2.1 Estimating Demand for Chickens

To calculate changes in consumer surplus due to changes in industry concentration, we first need to estimate consumers’ demand for meats including beef, pork and chicken. We use the almost ideal demand system (AIDS) model introduced by Deaton and Muellbauer (1980). The system consists of demand equations for beef, pork, poultry, and other (food and nonfood) consumption items\textsuperscript{16}. Inclusion of The inclusion of an equation representing consumption of “all other goods” (food and non-food) and use of per capital total personal consumption expenditures as the income variable implies that we are estimating unconditional demand system instead of conditional demand system\textsuperscript{17}.

The AIDS model starts with the following expenditure function for a representative consumer:

\begin{equation}
\log e(u, p) = a(p) + ub(p),
\end{equation}

where \(a(p) = \alpha_0 + \sum_k \alpha_k \log p_k + 0.5 \sum_k \sum_j \gamma_{kj} \log p_k \log p_j\), \(b(p) = \beta_0 \prod_k p_{kj}^{\beta_k}\), \(p_k\) is the price for good \(k\) and \(\alpha, \beta\)s and \(\gamma\)s are parameters to be estimated.

\textsuperscript{15} I want to appreciate Michael Wohlgenant’s guidance and help in this part: including the suggestion of demand estimations (use unconditional demand system instead of conditional demand system), seasonal dummies and calculation of compensating variations as an alternative measure of consumer welfare.

\textsuperscript{16} LaFrance and Hanemann (1989) proved in their paper that incomplete demand systems are weakly integrable if the incomplete demand systems are augmented with an artificial composite commodity representing “other goods”. And they also showed that the exact welfare measures can be obtained from directly from any weakly integrable set of demand functions.

\textsuperscript{17} Hanemann and Morey(1992) showed in his paper that even with the assumption of separability, the partial welfare (calculated from partial demand system) provide, in general, only a limited amount of information about compensating variation. Because the purpose of this chapter welfare effect of higher concentration in the US broiler industry, unconditional demand system is estimated instead of conditional demand system. I want to appreciate Michael Wohlgenant’s guidance and help on this; he pointed out the problem of using conditional demand system to calculated welfare in my dissertation and gave me suggestions on how to fix this.
Applying the Shephard’s Lemma to (12) yields the following demand system,

\[ s_i = \alpha_i + \sum_k \gamma_{ki} \log p_k + \beta_i \log \left( \frac{e}{p} \right) \text{ for all } i, \]

where \( s_i \) is the expenditure share of good \( i \), \( P \) is the price index, that is, \( \log P = a(p) \) and \( e \) is the representative consumer’s budget for meat consumption. For estimation purposes, the AIDS model is often re-formulated as the LA/AIDS model by replacing the price index \( \log P \) using the Stone index:

\[ \log P^* = \sum_k s_k \log p_k. \]

The resulting LA/AIDS model is simpler and it makes the estimating equation (13) linear in parameters. Moschini (1996) shows that the Stone index is not invariant to price scaling and recommends using price indices instead of actual prices. This means we need to normalize each price series in (13) such that the price of each good takes the value of one in the base period.

To take into account of the year, seasonal shocks in meat consumption, we include time trend and quarter dummies in (14):

\[ s_{it} = \alpha_i + \theta_i t + d_{i1} Q_{1t} + d_{i2} Q_{2t} + d_{i3} Q_{3t} + \sum_{j=1}^{n} \gamma_{ij} \log (p_{jt}) + \beta_i \log \left( \frac{e_{it}}{p_{it}} \right) + \epsilon_{it} \]

for all \( i \),

where the subscript \( t \) is added to the variables to denote the time period, the \( t \) variable is the time trend, \( Q_{kt} \)s are the quarterly dummy variables and \( \epsilon_{it} \) is an error term appended to the equation to turn the theoretical model (13) into an empirical model (15). To avoid the endogeneity problem, we replace \( s_{it} \) with \( \tilde{s}_{it} \) in (14) when calculating the Stone price index.
where $\bar{s}_i$ is the average share of good $i$ across different time periods. Also, to address the possible autocorrelations in the error term $\varepsilon_{it}$, we take the first difference of (15).

$$\Delta s_{it} = \theta_i + d_{i1}\Delta Q_{1t} + d_{i2}\Delta Q_{2t} + d_{i3}\Delta Q_{3t} + \sum_{j=1}^{n} \gamma_{ij} \Delta \log(p_{jt}) + \beta_i \Delta \log\left(\frac{\varepsilon_{it}}{p_t}\right) + \Delta \varepsilon_{it} \text{ for all } i,$$

(16) is the final empirical demand system model we estimate. We impose the following set of restrictions, $\sum_k \alpha_k = 1$, $\sum_k \gamma_{kl} = \sum_i \gamma_{kl} = 0$, $\sum_k \beta_k = 0$ and $\gamma_{kl} = \gamma_{lk}$ such that the demand system satisfies the homogeneity and symmetry conditions, as required by the demand theory. This demand system is then estimated by ITSUR as well.

### 3.3.2.2 Change in Consumer Surplus

To compute the change in consumer surplus due to changes in industry concentration in the broiler processing industry, we need to derive the demand function for chicken from the AIDS model. By definition, the expenditure share for chicken is:

$$s_{ct} = \frac{p_{ct}q_{cet}}{e_t} = \alpha_c + \theta_c t + d_{i1}Q_{1t} + d_{i2}Q_{2t} + d_{i3}Q_{3t} + \sum_{j=1}^{n} \gamma_{cj} \log(p_{jt}) + \beta_c \log\left(\frac{\varepsilon_{ct}}{p_{ct}}\right) + \varepsilon_{ct},$$

where the subscript $c$ denotes chicken. Therefore:

$$q_{ct} = \frac{\alpha_c + \theta_c t + d_{i1}Q_{1t} + d_{i2}Q_{2t} + d_{i3}Q_{3t} + \sum_{j=1}^{n} \gamma_{cj} \log(p_{jt}) + \beta_c \log\left(\frac{\varepsilon_{ct}}{p_{ct}}\right) + \varepsilon_{ct}}{p_{ct}},$$

and the consumer surplus is:

\[\text{LaFrance and Hanemann (1989) noted in their paper that the consumer surplus line integral is not unique and not equal to exact welfare, in general, but required more restrictions. Hausman (1981) also pointed out the primary condition for CS to be a good approximation to CV is constant marginal utility of income. He argues that in the case of single price change no approximation is necessary to measure consumer welfare change. I want to appreciate Michael Wohlgenant raises this issue in my dissertation and suggests me use CV instead of CS as a measure of consumer welfare. This part is still kept in my dissertation for comparison purpose.}\]
where \( p_{ct}^- \) is the price of chicken in period \( t \) and \( p_{ct}^+ \) is the price of chicken when zero amount is consumed. For \( p_{ct}^- \), we use the yearly broiler price from USDA for year \( t \).

Computing \( p_{ct}^+ \), is more involved. Let \( A_{ct} = e_t (\alpha_c + \theta_c t + d_{t1}Q_{1t} + d_{t2}Q_{2t} + d_{t3}Q_{3t} + \sum_{j=1}^{n} \log(p_{jt}) + \beta_c \log(e_t) - \beta_c \sum_{j \neq i} \log(p_{jt}) + \varepsilon_{ct}) \) and \( B_{ct} = e_t (\gamma_{cc} - \beta_c \bar{s}_c) \), then (18) can be rewritten as

\[
q_{ct}(p_{ct}) = \frac{A_{ct} + B_{ct} \log(p_{ct})}{p_{ct}}. 
\]

When \( p_{ct} = e^{\frac{A_{ct}}{B_{ct}}} \), \( q_{ct}(p_{ct}) = 0 \). As a result, one may conclude that \( p_{ct}^+ = e^{\frac{A_{ct}}{B_{ct}}} \) is the choke price for chickens. But this conclusion might be incorrect because this result does not take the shape of the demand curve into account. To learn more about the shape of the demand curve, we take the partial derivative of the demand function for chicken with respect to the price of chicken:

\[
\frac{\partial q_{ct}(p_{ct})}{\partial p_{ct}} = \frac{B_{ct}}{p_{ct}^2} - \frac{A_{ct} + B_{ct} \log(p_{ct})}{p_{ct}^2} = \frac{-A_{ct} + B_{ct} \log(p_{ct})}{p_{ct}^2} 
\]

By setting (21) equal to zero, we see that when \( p_{ct} = e^{1 - \frac{A_{ct}}{B_{ct}}} \), \( q_{ct}(p_{ct}) \) attains its extreme value (the extreme value is \( B_{ct} e^{\frac{A_{ct}-1}{B_{ct}}} \)). Whether this value is a maximum or a minimum depends on the sign of the second derivative of the demand function evaluated at the extreme value. The second derivative of the demand function with respect to price is:

\[
\frac{\partial^2 q_{ct}(p_{ct})}{\partial p_{ct}^2} = \frac{2A_{ct} - 3B_{ct} + 2B_{ct} \log(p_{ct})}{p_{ct}^2}. 
\]
Evaluating (22) at \( p_{ct} = e^{1 - \frac{A_{ct}}{B_{ct}}} \) yields \( \frac{\partial^2 q_{ct}(p_{ct})}{\partial p_{ct}^2} = -\frac{B_{ct}}{p_{ct}^2} \). So if \( B_{ct} \) is negative, which means that the demand for chicken is elastic, the extreme value is a minimum. If \( B_{ct} \) is positive, which means that the demand for chicken is inelastic, the extreme value is a maximum. The two cases are illustrated in Figures 3.1 and 3.2.

Therefore, when \( B_{ct} < 0 \), \( p_{ct}^+ = e^{-\frac{A_{ct}}{B_{ct}}} \). But, as we can see from Figure 3.1, when \( B_{ct} > 0 \), \( e^{-\frac{A_{ct}}{B_{ct}}} \) is not the real choke price because for prices above \( e^{1 - \frac{A_{ct}}{B_{ct}}} \), the quantity will decrease but will never go to zero again. In other words, there is no real choke price when \( B_{ct} > 0 \). This implies that when demand is inelastic, \( p_{ct}^+ = +\infty \), the consumer surplus will be positive infinity as well. So we could only calculate the change in consumer surplus instead of the absolute value of consumer surplus. The change in consumer surplus between two years could be expressed as:

\[
\Delta C_{S_{ct}} = C_{S_{ct_2}} - C_{S_{ct_1}} = \int_{p_{ct_2}}^{p_{ct_1}} q_{ct_2}(p_c) dp_c - \int_{p_{ct_1}}^{p_{ct_2}} q_{ct_1}(p_c) dp_c
\]

where \( p_{ct_1} \) is the chicken price in year \( t_1 \) and \( p_{ct_2} \) is the chicken price in year \( t_2 \).

From (23), it is clear that there are two sources of the changes in consumer surplus across different time periods. The first source is the change in the demand function, that is, the demand function for chickens changes from \( q_{ct_1}(\cdot) \) to \( q_{ct_2}(\cdot) \). The second source is the change in the poultry price, that is, the price for chickens changes from \( p_{ct_1} \) to \( p_{ct_2} \). Since we are only interested in the consumer surplus change resulting from the change in chicken price caused by changes in industry concentration in the broiler processing industry, we fix the demand functions in the two years in (23) to be the same. As our data set span from the
period of 1992 to 2007, we compute two versions of (23) for each pair of years, once using the demand function for chickens in 1992 and once using the demand function for chicken in 2007. With this, (23) becomes:

\[
\Delta CS_c^{1992} = \int_{p_{ct_1}}^{p_{ct_2}} q_{c1992}(p_c) dp_c \quad \text{or} \quad \Delta CS_c^{2007} = \int_{p_{ct_1}}^{p_{ct_2}} q_{c2007}(p_c) dp_c.
\]

Finally, note that since we use (16) to estimate the demand system, \(\alpha_c\) and \(\varepsilon_{ct}\) are not estimated. However, we need an estimate for \(\alpha_c + \varepsilon_{ct}\) to compute the change in consumer surplus using (24). We use the difference between the observed expenditure share for chicken and the estimated value of the right hand side of (15) excluding the \(\alpha_c + \varepsilon_{ct}\), that is,

\[
\alpha_c + \varepsilon_{ct} = s_{ct} - [\theta_t d_{ct_1} + \hat{d}_{c1} Q_{1t} + \hat{d}_{c2} Q_{2t} + \hat{d}_{c3} Q_{3t} + \sum_{j=1}^{m} \hat{\gamma}_{cj} \log(p_{jt}) + \hat{\beta}_c \log(\hat{e}_{ct})].
\]

Where \(\theta_c, \hat{d}_{c1}, \hat{d}_{c2}, \hat{\gamma}_{cj}s\) and \(\hat{\beta}_c\) are parameter estimators.

With the method above, we implicitly assume that the change in output price is due entirely to change in HHI. However, a change in output price could be caused by development in the export market. For example, a positive shock in the export market could increase price of leg quarters (main export item). This could to decrease domestic price (for white meat), because poultry companies always tend to cross-subsidize their export by charging higher prices for domestic market. However, except in the first period of my study (1992 to 1997), export-to-production ratios were fairly stable (see Figure 2.7). This indicates there is no major shock coming from the export market. Hence, it is reasonable to assume the output price change is
strictly caused by HHI. From 1992 to 1997, the export ratio increased dramatically from around 7.5% to more than 15% (more than doubled). So during this time period, increase in consumer surplus could have been partially caused by positive shocks in the export market.

3.3.3 Compensating Variation

In fact, compensating variation (CV) is generally considered to be a better measurement of the welfare effect on consumers than CS. CV is defined as the amount of money consumers would pay or would need to be paid to be just as well off after the price change as they were before the price change. In most empirical studies, because Hicksian demand is generally not observable, CS (calculated from Marshallian demand) is used as an approximation of CV (calculated from Hicksian demand). The primary condition for CS to be a good approximation to CV is constant marginal utility of income. Hausman (1981) argues that in the case of single price change no approximation is necessary to measure consumer welfare change. In his paper, by developing a method to calculate unobservable Hicksian demand function from observable Marshallian demand function, he was able to estimate the exact measure of consumer welfare changes. In this part of this chapter, we follow Hausman’s approach to calculate compensating variation. Instead of a general demand function, we apply his approach to LA/AIDS model.

In our model, following Hausman’s approach, we rewrite (12) as,

\[ u(e, p) = (\log e - \alpha_0 - \sum_k a_k \log p_k - 0.5 \sum_k \sum_j \gamma_{k,j} \log p_k \log p_j)/\beta_0 \prod_k p_k^{\beta_k}. \]
where $u(e, p)$ is the representative consumer’s indirect utility given expenditure $e$ and price vector $p$. Let $u_{t_1} = u(e_{t_1}, p_{t_1})$ denotes the indirect utility in year $t_1$. We then have the following formula for CV:

\[(27). CV = e(u_{t_1}, p_{t_2}) - e(u_{t_1}, p_{t_1}).\]

where the expenditure function $e(\cdot, \cdot)$ is defined in (12) and $p_{t_2}$ is the price vector for all products in the demand system in year $t_2$. We are now ready to state the following result.

**Result1:** When the prices for beef, pork and “all other goods” remain the same and only the price of chicken changes from $p_{ct_1}$ to $p_{ct_2}$, (27) can be rewritten as follows:

\[(28). CV = e_{t_1}\{\exp[ E_{ct_1}(\Delta \log p_c + 0.5 \gamma_{cc}(\Delta \log p_c)^2 + [e^{\beta_c \Delta \log p_c} - 1](F_{t_1} - \alpha_0)] - 1\},\]

where $\Delta \log p_c = \log p_{ct_2} - \log p_{ct_1}$, $E_{ct_1} = \alpha_c + \sum_j \gamma_{cj} \log p_{jt_1}$ and $F_{t_1} = \log e_{t_1} - \sum_k \alpha_{k1} \log p_{kt_1} - 0.5 \sum_k \sum_j \gamma_{kj} \log p_{kt_1} \log p_{jt_1}$.

Since we estimate our demand system using (16), $\alpha_0$ is not estimated. If $\beta_c \Delta \log p_c$ is small, (28) can be rewritten as:

\[(29). CV = e_{t_1}\{\exp[s_{ct_1}(\Delta \log p_c + 0.5 \gamma_{cc}(\Delta \log p_c)^2)] - 1\},\]

where $s_{ct_1}$ is the expenditure share of poultry at time $t_1$.

**Proof:** see the Appendix.

### 3.4 Data

#### 3.4.1 Census data

The estimation of the cost function and the calculation of the producer surplus are based on the data from the Census of Manufactures. Our sample consists of plants in the broiler processing industry (NAICS code 311615) in years 1992, 1997, 2002 and 2007. Since we are
only interested in the producer surplus for broilers, we focus on those plants which use live broilers (young chickens including commercial broilers) as the main input material and for which processed broiler meat (broilers and fryers under 20 weeks of age, roasters and capons) account for more than 90% of the output values.

Using the Census data, we created the following variables that are needed to estimate the input demand system (3) and compute the producer surplus (11) for each plant. The output variable \( y \) is the total processed broiler meat produced (in thousands of lbs.), which is directly available from the Census. Input quantities \( x_s \) and prices \( w_s \) were constructed as follows. There are 4 inputs in broiler production: materials, labor, energy and capital. Since one processed broiler comes from one live broiler, we use the total live broiler used in production (in thousands of lbs.) as the quantity for materials, \( x_m \). The total live broilers used in production are directly available in the Census data. The materials price, \( w_m \), was computed by dividing the expenditure on materials (directly available in the Census data and including expenditure on live broilers and boxes and other packaging materials, also in terms of thousands of dollars) by \( x_m \).

The labor price, \( w_l \), was calculated by dividing the expenditure on production workers (directly available in the Census data and including annual payroll and fringe benefits for both leased and non-leased workers, also in terms of thousands of dollars) by the total production workers’ production hours. The labor quantity, \( x_l \), was computed by dividing the sum of the expenditure on production workers and non-production workers (both of which are directly available in the Census data and in terms of thousands of dollars) by \( w_l \). The
implicit assumption here is that production workers and non-production workers have the same average wage rate.\textsuperscript{19}

The energy price, $w_e$, was calculated by dividing the expenditure on electricity (directly available in the Census data and in terms of thousands of dollars) by the quantity of electricity used (directly available in the Census data and in terms of Kilowatts). The energy quantity, $x_e$, was computed by dividing the sum of the expenditure on electricity and fuel (both of which are directly available in the Census data and in terms of thousand dollars) by $w_e$. The implicit assumption here is that the electricity price and the fuel price are the same when electricity and fuel are converted into the same unit.\textsuperscript{20}

The capital price, $w_k$, was calculated by dividing the depreciation charges (directly available in the Census data and in terms of thousands of dollars) by the total of value of assets at the beginning of the year (directly available in the Census data and in terms of thousands of dollars)\textsuperscript{21}. The capital quantity, $x_k$, was computed by dividing the sum of the depreciation charges and rental payments for machines and buildings (both of which are directly available in the Census data and in terms of thousands of dollars) by $w_k$. The implicit assumption here is that the rental rate for machines and buildings is the same as the depreciation rate for machines and buildings the plant owns.\textsuperscript{22}

\textsuperscript{19} This assumption is necessary as the Census data does not report the total hours for non-production workers.
\textsuperscript{20} This assumption is necessary as the Census data does not report the quantity of fuel used.
\textsuperscript{21} This method may not be accurate. The average of $w_k$ is quite different from the industry level rental price used in Chapter 4. Further improvement is needed for this part in the future.
\textsuperscript{22} This assumption is necessary as the Census data does not report how many machines and buildings a plant rents.
Finally, the total value of shipment in thousands of dollars \((TR\text{ in } (11))\) is directly available from the Census data. All the input prices and the total value of shipment were then deflated by the CPI.

Table 3.1 reports the summary statistics for all the variables created using the Census data. Comparing the means and the weighted means (weighted by corresponding input quantity) of input prices, we can see that weighted means are always lower than non-weighted means. This implies that larger plants get lower input prices. We also notice that labor prices had been increasing over the sample period. There was no clear trend in the prices for energy, materials and capital. On the other hand, both average input quantities (energy, material, labor and capital) and output quantity had been increasing over the sample period. This means, on average, the size of broiler processing plants had been increasing over the sample period.

### 3.4.2 USDA Data

The quarterly data for estimating the demand system (16) are from USDA-Economic Research Service (ERS). For meat consumption quantities, we use the quarterly per capita data for beef, pork and broiler from the “Quarterly Red Meat, Poultry, and Egg Supply and Disappearance and per Capita Disappearance” table.\(^{23}\) For retail prices, we use the average of the monthly retail prices available from the “Retail Prices for Beef, Pork, Poultry cuts, Eggs, and Dairy Products” table.\(^{24}\) The coverage of the data is from 1989 to 2009. All the meat prices were then deflated by overall CPI. The price of "all other consumption goods" is

\(^{23}\) This table can be found at [http://www.ers.usda.gov/publications/ldp/LDPTables.htm](http://www.ers.usda.gov/publications/ldp/LDPTables.htm).

\(^{24}\) This table can be found at [http://www.ers.usda.gov/data/meatpricespreads/](http://www.ers.usda.gov/data/meatpricespreads/).
obtained from the overall CPI, per capita total personal consumption expenditures (deflated by overall CPI), constant dollar expenditures, and price indexes for beef, pork, and poultry. Per capita personal consumption expenditures and CPI for beef, pork, and poultry are used to calculate expenditure share weights for the four goods. Then price for “all other goods” can be calculated from equation: \( CPI = \sum_s CPI_i \), where \( CPI_i \) is the price index for the \( i \)th good, \( s_i \) is the expenditure share of \( i \)th good. (Wohlgenant 1989. p. 172). Overall CPI, CPI for beef, CPI for pork, CPI for broiler, total personal consumption expenditure and population are come from Economics Research of Federal Reserve Bank of St. Louis.

Table 3.2 reports the summary statistics for the retail prices and quarterly per capita consumption quantities for the three meats in our demand system. On average, each person consumed 16.51 lbs, 12.70 lbs, 18.55 lbs of beef, pork and broilers respectively, per quarter during the sample period. This indicates that chicken has replaced beef and became the most-consumed meat in the USA. From this table, we can also see that consumption of broilers has the highest standard deviation and range compared to other meats. This indicates that broiler consumption quantity had been more volatile than those of other meats during the sample period. This could be due to more seasonal variations in chicken consumption or due to the fact that people have been eating more and more white meat recently for health reasons. Average real retail prices for beef, pork and broiler during the sample period were $2.12/lb, $1.60/lb and $1.02/lb, respectively. The standard deviations of real retail prices for beef, pork and broiler are close to each other (around $0.1).

25 Poultry CPI is used instead of broiler CPI because broiler CPI data is not available for 1997 and earlier. Use poultry CPI as an approximation for broiler CPI would be reasonable if turkey price has relative small impact on poultry CPI. From my data, average expenditure share of turkey on poultry is about 5%. So it is reasonable to assume turkey price has small impact on poultry CPI.
3.5 Results

3.5.1 Producer Surplus

Using the Census data, we estimated the input demand system (2) using iterative seemingly unrelated regression (ITSUR). The estimation is conducted separately for each of the four census years. Parameter estimates are reported in Table 3.3. Most $\beta_i$s are not significant, except $\beta_l$ in 2007 which is positive and significant. This implies that fixed costs in 1992, 1997 and 2002 are not significantly different from zero, while fixed cost in 2007 is positive and significant. All $\delta_i$s are negative with some of them significant, but none of them are economically significant (all of them are small in magnitude: smaller than $10^{-6}$). From equation (6), we can see that if $2 \sum \delta_i w_i$ is positive, marginal cost function is increasing in quantity. If $2 \sum \delta_i w_i$ is negative, marginal cost function is decreasing in quantity $y$. Using estimated $\delta_i$s and yearly weighted average input prices from Table 3.1, we could calculate $2 \sum \delta_i w_i$ for each census year. They are $-4.35 \times 10^{-6}$, $-1.87 \times 10^{-7}$, $-1.06 \times 10^{-6}$ and $-2.94 \times 10^{-7}$ for 1992, 1997, 2002 and 2007 respectively. This means our marginal cost function decreased 1992, 1997, 2002 and 2007. But the magnitude of increase or decrease was small. That is, our marginal cost function is approximately constant. Take 2007 as an example: $2 \sum \delta_i w_i = -2.94 \times 10^{-7}$ means if the processing plant increased output by one thousand pounds, the marginal cost of broiler decreased by $2.94 \times 10^{-7}$ per pound. The last four rows of Table 3.3 represent the adjusted R-squared of input demand equations for each year. One of the most important properties of cost function is concavity in input price.
The eigenvalues of the Hessian Matrix\(^{26}\) of cost function are: -0.81, -37143.36, -96896.8, -388201.6. This implies our cost function is concave.

Input demand elasticities calculated from the parameters are shown in Table 3.4. Most own price elasticities for material, energy, labor and capital were negative and significant for years 1992, 1997, 2002 and 2007, except for the materials own price elasticity in 2007, which is positive and marginally significant at 10% (p-value equals to 9.3%). This implies, taking price elasticity of materials in 1992 (-0.1166) as an example, a one percentage point increase in the price of material will decrease the demand of materials by 0.1166 percentage point. Most cross-price elasticities are positive, and some of them are significant\(^{27}\). This means, taking material and labor in 1992 as an example, when material prices increases, demand for labor increases; on the other hand, when labor price increases, the demand for material also increases. This implies that materials and labor were substitutes in 1992. Cross-price elasticities between labor and capital in 2002, material and energy in 2007 are negative and significant. Taking labor and capital in 2002 as an example, this implies they are complements. In other words, if price of labor increases, demand for capital will decrease. Other cross-price elasticities are not significant.

\(^{26}\) Hessian Matrix of cost function is \[
\left[ \frac{\partial^2 c_n}{\partial w_{in} \partial w_{jn}} \right]_{K \times K},
\]
where \[
\frac{\partial^2 c_n}{\partial w_{in}^2} = -\frac{1}{2} \sum_{j \neq i} \beta_{ij} w_{in}^{-3/2} w_{jn}^{1/2} \gamma_n, \quad \frac{\partial^2 c_n}{\partial w_{in} \partial w_{jn}} = \frac{1}{2} \beta_{ij} w_{in}^{-1/2} w_{jn}^{-1/2} \gamma_n \text{ for } i \neq j.
\] As mentioned above, we estimate four cost functions (one for each year), this Hessian Matrix is the average of the four Hessian Matrices.

\(^{27}\) As shown in Table 3.4, cross-price elasticities between material and energy, material and labor, material and capital in 1992, material and labor, energy and labor in 1997, material and energy, material and labor, material and capital, energy and labor in 2002, energy and labor, labor and capital in 2007 are positive and significant.
Using the estimates, we then computed the producer surplus for each plant in each census year in our sample using (11) and sum the producer surplus across all plants in the sample to obtain the total producer surplus by census year. In order to correct for the quantity difference between the US broiler production reported by USDA and the total production quantity in our sample (because as mentioned above, we only focused on plants for which processed broiler account for more than 90% of the total value of shipment), we multiply the producer surplus estimated in our sample by the ratio of US total processed broiler production reported by USDA to total production quantity in our sample.

The producer surplus results are reported in Table 3.5, together with market concentration measures. As mentioned above, we calculated two versions of producer surplus: one uses plant-level input prices where all prices change over time and across plants (version 1, listed in part one of Table 3.5); the other version uses historical industry-level average labor, energy, and capital prices while allowing materials (live chicken) price to change over time (version 2, listed in part two of Table 3.5). Overall, producer surplus using historical input prices was higher than producer surplus using plant-level input prices. This is because labor price increased gradually during the time period (See Table 3.1). Although energy price and capital price fluctuated, the increase in labor price dominated.

From Table 3.5, we can also see that total producer surplus (both versions) increased when industry became more concentrated (from 1992 to 2002), and decreased when industry became less concentrated (from 2002 to 2007). Our results are consistent with Williamson’s (1968) conclusion: when output price decreases accompanied with higher concentration, producer surplus will increase.
On the other hand, changes in per capita producer surplus were different from the change in total producer surplus due to growth in population. Table 3.5 also report per capita producer surplus and its percentage change (column 7 and column 8). Overall, because of positive growth in population, the percentage change in producer surplus per capita was lower than the percentage change in total producer surplus. For most time periods, the directions of change for per capita producer surplus using instant input prices and for per capita producer surplus using historical input prices were consistent, except for the period from 1997 to 2002. From 1997 to 2002, per capita producer surplus using instant input prices decreased by 1.84%, while per capita producer surplus using historical input prices increased by 1.37%.

3.5.2 Demand Estimation
Using retail prices and consumption quantities data from USDA-ERS, we estimate the demand system using (16). Estimation results are reported in Table 3.6. The last two rows of Table 3.6 report the adjusted R squared of the demand system. Using the estimates, we then calculated the uncompensated (Marshallian) price and income elasticities. These results are reported in Table 3.7. The own uncompensated price elasticities for beef and “all other goods” are all negative and significant. This means, taking beef as an example, if personal consumption expenditure and prices of other meats and “all other goods” are fixed, an increase in beef price will decrease the consumption of beef. The own uncompensated price elasticities for pork and chickens are negative but not significant. Uncompensated cross price elasticities for “all other goods” with respect to the price of beef, broiler and pork were

28 The elasticity for broilers does not change a lot when turkey is included or omitted.
negative and significant. This implies that they are gross compliments. Taking “all other goods” and beef as examples, given personal consumption expenditure and prices of pork and broilers, an increase in beef price will the consumption of all other goods. The rest of uncompensated cross price elasticities are not significant. Finally, income elasticities for beef, broiler and “all other goods” were estimated to be positive and significant (income elasticity for pork is positive but not significant). This verifies that beef and broiler are normal goods.

Then, using the Slutsky equation \( e_{ij}^c = e_{ij} + e_i S_j \), where \( e_{ij}^c \) is the compensated elasticity, \( e_{ij} \) is uncompensated elasticity, \( e_i \) is income elasticity, \( S_j \) is expenditure share, we turn uncompensated price elasticities into compensated (Hicksian) price elasticities. Results are reported in Table 3.8. The compensated own price elasticities for beef and “all other goods” were estimated to be negative and significant. Compensated own price elasticity for broiler and pork was negative but not significant\(^{29}\). Consistent with theory, compensated own price elasticity for a good should be negative. The compensated cross price elasticity between beef and “all other goods” is estimated to be positive and significant, indicating beef and “all other goods” are net substitutes. Other compensated cross price elasticity estimates are not significant.

\(^{29}\) The elasticity for broilers does not change a lot when turkey is included or omitted.
One of the most important properties of expenditure function is concavity in product prices. This requires the Slutsky matrix\(^{30}\) of the demand system to be negative semi-definite. By checking the eigenvalues of the Slutsky matrix at each observation, I find that the demand system is concave on average (eigenvalues are negative on average: -0.000012, -0.986672, -2.01774, -4.430901), I conclude that expenditure function is concave in product prices on average\(^{31}\).

### 3.5.3 Consumer Surplus and Compensating Variation

As discussed in subsection 3.2.2, to compute consumer surplus, we first need to check whether \(B_{ct}\), which is defined in (20) above, is positive or negative. Using parameter estimates from the demand estimation and data, we compute \(B_{ct}\) for each of the census years and report the results in the second column of Table 3.9. As we can see, \(B_{ct}\) was positive for all census years. This implies that the demand curve for chicken is represented by Figure 3.2, where the choke price is positive infinity, rather than Figure 3.1. As a result, we cannot compute the absolute value for consumer surplus and can only compute the change in consumer surplus between two census years using equation (24).

Also, Figure 3.2 shows that the demand curve was not wel-behaved when the price is below \(e^{-\frac{A_{ct}}{B_{ct}}}\). We then computed \(e^{-\frac{A_{ct}}{B_{ct}}\cdot} \) for each census year and report them in the third

\(^{30}\) Slutsky matrix is \(\left[\frac{\partial h_i(P,u)}{\partial P_j}\right]_{M \times M}\), where \(h_i(P,u)\) is Hessian demand, \(P\) is a vector of prices, \(u\) is utility, \(P_j\) is price of good \(j\). We have already calculate compensated elasticities \(e_{ij}^c\), where \(e_{ij}^c = \frac{\partial h_i(P,u)}{\partial P_j} \cdot \frac{P_j}{h_i(P,u)}\), so \(\frac{\partial h_i(P,u)}{\partial P_j} = e_{ij}^c \cdot \frac{h_i(P,u)}{P_j}\).

\(^{31}\) Concavity is not satisfied when \(t\) is large, but it is satisfied when \(t\) is small. So specific care need to be taken when interpreting consumer surplus (CS) and compensating variation (CV), specifically CS calculated from demand curve in 2007.
column of Table 3.9. Compared with chicken prices, which are reported in the last column of Table 3.9, we find that chicken prices are always lower than the corresponding $e^{ \frac{A_{cl}}{B_{ct}s}}$.

Therefore, we conclude that price movements during the sample period occurred in the segment of the demand curve where the curve was not well-behaved and using equation (24) to calculate change in consumer surplus may not be accurate. Fortunately, we have an alternative method (CV) to measure consumer welfare. We will still present CS results for comparison purpose.

Consumer surplus results are reported in Table 3.10. No matter whether we fix the demand curve at the 1992 level or at the 2007 level, consumer surplus increased continuously during the sample period. This was mainly driven by the fact that retail broiler prices had been decreasing during the same time period, as shown in Table 3.2. The change in consumer surplus was especially large between year 2002 and year 2007 because the price of broiler decreased $0.17/lb during that time period, compared with $0.05/lb and $0.03/lb between 1992 and 1997 and between 1997 and 2002, respectively.

An alternative measure of consumer welfare change is CV. When computing CV using (29), we approximate $e^{\beta_c \Delta \log p_c} - 1$ with $\beta_c \Delta \log p_c$. As discussed above, this assumption has a small effect on the computed CV if $\beta_c \Delta \log p_c$ is close to 0. Using the data and the estimate of $\beta_c$ from Table 3.6, we compute $\beta_c \Delta \log p_c$ and $e^{\beta_c \Delta \log p_c} - 1$ for different census years. The results are reported in the second and third columns of Table 3.11. As we can see, $\beta_c \Delta \log p_c$ is always a good approximation for $e^{\beta_c \Delta \log p_c} - 1$. Therefore, we can compute the CV using (29) and the results are collected in the fourth column of Table 3.11. By comparing
the results of CV to results of CS, we can see that CS is not a good approximation to CV when price change is large (Hausman (1981)).

3.5.4 Changes in Social Welfare

We now examine the changes in social welfare, which is the sum of the changes in producer surplus and the changes in consumer welfare. Using results from Table 3.5, we computed the changes in producer surplus across different census years. These are reported in the second (use instant input prices) and third (use historical input prices) columns of Table 3.12. We then took the average of $\Delta CS_c^{2007}$ and $\Delta CS_c^{1992}$ from Table 3.10 as the changes in consumer surplus across different census years. These numbers are reported in the fourth column of Table 3.12. The CVs across different census years are reported again in the fifth column of Table 3.12. The last four columns of Table 3.12 report the changes in social welfare (with different combinations of measures of consumer surplus and producer surplus). Results show that between 1992 and 1997, both consumer and producer welfare increased, and as a result, the social welfare had been increasing. The increase in producer welfare consisted mostly of the increase in social welfare (more than 90%). The industry concentration measures reported in Table 3.5 show that this was the time period during which major consolidations happened. These mergers and acquisitions resulted in major efficiency gains for the broiler processing plants. These producers passed part of the gain to consumers through a lower price for processed broiler meat, resulting in gains for consumers as well.

Secondly, between 1997 and 2002, increases in producer surplus slowed down and the trend even reversed for some types of measurement. This was because consolidations slowed

---

32 Although CS is not a good approximation to CV, we still include it in the table for comparison purpose
down during this time period. Consumer welfare, however, continued to increase during this time period because of lower broiler retail price (see Table 3.2) and higher per capita consumption of broilers (see Figure 2.2). The loss in producer surplus was smaller than the increase in consumer welfare, resulting in a positive change in social welfare during this time period.

On the other hand, between 2002 and 2007, producer surplus decreased. This happened for several reasons. First, from Table 3.5, it is clear that during this time period, consolidations slowed down and the trend was even reversed. As a result, there was little gain in terms of production efficiency. Second, costs for producers, especially labor and materials, rose sharply during this time period. This can be seen from Table 3.1. Third, output price, that is, retail price for processed broiler meat, decreased sharply during this time period (see Table 3.2), possibly caused by fierce competition among producers. Consumer welfare again continued to increase during this time period, largely due to the fact that retail price for processed meat decreased sharply. The loss in producer surplus was larger than the increase in consumer welfare, resulting in a negative change in social welfare during this time period.

### 3.6 Conclusions

This paper is a study of welfare effects of mergers and acquisition in the broiler processing industry. Our study covers the period of four census years from 1992 to 2007, during which the industry experienced very active horizontal consolidation. Although the various consequences of horizontal integration in the meat packing industries have been studied before, we picked the broiler industry because of its specific organization that relies
exclusively on the production contracts with independent growers as the only source of the supply of live birds. There are reasons to believe that the welfare implications of mergers and acquisitions under this type of organizational structure could be different than in some other meat packing industry characterized by competition on the market for live animals. Another interesting issue is the welfare implications of mergers and acquisitions on contract growers, which we do not study in this paper, but it presents itself as a challenging object of future research.

By estimating LA/AIDS demand function (with data from USDA-ERS) and generalized Leontief cost function (with data from Census of Manufactures), we computed producer surplus, consumer welfare and social welfare. The HHI, constructed with data from Census of Manufactures, increased from 1992 to 2002 and decreased from 2002 to 2007. By comparing the welfare measures with HHI, we found that: during the period of 1992 to 2002 (HHI increasing period), both producer surplus and consumer welfare and hence social welfare had been increasing; from 2002 to 2007 (HHI decreasing period), producer surplus shrunk, but consumer welfare was still increasing due to lower retail price. With consumer welfare’s gain less than the loss in producer surplus, the change in social welfare was negative during this time period.
Table 3.1: Summary Statistics for Cost Function Estimations, 1992-2007

<table>
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<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Price ($/W)</td>
<td>0.0540 (1.38E-2)</td>
<td>0.0523 (1.40E-2)</td>
<td>0.0513 (1.71E-2)</td>
<td>0.0658 (3.06E-2)</td>
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<tr>
<td>Material Price ($/lb)</td>
<td>0.3325 (1.75E-1)</td>
<td>0.3853 (3.13E-1)</td>
<td>0.3317 (1.75E-1)</td>
<td>0.5194 (9.89E-1)</td>
</tr>
<tr>
<td>Labor Price ($/hour)</td>
<td>9.0172 (1.77)</td>
<td>10.7594 (4.82)</td>
<td>11.8774 (2.09)</td>
<td>15.327 (3.32)</td>
</tr>
<tr>
<td>Capital Price</td>
<td>0.1050 (1.25E-2)</td>
<td>0.0769 (3.56E-2)</td>
<td>0.0825 (6.16E-2)</td>
<td>0.0830 (4.93E-2)</td>
</tr>
<tr>
<td>Energy Quantity (Thousands kW)</td>
<td>18900 (13600)</td>
<td>26200 (19000)</td>
<td>33500 (29700)</td>
<td>44400 (36800)</td>
</tr>
<tr>
<td>Material Quantity (Thousands lbs)</td>
<td>170000 (97300)</td>
<td>202600 (109700)</td>
<td>215600 (117200)</td>
<td>222800 (227500)</td>
</tr>
<tr>
<td>Labor Quantity (Thousands hours)</td>
<td>1500 (900)</td>
<td>1800 (1000)</td>
<td>1800 (1000)</td>
<td>1900 (1100)</td>
</tr>
<tr>
<td>Capital Quantity ($)</td>
<td>17200 (79400)</td>
<td>27400 (89200)</td>
<td>35100 (145500)</td>
<td>40100 (153100)</td>
</tr>
<tr>
<td>Output Quantity (Thousands lbs)</td>
<td>137200 (79400)</td>
<td>172900 (89200)</td>
<td>201500 (145500)</td>
<td>216400 (153100)</td>
</tr>
</tbody>
</table>

Weighted Means:

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<tr>
<td>Energy Price ($/W)</td>
<td>0.0503 (1.73)</td>
<td>0.0477 (2.14)</td>
<td>0.0441 (2.83)</td>
<td>0.0577 (4.56)</td>
</tr>
<tr>
<td>Material Price ($/lb)</td>
<td>0.3081 (36.15)</td>
<td>0.3421 (38.09)</td>
<td>0.2958 (51.54)</td>
<td>0.3502 (83.19)</td>
</tr>
<tr>
<td>Labor Price ($/hour)</td>
<td>8.8454 (66.74)</td>
<td>10.016 (103.94)</td>
<td>11.7557 (81.14)</td>
<td>15.1988 (139.33)</td>
</tr>
<tr>
<td>Capital Price</td>
<td>0.0813 (10.33)</td>
<td>0.0724 (4.69)</td>
<td>0.0803 (13.31)</td>
<td>0.0749 (7.09)</td>
</tr>
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</table>

Notes: input quantities are rounded to its nearest hundreds. Standard errors are given in parentheses.
Table 3.2: Summary Statistics of Retail Prices and Consumption Quantities for Meats, 1989-2009

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<tr>
<th>Variables</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>Quantity (lbs per capita):</td>
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</tr>
<tr>
<td>Beef</td>
<td>16.51</td>
<td>0.64</td>
<td>14.72</td>
<td>17.55</td>
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<tr>
<td>Pork</td>
<td>12.70</td>
<td>0.65</td>
<td>11.33</td>
<td>14.31</td>
</tr>
<tr>
<td>Broiler</td>
<td>18.55</td>
<td>2.27</td>
<td>13.67</td>
<td>22.13</td>
</tr>
<tr>
<td>Price ($/lb):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>2.12</td>
<td>0.09</td>
<td>1.91</td>
<td>2.32</td>
</tr>
<tr>
<td>Pork</td>
<td>1.60</td>
<td>0.10</td>
<td>1.44</td>
<td>1.81</td>
</tr>
<tr>
<td>Broiler</td>
<td>1.02</td>
<td>0.11</td>
<td>0.82</td>
<td>1.31</td>
</tr>
<tr>
<td>Broiler Price by Year ($/lb):</td>
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<td></td>
<td></td>
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<tr>
<td>1992</td>
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<td>1.03</td>
<td>1.11</td>
</tr>
<tr>
<td>1997</td>
<td>1.04</td>
<td>0.01</td>
<td>1.02</td>
<td>1.06</td>
</tr>
<tr>
<td>2002</td>
<td>1.01</td>
<td>0.12</td>
<td>0.99</td>
<td>1.04</td>
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<tr>
<td>2007</td>
<td>0.84</td>
<td>0.12</td>
<td>0.80</td>
<td>0.87</td>
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### Table 3.3: Generalized Leontief Cost Function and Input Demand System Estimation

#### Results

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<td>$\beta_m$</td>
<td>-1305.88 (14175.3)</td>
<td>33016.21 (25827.8)</td>
<td>19624.05 (16335.3)</td>
<td>14998.19 (43404.4)</td>
</tr>
<tr>
<td>$\beta_e$</td>
<td>1096.68 (2944.7)</td>
<td>-1313.43 (4985.7)</td>
<td>2842.80 (4207.5)</td>
<td>2457.32 (6218.0)</td>
</tr>
<tr>
<td>$\beta_l$</td>
<td>166.65 (163.4)</td>
<td>-43.82 (222.9)</td>
<td>212.37 (165.8)</td>
<td>804.76*** (179.9)</td>
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<td>$\beta_k$</td>
<td>-3042.33 (1512.7)</td>
<td>2622.982 (6073.2)</td>
<td>6944.03 (4894.4)</td>
<td>3106.40 (6591.9)</td>
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<tr>
<td>$\beta_{mm}$</td>
<td>1.2144*** (1.72E-1)</td>
<td>1.0076*** (2.77E-1)</td>
<td>1.0910*** (1.18E-1)</td>
<td>1.0345*** (3.52E-1)</td>
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<tr>
<td>$\beta_{me}$</td>
<td>0.0677*** (8.56E-3)</td>
<td>0.0164*** (1.20E-2)</td>
<td>0.0213** (9.40E-3)</td>
<td>-0.00667 (4.02E-3)</td>
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<tr>
<td>$\beta_{ml}$</td>
<td>0.0494*** (5.65E-3)</td>
<td>0.0179 (6.24E-3)</td>
<td>0.0303*** (5.64E-3)</td>
<td>-0.0032 (1.95E-3)</td>
</tr>
<tr>
<td>$\beta_{mk}$</td>
<td>0.0241* (1.38E-2)</td>
<td>0.0224 (1.64E-2)</td>
<td>0.0665*** (1.51E-2)</td>
<td>-0.0028 (4.67E-3)</td>
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<tr>
<td>$\beta_{ee}$</td>
<td>0.0217 (4.83E-2)</td>
<td>0.0123 (6.48E-2)</td>
<td>-0.0601* (3.56E-2)</td>
<td>-0.0313 (6.64E-2)</td>
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<tr>
<td>$\beta_{el}$</td>
<td>-0.00259 (2.52E-3)</td>
<td>0.0124*** (2.73E-3)</td>
<td>0.0129*** (2.28E-3)</td>
<td>0.0227*** (3.61E-3)</td>
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<tr>
<td>$\beta_{ek}$</td>
<td>0.007521 (9.47E-3)</td>
<td>-0.0129 (1.91E-2)</td>
<td>-0.01035 (1.29E-2)</td>
<td>-0.0160** (2.69E-3)</td>
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Table 3.3 Continued

<table>
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<tr>
<th>β</th>
<th>βll</th>
<th>βlk</th>
<th>βkk</th>
<th>δm</th>
<th>δe</th>
<th>δl</th>
<th>δk</th>
<th>R²</th>
<th>R²</th>
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<tr>
<td>θ</td>
<td>0.001345 (2.13E-3)</td>
<td>0.00322 (3.24E-3)</td>
<td>0.1477*** (5.15E-2)</td>
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<td>-2.13E-7** (9.21E-8)</td>
<td>-7.33E-9 (5.05E-9)</td>
<td>-5.42E-7*** (1.34E-7)</td>
<td>0.6979</td>
<td>0.3408</td>
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<td>0.0768 (7.18E-2)</td>
<td>-6.49E-7 (6.73E-7)</td>
<td>-2.78E-7* (1.31E-8)</td>
<td>-1.27E-8* (5.83E-9)</td>
<td>-1.13E-7 (1.60E-7)</td>
<td>0.4912</td>
<td>0.3769</td>
<td>0.5564</td>
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<td>0.1356*** (3.33E-2)</td>
<td>-1.15E-2*** (1.34E-7)</td>
<td>-1.43E-7*** (3.68E-8)</td>
<td>-5.88E-9*** (1.36E-9)</td>
<td>-6.39E-8 (4.04E-8)</td>
<td>0.6016</td>
<td>0.5927</td>
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<td>-1.98E-7 (5.83E-7)</td>
<td>-2.84E-7*** (8.38E-8)</td>
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<td>-2.15E-7** (8.92E-8)</td>
<td>0.3172</td>
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<td>0.5074</td>
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</table>

Notes: m denotes material, l denotes labor, k denotes capital, e denotes energy. * means significant at 10% level, ** means significant at 5% level and *** means significant at 1% level. The last four rows record Adjusted R-squared ($R_a^2$) for material, energy, labor and capital respectively for each year. Standard errors are given in parentheses.
Table 3.4: Input Demand Elasticity

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<td>(6.97E-2)</td>
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<td>-0.0327 (4.88E-2)</td>
<td>0.1531 (1.329E-1)</td>
<td>-0.2731*** (1.04E-1)</td>
</tr>
<tr>
<td></td>
<td>(4.55E-3)</td>
<td>(9.88E-3)</td>
<td>(1.14E-1)</td>
<td>(4.88E-2)</td>
<td>(1.329E-1)</td>
<td>(1.04E-1)</td>
</tr>
<tr>
<td></td>
<td>-0.0261***</td>
<td>-0.0370***</td>
<td>0.3636***</td>
<td>-0.0219 (2.73E-2)</td>
<td>-0.2898***</td>
<td>-0.0520***</td>
</tr>
<tr>
<td></td>
<td>(2.81E-3)</td>
<td>(9.88E-3)</td>
<td>(8.71E-2)</td>
<td>(2.73E-2)</td>
<td>(7.98E-2)</td>
<td>(1.75E-2)</td>
</tr>
<tr>
<td></td>
<td>-0.0089***</td>
<td>0.0383**</td>
<td>-0.0144 (2.41E-2)</td>
<td>-0.0337 (5.62E-2)</td>
<td>0.3352**</td>
<td>-0.2871**</td>
</tr>
<tr>
<td></td>
<td>(2.81E-3)</td>
<td>(1.59E-2)</td>
<td>(2.41E-2)</td>
<td>(5.62E-2)</td>
<td>(1.41E-1)</td>
<td>(1.21E-1)</td>
</tr>
</tbody>
</table>

Notes: m denotes material, l denotes labor, k denotes capital, e denotes energy. * means significant at 10% level, ** means significant at 5% level and *** means significant at 1% level. Standard errors are given in parentheses.
Table 3.5: Producer Surplus, 1992-2007

<table>
<thead>
<tr>
<th>Year</th>
<th>HHI</th>
<th>Top-4</th>
<th>Top-8</th>
<th>PS (million $)</th>
<th>% Change in PS</th>
<th>PS per Capita ($)</th>
<th>% Change in PS per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>0.0735</td>
<td>0.4424</td>
<td>0.6030</td>
<td>8712951.91</td>
<td>34.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>0.1193</td>
<td>0.5165</td>
<td>0.6753</td>
<td>11882140.44</td>
<td>36.37</td>
<td>44.37</td>
<td>29.88</td>
</tr>
<tr>
<td>2002</td>
<td>0.1347</td>
<td>0.5776</td>
<td>0.7347</td>
<td>12535087.60</td>
<td>5.50</td>
<td>43.55</td>
<td>-1.84</td>
</tr>
<tr>
<td>2007</td>
<td>0.1224</td>
<td>0.5852</td>
<td>0.7214</td>
<td>2050799.23</td>
<td>-83.64</td>
<td>6.80</td>
<td>-84.39</td>
</tr>
</tbody>
</table>

Using Plant-level input prices (all input prices change over time)

<table>
<thead>
<tr>
<th>Year</th>
<th>HHI</th>
<th>Top-4</th>
<th>Top-8</th>
<th>PS (million $)</th>
<th>% Change in PS</th>
<th>PS per Capita ($)</th>
<th>% Change in PS per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>0.0735</td>
<td>0.4424</td>
<td>0.6030</td>
<td>8761379.05</td>
<td>34.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>0.1193</td>
<td>0.5165</td>
<td>0.6753</td>
<td>12454896.29</td>
<td>42.16</td>
<td>46.51</td>
<td>35.39</td>
</tr>
<tr>
<td>2002</td>
<td>0.1347</td>
<td>0.5776</td>
<td>0.7347</td>
<td>13569721.20</td>
<td>8.95</td>
<td>47.15</td>
<td>1.37</td>
</tr>
<tr>
<td>2007</td>
<td>0.1224</td>
<td>0.5852</td>
<td>0.7214</td>
<td>2988339.94</td>
<td>-77.98</td>
<td>9.91</td>
<td>-78.98</td>
</tr>
</tbody>
</table>
Table 3.6: LA/AIDS Demand System Estimation Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\gamma_{bb})</td>
<td>0.0049*** (8.54E-4)</td>
</tr>
<tr>
<td>(\gamma_{bp})</td>
<td>0.0004 (5.66E-4)</td>
</tr>
<tr>
<td>(\gamma_{bc})</td>
<td>-0.0006 (4.85E-4)</td>
</tr>
<tr>
<td>(\gamma_{bo})</td>
<td>-0.0048*** (1.10E-3)</td>
</tr>
<tr>
<td>(\gamma_{pb})</td>
<td>0.0004 (5.66E-4)</td>
</tr>
<tr>
<td>(\gamma_{pp})</td>
<td>0.0044*** (8.22E-4)</td>
</tr>
<tr>
<td>(\gamma_{pc})</td>
<td>-0.0004 (5.07E-4)</td>
</tr>
<tr>
<td>(\gamma_{po})</td>
<td>-0.0047*** (9.97E-4)</td>
</tr>
<tr>
<td>(\gamma_{cb})</td>
<td>-0.0006 (4.85E-4)</td>
</tr>
<tr>
<td>(\gamma_{cp})</td>
<td>-0.0002 (5.07E-4)</td>
</tr>
<tr>
<td>(\gamma_{cc})</td>
<td>0.0045*** (6.02E-4)</td>
</tr>
<tr>
<td>(\gamma_{co})</td>
<td>-0.0038*** (8.67E-4)</td>
</tr>
<tr>
<td>(\beta_b)</td>
<td>-0.00026 (0.003.48E-3)</td>
</tr>
<tr>
<td>(\beta_p)</td>
<td>-0.00547** (0.002.57E-3)</td>
</tr>
<tr>
<td>(\beta_c)</td>
<td>0.000094 (0.002.28E-3)</td>
</tr>
<tr>
<td>(\beta_o)</td>
<td>0.005641 (0.005.44E-3)</td>
</tr>
</tbody>
</table>

\(R^2\) Beef: 0.8254
\(R^2\) Pork: 0.8760
\(R^2\) Broiler: 0.7282

Notes: b denotes beef, p denotes pork, c denotes chicken. * means significant at 10% and *** means significant at 1% level. Seasonal dummies are controlled in the model. Standard errors are given in parentheses.

Turkey is deleted from the demand system because own price elasticity of turkey is negative (because of seasonality), and deleting turkey from the demand system does not change the significance of broiler elasticities.
<table>
<thead>
<tr>
<th>Elasticities</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>e_{bb}</td>
<td>-0.4907*** (8.83E-2)</td>
</tr>
<tr>
<td>e_{bp}</td>
<td>0.0464 (5.86E-2)</td>
</tr>
<tr>
<td>e_{bc}</td>
<td>-0.0576 (5.02E-2)</td>
</tr>
<tr>
<td>e_{bo}</td>
<td>-0.4708 (3.72E-1)</td>
</tr>
<tr>
<td>e_{pb}</td>
<td>0.0889 (1.00E-1)</td>
</tr>
<tr>
<td>e_{pp}</td>
<td>-0.2207 (1.46E-1)</td>
</tr>
<tr>
<td>e_{pc}</td>
<td>-0.0222 (9.02E-2)</td>
</tr>
<tr>
<td>e_{po}</td>
<td>0.1262 (4.80E-1)</td>
</tr>
<tr>
<td>e_{cb}</td>
<td>-0.1092 (9.45E-2)</td>
</tr>
<tr>
<td>e_{cp}</td>
<td>-0.0300 (9.90E-2)</td>
</tr>
<tr>
<td>e_{cc}</td>
<td>-0.1127 (1.18E-1)</td>
</tr>
<tr>
<td>e_{co}</td>
<td>-0.7664 (4.64E-1)</td>
</tr>
<tr>
<td>e_{ob}</td>
<td>-0.0050*** (1.13E-3)</td>
</tr>
<tr>
<td>e_{op}</td>
<td>-0.0048*** (1.02E-3)</td>
</tr>
<tr>
<td>e_{oc}</td>
<td>-0.0039*** (8.86E-4)</td>
</tr>
<tr>
<td>e_{oo}</td>
<td>-0.9865*** (2.13E-3)</td>
</tr>
<tr>
<td>e_{b}</td>
<td>0.9727*** (3.60E-1)</td>
</tr>
<tr>
<td>e_{p}</td>
<td>0.0278 (4.57E-1)</td>
</tr>
<tr>
<td>e_{c}</td>
<td>1.0183** (4.46E-1)</td>
</tr>
<tr>
<td>e_{o}</td>
<td>1.0056*** (5.47E-3)</td>
</tr>
</tbody>
</table>

Notes: b denotes beef, p denotes pork, c denotes chicken. * means significant at 10% level, ** means significant at 5% level and *** means significant at 1% level. Standard errors are given in parentheses.
Table 3.8: Compensated Price Elasticities

<table>
<thead>
<tr>
<th>Elasticities</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_{bb}$</td>
<td>-0.4812*** (8.84E-2)</td>
</tr>
<tr>
<td>$e_{bp}$</td>
<td>0.0519 (5.85E-2)</td>
</tr>
<tr>
<td>$e_{bc}$</td>
<td>-0.0527 (5.01E-2)</td>
</tr>
<tr>
<td>$e_{bo}$</td>
<td>0.4820*** (1.142E-1)</td>
</tr>
<tr>
<td>$e_{pb}$</td>
<td>0.0891 (1.01E-1)</td>
</tr>
<tr>
<td>$e_{pp}$</td>
<td>-0.2205 (1.46E-1)</td>
</tr>
<tr>
<td>$e_{pc}$</td>
<td>-0.0220 (9.00E-2)</td>
</tr>
<tr>
<td>$e_{po}$</td>
<td>0.1534 (1.77E-1)</td>
</tr>
<tr>
<td>$e_{cb}$</td>
<td>-0.0994 (9.46E-2)</td>
</tr>
<tr>
<td>$e_{cp}$</td>
<td>-0.0242 (9.89E-2)</td>
</tr>
<tr>
<td>$e_{cc}$</td>
<td>-0.1075 (1.18E-1)</td>
</tr>
<tr>
<td>$e_{co}$</td>
<td>0.2311 (1.69E-1)</td>
</tr>
<tr>
<td>$e_{ob}$</td>
<td>0.0048*** (1.13E-3)</td>
</tr>
<tr>
<td>$e_{op}$</td>
<td>0.0009 (1.02E-3)</td>
</tr>
<tr>
<td>$e_{oc}$</td>
<td>0.0012 (8.85E-4)</td>
</tr>
<tr>
<td>$e_{oo}$</td>
<td>-0.0068*** (2.13E-3)</td>
</tr>
</tbody>
</table>

Notes: b denotes beef, p denotes pork, c denotes chicken. *** means significant at 1% level. Standard errors are given in parentheses.
Table 3.9: Extreme Prices, 1992-2007

<table>
<thead>
<tr>
<th>Year</th>
<th>$B_{ct}$ ($/lb)</th>
<th>$e^{\frac{A_{ct}}{B_{ct}}}$ ($/lb)</th>
<th>Broiler Price ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>13.35</td>
<td>2.16</td>
<td>1.09</td>
</tr>
<tr>
<td>1997</td>
<td>14.44</td>
<td>2.18</td>
<td>1.04</td>
</tr>
<tr>
<td>2002</td>
<td>16.31</td>
<td>2.20</td>
<td>1.01</td>
</tr>
<tr>
<td>2007</td>
<td>17.73</td>
<td>2.32</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table 3.10: Change in Consumer Surplus per Capita ($)

<table>
<thead>
<tr>
<th>Year</th>
<th>$\Delta CS_c^{2007}$</th>
<th>$\Delta CS_c^{1992}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992-1997</td>
<td>0.6454</td>
<td>0.7578</td>
</tr>
<tr>
<td>1997-2002</td>
<td>0.4152</td>
<td>0.4675</td>
</tr>
<tr>
<td>2002-2007</td>
<td>0.8585</td>
<td>1.0963</td>
</tr>
</tbody>
</table>
### Table 3.11: Compensating Variation ($)

<table>
<thead>
<tr>
<th>Year</th>
<th>( \beta_c \Delta \log p_c )</th>
<th>( e^{\beta_c \Delta \log p_c} - 1 )</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992-1997</td>
<td>-6.9123E-6</td>
<td>-6.9122E-6</td>
<td>4.64</td>
</tr>
<tr>
<td>1997-2002</td>
<td>-3.9393E-6</td>
<td>-3.9393E-6</td>
<td>3.03</td>
</tr>
<tr>
<td>2007-2007</td>
<td>-1.1441E-5</td>
<td>-1.1441E-5</td>
<td>9.21</td>
</tr>
</tbody>
</table>

### Table 3.12: Social Welfare Changes per Capita ($)

<table>
<thead>
<tr>
<th>Year</th>
<th>( \Delta PS_p )</th>
<th>( \Delta PS_{avg} )</th>
<th>( \Delta CS )</th>
<th>CV</th>
<th>( \Delta PS_p + \Delta CS ) + CV</th>
<th>( \Delta PS_{avg} + \Delta CS ) + CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>92-97</td>
<td>29.88</td>
<td>35.39</td>
<td>0.70</td>
<td>4.64</td>
<td>30.58</td>
<td>34.52</td>
</tr>
<tr>
<td>97-02</td>
<td>-1.84</td>
<td>1.37</td>
<td>0.44</td>
<td>3.03</td>
<td>-1.4</td>
<td>1.19</td>
</tr>
<tr>
<td>02-07</td>
<td>-84.39</td>
<td>-78.98</td>
<td>0.98</td>
<td>9.21</td>
<td>-83.41</td>
<td>-75.18</td>
</tr>
</tbody>
</table>

Notes: \( \Delta PS_p \) is change in producer surplus using plant-level output prices and allowing all input prices change over time, calculated from part one of Table 3.5; \( \Delta PS_{avg} \) is change in producer surplus using industry-level output prices by fix all other input prices except material calculated from part two of Table 3.5; \( \Delta CS \) is average of \( \Delta CS_{c}^{2007} \) and \( \Delta CS_{c}^{1992} \) from Table 3.10; CV is compensating variation from Table 3.11.
Figure 3.1: Demand Curve for Chicken when $B_{ct} < 0$
Figure 3.2: Demand Curve for Chicken when $B_{ct} > 0$
CHAPTER 4: THE EFFECTS OF PRODUCTIVITY AND DEMAND-SPECIFIC FACTORS ON PLANTS’ SURVIVAL AND OWNERSHIP CHANGE

4.1. Introduction

The importance of productivity on the within-industry reallocation (entry, exit, mergers) has received significant attention in both theoretical and empirical literature. Models describing industry dynamics/selection link firms’ productivity levels to their performance and survival. Low productivity firms are less likely to survive, whereas high productivity firms will increase their market share either through their own growth or the acquisitions of other firms.

In real life, the productivity-survival link is an over-simplification because what drives the within-industry selection is not the productivity per se but the profitability, where productivity is only one of the several factors that determines profits. Empirical research generally finds that plants with higher measured productivity levels tend to grow faster and are more likely to survive. The examples are found in Baily, Hulten and Campbell (1992) for the US manufacturing plants; Olley and Pakes (1996) for the U.S. telecommunication equipment industry; Dwyer (1995) for the U.S. textile industry; and Baldwin (1995) for the Canadian manufacturing sector. But most of the literature in this field relies on the so called traditional productivity measure (revenue divided by a common industry-level deflator as a measure of output). This may be acceptable, and even desirable, if product quality differences are fully reflected in prices. However, this can be problematic if other factors, such as demand-specific factors which vary across producers, are embodied in price

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34 Any opinions and conclusions expressed herein are those of the author(s) and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.
variations across producers. In this case, traditional productivity (revenue-based productivity) confounds both the effects of physical productivity and demand-specific factors on market selection.

To see how the usage of traditional productivity confounds the effects of physical productivity and demand-specific factors on market selection requires clarification of the relationship between traditional productivity, physical productivity and demand-specific factors. The traditional productivity measure uses revenue as a measure of output, while physical productivity uses real output (that is, the traditional productivity measure is a product of price and physical productivity). Price is positively correlated with demand-specific factors, because the stronger the consumers’ preference for the product, the higher the price that a producer can charge for the product. So in fact, higher traditional productivity does not necessary mean higher physical productivity; it could be a result of higher consumers’ preferences for the product or the entire host of other idiosyncratic factors influencing firm’s demand, all of which can increase the probability of the firm’s survival. So using traditional productivity to study the effect of productivity on market selection is flawed because it ignores the effects demand-specific factors. The theoretical framework part of this paper shows how demand-specific factors theoretically affect price.

The most closely related study to the current study is Foster, Haltiwanger and Syverson’s (2008) in which the authors observed plant-level production quantities and prices so they could measure “physical productivity” and plant level demand-specific factors separately.

Demand-specific factors denote the consumers’ preference of one product over another. Potential sources of demand-specific factors could be the transportation cost, market power and the long-run relationship between the wholesale producers and retailers (Foster, Haltiwanger and Syverson’s (2008)).
This allowed them to measure the effects of physical productivity and plant level demand-specific factors on plants’ probability of survival separately and hence compare the effect of “revenue-based productivity” and “physical productivity.” By using a sample of approximately 18,000 plant-level observations of producers of eleven homogenous products, they found that higher “revenue-based productivity” increases the probability of survival. And by separating “revenue-based productivity” into “physical productivity” and the plant-level demand-specific factors, they concluded that both physical productivity and plant level demand-specific factors increase the probability of survival, while the dominant factors determining survival are the plant level demand-specific factors. This means “revenue-based productivity” overstates the effects of productivity on survival; thus, it is important to separate “revenue-based productivity” into “physical productivity” and plant-level prices.

In the remainder of the paper, I rely on the methodology of Foster, Haltiwanger and Syverson (2008) to study the effects of productivity and demand-specific factor on plants survival in the U.S. poultry processing industry. The relationship between productivity, demand-specific factors and survival of poultry processing plants has not been studied before. However there are a couple of papers that explore plant-level dynamics in the meat packing industry. Anderson et al. (1998) use plant-level data of the US beef packing industry from 1991 to 1993 to study the effect of plant-level characteristics, market structure characteristics, and supply and demand shifters on the probability of plant exit. They find that the effects of plant and market structure characteristics are significant while the effects of supply and demand shifters are not. Muth et al. (2002) used plant-level data in the U.S. red meat slaughtering industry from the pre-HACCP period (1993 to 1996) and the
implementation period (1996 to 2000) and the plant’s age as a proxy for a plant’s productivity\textsuperscript{36}. They find that very young or very old plants have a higher probability of exit. They also find small plants, plants with small market share in a concentrated region, plants in regions with low rate of entry, and plants in regions with low wages are more likely to exit.

There are two reasons I chose to study the U.S. broiler industry. First, during the last two decades, the broiler industry has been very dynamic. The Herfindahl index (HHI) of the poultry processing industry increased from 735 to 1224 from 1992 to 2007 (calculated from Census Data). The industry's Top-4 concentration ratio increased from 44.24\% in 1992 to 58.52\% in 2007, and Top-8 concentration ratio increased from 60.30\% to 72.14\%.\textsuperscript{37} Based on the data in my sample (which will be discussed in detail below), there were 59 out of 471 US broiler processing plants that closed down and 53 of that were acquired by other firms. This provides a compelling reason to study the effects of productivity and demand-specific factors on plant survival. Second, the broiler industry is entirely vertically integrated, from breeding flocks and hatcheries to feed mills, transportation divisions and processing plants. The finishing stage of production is organized almost entirely through production contracts with independent growers. Hence, the failure of a poultry processing plant will not only harm

\textsuperscript{36} The assumption here is that new plants incorporate new technologies and hence are more productive than older plants. This is problematic because demand-specific factors are likely to positively correlate with a plant’s age. A very young plant may have high productivity while have low demand-specific factors. Conversely, a very old plant may have low productivity but high demand-specific factors. Overall, the plant is profitable or not depending on which factors dominate.

\textsuperscript{37} Top-4 and Top-8 is the top 4 firms’ market share and top 8 firms’ market share in the value of shipments with Census Data respectively.
the employees and owners of the plant, but also their contract growers who might not be able to obtain another contract.38

In addition to studying the effects of physical productivity and demand-specific factors on plant survival, I also study the effects of physical productivity and demand-specific factors on ownership change. Most previous studies treat acquired plants as exits from the industry. I make a distinction between the plants that are acquired by other firms from plants that truly exited the industry for the following two reasons. First, there are ample reasons why plants that have completely exited the industry could be fundamentally different from plants that have been acquired by other firms in the sense that the acquired plants need to have been good enough to have attracted other buyers. Second, the effect of exit in terms of selling the plant (that is, in terms of ownership change) is not the same as completely closing down the plant. The compensation the owner of the plants gets is normally higher when the plant is sold instead of liquidated; existing employees could be employed by the new owner; and the contract growers still have an opportunity to renew the production with new owner.

Finally, given the fact that the poultry industry’s volume of production has almost doubled during the studied period, I also analyze the firm-level expansion. I define the expanding firms as those that either opened new plants or acquired plants from other firms. I study the effects of physical productivity and demand-specific factors on the probability of the firms’ expansion.

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38 Live broilers can only ship relatively short distances (approximately 60 miles or two hours by truck) from a farm to a processing plant, so many processing plants (integrators) tend to have some degree of monopsony power. The effects of plant closures on contract growers’ welfare are not addressed in this study but are left as a subject of future research.
The results show that higher demand-specific factors will decrease the probability of exit, increase the probability of ownership change, and increase the probability of survival. The effect of physical productivity on the probability of exit or ownership change is generally insignificant. The results also show that firms with higher demand-specific factors have higher probability to expand their businesses.

4.2. Theoretical Framework

Productivity is commonly defined as the efficiency with which producers convert resources into output. The importance of productivity on the within-industry reallocation (entry, exit, mergers) has received significant attention in the industrial organization literature. Generally speaking, the literature shows that low productivity firms are less likely to survive, while high productivity firms will increase their market share either through their own growth or the acquisitions of other firms.

The starting point of the theoretical literature on the linkages between producers’ productivity levels and their performance and survival is Jovanovic (1982). In this paper, Jovanovic developed a passive learning model with unknown but time-invariant productivity in a perfectly competitive market. Each firm gradually learns its productivity (efficiency) over time. Firms that find themselves efficient will survive; firms who find themselves inefficient will exit. In contrast, Ericson and Pakes (1989) develop an active learning model with stochastic efficiency. In this model, a firm could actively invest in research and development to improve its efficiency, but the outcome of the investment is random. Firms that receive a series of negative shocks (not efficient) will drop out of the industry. Instead of a learning approach, Lambson (1991) considers another model where firms have common
shocks to input prices, and they can choose by themselves the available technologies. The efficiency of the technology depends on the prevailing market conditions, and firms with higher efficiency are more likely to survive. He also finds that firm turnover decreases with higher sunk cost.

Similarly, Hopenhayn (1992) developed a stochastic dynamic model in a perfectly competitive industry. In the stationary equilibrium of his model, entry and exit rates are equal, and so are the job creation and destruction. The main prediction of his model is similar with Lambson (1991); that is, firm turnover is negatively related to entry cost. Several other papers follow in the footsteps of Hopenhayn’s (1992) stochastic dynamic model, (Asplund and Nocke, 2006; Bergin and Bernhardt, 1996; Hopenhayn and Rogerson, 1993; Melitz, 2003).

The above models make perfect sense if productivity can be measured precisely. But normally plant-level data on physical quantity of output is not available. Instead, plant-level revenue is typically recorded. Therefore, when constructing productivity, researchers usually use deflated revenue as the measure of output quantity (traditional productivity or revenue-based productivity). As mentioned above, using revenue-based productivity could be problematic if demand-specific factors are embodied in price variation across producers. In this case, traditional productivity (or revenue-base productivity) confounds both the effects of physical productivity and demand-specific factors on market selection.

The problems associated with the measure of traditional productivity have been noticed in the literature before. Abbott (1992) documents the extent of price dispersion within various industries and outlines possible implications for the measurement of aggregates.
Klette and Griliches (1996) and Mairesse and Jaumandreu (2005) consider how intra-industry price fluctuations can affect production functions and productivity estimates. Katayama, Lu and Tybout (2003) demonstrate that revenue-based output and expenditure-based input measures can lead to productivity measurement error and incorrect interpretations about how heterogeneous producers respond to shocks and associated welfare implications.

The theoretical foundation for the current study’s empirical approach is found in Foster, Haltiwanger and Syverson (2008). Their paper shows how idiosyncratic technology and demand-specific factors can jointly determine producers’ long-run survival prospects in industry equilibrium. In their model, consumers maximize utility by choosing over different varieties of products within the industry. Firms in the industry choose the output price given firm-specific demand curve, input price and technology to maximize profit. Outsiders choose whether to pay the entry cost to take a draw of a combination of firm-specific demand, input prices and technology. After receiving a draw, they will decide whether to enter the industry or not depending on the value of the combination of firm-specific demand, input prices and technology. We illustrate their model with a simple example:

In order to obtain a firm-specific demand function, we start with the utility function of a representative individual:

\[
U = y + \sum_{i=1}^{N} (\alpha + \mu_i) q_i - 0.5\beta (\sum_{i=1}^{N} q_i)^2 - 0.5\epsilon \sum_{i=1}^{N} q_i^2,
\]

where \(N\) is the number of producers in the industry; \(y\) is the quantity of a numeraire good; \(\mu_i\) is demand-specific factor which represents the consumer’s preference for good \(i\) which could
be positive or negative; \( q \) is the quantity of good \( i \); \( \alpha > 0, \beta > 0, \epsilon > 0 \). The utility function could be expressed in another way:

\[
U = y + \alpha \sum_{i=1}^{N} q_i - 0.5(\beta + \frac{\epsilon}{N})(\sum_{i=1}^{N} q_i)^2 + \sum_{i=1}^{N} \mu_i q_i - 0.5\epsilon \sum_{i=1}^{N} (q_i - \bar{q})^2.
\]

(2)

This equation is obtained by adding and subtracting the original utility function by \( 0.5\epsilon N\bar{q}^2 \), where \( \bar{q} = \frac{1}{N} \sum_{i=1}^{N} q_i \). In fact, the first two terms of the utility function above are the quadratic form of total consumption of the industry output. \( \sum_{i=1}^{N} \mu_i q_i \) is a term capturing idiosyncratic tastes for particular varieties. The last term \( 0.5\epsilon \sum_{i=1}^{N} (q_i - \bar{q})^2 \) gives consumer incentive to consume equally amount of each \( q_i \). The higher the \( \epsilon \) is, the less likely that consumers could substitute goods from within the industry with each other. The representative consumer maximizes utility by choosing \( y \) and \( q_i \)'s subject to the budget constraint:

\[
I = y + \sum_{i=1}^{N} p_i q_i,
\]

(3)  
where \( I \) represents income. If we use the above utility function and the budget constraint, we can construct the Lagrange equation as:

\[
L = y + \sum_{i=1}^{N} (\alpha + \mu_i)q_i - 0.5\beta(\sum_{i=1}^{N} q_i)^2 - 0.5\epsilon \sum_{i=1}^{N} q_i^2 + \lambda(I - y - \sum_{i=1}^{N} p_i q_i)
\]

(4)

The first order conditions for the maximization problem are:

(5.a) \( \frac{\partial L}{\partial y} = 1 - \lambda = 0 \),

(5.b) \( \frac{\partial L}{\partial q_i} = \alpha + \mu_i - \beta \sum_{i=1}^{N} q_i - \epsilon q_i - \lambda p_i = 0 \) for all \( i \),

(5.c) \( \frac{\partial L}{\partial \lambda} = I - y - \sum_{i=1}^{N} p_i q_i = 0 \).
By substituting $\lambda=1$ (from (5.a)) into (5.b), we obtain:

$$\beta \sum_{i=1}^{N} q_i + \varepsilon q_i = \alpha + \mu_i - p_i \text{ for all } i.$$  

By solving the equation system above, we obtain the demand curve for product $i$:

$$q_i = \frac{1}{N \beta + \varepsilon} \alpha - \frac{1}{N \beta + \varepsilon} \overline{\mu} + \frac{1}{N \beta + \varepsilon} \overline{p} + \frac{1}{\varepsilon} \mu_i - \frac{1}{\varepsilon} p_i,$$

where $\overline{\mu}$ is the mean of $\mu_i$; $\overline{p}$ is the industry price mean which equals to $\frac{1}{N} \sum_{i=1}^{N} p_i$. The demand curve (7) is the firm-specific demand of firm $i$. It shows that higher demand-specific factors for good $i$ (higher $\mu_i$) means higher demand. This demand curve will be later used to solve the profit maximization problem for producers.

The producers already participating in the industry choose $p_i$’s in order to maximize profit given demand curves, technology and input prices. For simplicity, we assume that firms have a simple firm-specific production function:

$$q_i = \tau_i x,$$

where $\tau_i$ represents technology or productivity, $x$ is the quantity of inputs. We also assume that each firm has firm-specific input prices $w_i$, which leads to the firm’s cost function:

$$C_i(q_i) = \frac{w_i}{\tau_i} q_i.$$

With these assumptions, producers’ profit function becomes:

$$\pi_i = \left( \frac{1}{N \beta + \varepsilon} \alpha - \frac{1}{N \beta + \varepsilon} \overline{\mu} + \frac{1}{N \beta + \varepsilon} \overline{p} + \frac{1}{\varepsilon} \mu_i - \frac{1}{\varepsilon} p_i \right) \left( p_i - \frac{w_i}{\tau_i} \right).$$

Firms in the industry choose $p_i$ to maximize profit. Each producer takes the industry price mean as given, because when $N$ is large, the individual firm’s price does not affect the
industry’s price mean. By taking the partial derivative of equation (10) with respect to $p_i$, and solving the first order condition, we obtain the optimal price of producer $i$:

$$\tag{11} p_i = \frac{1}{2N\beta+\varepsilon}\alpha - \frac{1}{2N\beta+\varepsilon}\bar{\mu} + \frac{N\beta}{2N\beta+\varepsilon}\bar{p} + \frac{1}{2}\mu_i + \frac{1}{2}\bar{\tau}_i.$$

Substituting equation (11) back into equation (10), we get the maximized profit function:

$$\tag{12} \pi_i = \frac{1}{4\varepsilon}\left(\frac{\varepsilon}{N\beta+\varepsilon}\alpha - \frac{N\beta}{N\beta+\varepsilon}\bar{\mu} + \frac{N\beta}{N\beta+\varepsilon}\bar{p} + \mu_i - \frac{\bar{w}_i}{\bar{\tau}_i}\right)^2.$$

Substituting optimal price function (11) back into the demand function (6), we get the equilibrium quantity of good $i$:

$$\tag{13} q_i = \frac{1}{2N\beta+\varepsilon}\alpha - \frac{1}{2N\beta+\varepsilon}\bar{\mu} + \frac{N\beta}{2N\beta+\varepsilon}\bar{p} + \frac{1}{2}\mu_i - \frac{1}{2}\bar{w}_i.$$

Equation (11) shows that the optimal price charged by producer $i$ is positively related to demand-specific factors and input price, and it is negatively related to technology-specific factors. Equilibrium quantity of good $i$ (equation (13)) is positively related to demand-specific factors and technology-specific factors, but negatively related to input price. These results are intuitive, because the more the representative consumer prefers the product, the higher the price the producer could charge, and the higher the equilibrium quantity. Higher input price and lower productivity will increase the marginal cost of the variety, which will induce the producer to increase the price to recover the cost and hence decrease the equilibrium quantity (supply curve shifts up).

With $\rho_i = \mu_i - \frac{\bar{w}_i}{\bar{\tau}_i}$ and $\rho^* = -\frac{\varepsilon}{N\beta+\varepsilon}\alpha + \frac{N\beta}{N\beta+\varepsilon}\bar{\mu} - \frac{N\beta}{N\beta+\varepsilon}\bar{p}$, the maximized profit function (12) can be rewritten as:

$$\tag{14} \pi_i = \frac{1}{4\varepsilon}(\rho_i - \rho^*)^2.$$
Equation (14) implies that in order to be profitable, $\rho_i$ has to be bigger than $\rho^*$. In other words, $\rho_i$, the “profitability-index” and $\rho^*$ is the threshold for producers to survive in the industry.

The potential entrants choose whether to pay the entry cost $s$ in order to take the chance to draw a combination of demand-specific factors, input price and technology-specific factors from a given distribution $f(\mu, \tau, w)$, where $\mu \in [\mu_l, \mu_u], \tau \in [\tau_l, \tau_u], w \in [w_l, w_u]$. If they choose to enter, they will get their combination of demand-specific factors, input price and technology-specific factors. Only when $\rho_i > \rho^*$, will the entrant choose to produce. If the entrant chooses to produce, $\rho^*$ will be modified because $\bar{\mu}$ and $\bar{p}$ will be changed as a result of new producers in the industry. These processes will continue until the expected value of entry in the industry is zero; that is, the equilibrium $\rho^*_e$ has to satisfy:

$$ EV = \int_{\tau_l}^{\tau_u} \int_{\rho_{l}^e+w/\tau}^{\rho_{u}^e+w/\tau} (\mu - \rho_i)^2 f(\mu, \tau, w) d\mu \ d\tau \ dw - s = 0 $$

In order to achieve the static equilibrium, there should be no entry and exit, so it has to be the case where $\rho^* = \rho^*_e$ (no entry) and $\rho_i \geq \rho^*$ for all $i$ (no exit). Thus, the profitability threshold $\rho^*_e$ is determined by the distribution of demand specific factors, technology and input price. Each producer’s $\rho_i$ has to be bigger than $\rho^*_e$ in order to survive in the industry.

In conclusion, the results show: (a) equilibrium price is negatively related to productivity and positively related to demand-specific factors and input prices; (b) firms with higher

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39 If $\rho_i$ has to be smaller than $\rho^*$, equation (13) implies output quantity is negative: $q_i = \frac{1}{2e \frac{N\beta}{\beta + e}} \bar{\alpha} - \frac{1}{2e \frac{N\beta}{\beta + e} \bar{\mu}} + \frac{1}{2e N\beta + e} \bar{p} + \frac{1}{2e} \mu_i - \frac{1}{2e} \tau_i = \frac{1}{2e} (\rho_i - \rho^*) < 0$. 

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demand-specific factors, higher productivity and lower input prices are more likely to survive.

4.3. Data and Measurement Issues

The data for this study comes from the Census of Manufactures (CM) conducted by U.S. Census Bureau every year ending in “2” and “7”. I selected years 1987, 1992, 1997, and 2002. The CM collects information on plants’ annual value of shipments and total volume of shipments when feasible (for chicken processing plants it is the total quantity of shipments in thousands of pounds). This allows us to compute plant-level prices and hence physical productivities.

Poultry processing plants are identified as NAICS codes 311615 (from 2002) or SIC codes 201500 (1997 and before). This categorization encompasses approximately 500 plants in each of the four census years. The output type for large poultry processing plants includes young chickens (3116151); processed poultry and small game products containing 20% or more poultry or meat (excluding soups) (311615D); turkeys (3116157); hens and foul (3116154); and other poultry and small game (311615A). The output type for small poultry processing plants is combined together (311615W). Because this study focuses only on broiler processing plants, I only kept plants that obtain at least 90 percent of their revenue from this study’s product of interest (see Section 4.3.1). This criterion results in approximately 170 plants each census year. The rest of the plants are of the following types: about 170 plants produce processed poultry and small game products containing 20% or

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40 Large plants have more than 250 employees, while small plants have less than 250 employees.
more poultry meat; about 60 plants process turkey; about 100 plants are small and their outputs are combined.

The exclusion of small plants from our sample could raise some concerns, but the inclusion of these plants is neither feasible nor necessary. It is not feasible to include these small plants because their outputs are aggregated; hence, there is no quantity data for individual plants. Additionally, it is not necessary to include these small plants because the small plants only account for a small portion of the total value of shipments for the industry as a whole (about 0.25% in 2002). Finally, I delete those plants that do not record live broilers as material input separately (they are reported together with other materials) (see Section 3.1). The final sample size in the current study is 110 plants in each census year on average.

Based on the observed patterns of the change in ownership, plants can be classified into three groups. Because we can only observe census years’ data for all plants, the time interval is always 5 years. The first group is comprised of plants that exited the industry. A plant is defined as exiting plant at year \( t \) if a plant was closed or stopped processing broilers between year \( t - 4 \) and \( t \) (including \( t \)). The second group consists of surviving plants. A plant is defined as a surviving plant at year \( t \) if it continued to operate under the same ownership between year \( t - 4 \) and \( t \) (including \( t \)). Finally, the third group consists of plants whose ownership changed because of mergers and acquisitions. A plant is defined as an acquired plant at year \( t \) if it changed its ownership because it was acquired by another owner between year \( t - 4 \) and \( t \) (including \( t \)) and continued processing broilers.
4.3.1. Measuring Productivity

Following Foster, Haltiwanger and Syverson’s (2008) model, physical productivity can be computed as follows:

\[
\text{tf}_{lt} = y_{lt} - \alpha_l x_{l,lt} - \alpha_k x_{k,lt} - \alpha_m x_{m,lt} - \alpha_e x_{e,lt},
\]

where the lower-case letters denote natural logarithms of establishment-level total factor productivity (TFP), physical output, labor hours, capital stock, materials and energy inputs; \(\alpha_l, \alpha_k, \alpha_m, \) and \(\alpha_e\) are the corresponding elasticities. Physical output consists of *processed chickens*, defined as 10-digit census product code: wet ice pack broilers and fryers (3116151111); dry ice pack broilers and fryers (3116151221); tray pack broilers and fryers (3116151331); other broilers and fryers (3116151441); roasters and capons (3116151551). The physical output is measured in thousands of pounds.

There are four inputs in broiler production: materials, labor, energy and capital. Input quantities \((x_{lt}s)\) and prices \((w_{lt}s)\) are constructed as follows: Materials, \(x_{m,lt}\), is measured as the total quantity of live broilers (in thousands of pounds) used in production (census material code 112320015: young chickens). The price of the materials (in nominal dollars per pound), \(w_{m,lt}\), was computed by dividing the expenditure on materials (in thousands of dollars) (including expenditure on live broilers, boxes and other packaging materials) by \(x_{m,lt}\). The labor price (in nominal dollars per hour), \(w_{l,lt}\), was calculated by dividing the expenditure on production workers (in thousands of dollars) (which includes annual payroll and fringe benefits for both leased and non-leased workers) by the total production workers’ production hours. The labor quantity (in thousands of hours), \(x_{l,lt}\), was computed by dividing
the sum of the expenditure on production workers and non-production workers (in thousands of dollars) by \( w_{t,lt} \). The implicit assumption here is that production workers and non-production workers have the same average wage rate.\(^{41}\) The energy price (in nominal dollars per kilowatt), \( w_{e,lt} \), was calculated by dividing the expenditure on electricity (in thousands of dollars) by the quantity of electricity used (in kilowatts). The energy quantity (in thousands of kilowatts), \( x_{e,lt} \), was computed by dividing the sum of the expenditure on electricity and fuel (in thousands of dollars) by \( w_{e,lt} \). The implicit assumption here is that the electricity price and the fuel price are the same when electricity and fuel are converted into the same units.\(^{42}\) Finally, prices for material, labor and energy were then deflated by CPI (2005=100).

The calculation of the rental price of capital and the quantity of capital is rather complicated\(^{43}\). The 3-digit industry level (in this case NAICS=311; Food, Beverage and Tobacco Products) rental price, \( w_{k,t} \), could be obtained by industry level capital income (\( KY_t \), in nominal billions of dollars) divided by the 3-digit industry level capital input (in nominal billions of dollars). \( KY_t \) is directly available from multifactor productivity data published by the Bureau of Labor Statistics (BLS).\(^{44}\) Capital input is not directly available, but could be constructed from productivity capital (\( PK_t \), in deflated billions of dollars); capital composition (\( KC_t \), a ratio, unit free); and price index of investment (\( PIINV \)), where \( PK_t \) and \( KC_t \) are directly available from the same table of BLS, and price index of

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\(^{41}\) This assumption is necessary as the Census data does not report the total hours for non-production workers. An alternative assumption could be assume the wages for non-production workers are 150% of those for production workers (Kehrig (2011) A.3)

\(^{42}\) This assumption is necessary as the Census data does not report the quantity of fuel used.

\(^{43}\) The method used here is based on Kehrig (2011) with some modifications.

investment is available from NBER\textsuperscript{45}. $PK_t$ is the deflated aggregate industry level productivity capital. $KC_t$ is the ratio of capital input in 2005 dollars to productivity capital in 2005 dollars. $PK_t \times KC_t / 100$ gives the capital input in 2005 dollars, which, when multiplied by the corresponding $PIINV$, gives the capital input in nominal dollars. For example, for 1992, it becomes $\frac{PK_t \times KC_t + PIINV92}{100}$. Finally, the industry level rental price\textsuperscript{46} is obtained as:

\begin{equation}
(17) \quad w_{k,t} = \frac{KY_t}{PK_t \times \frac{KC_t + PIINV92}{100}}.
\end{equation}

The quantity of capital (in thousands of nominal dollars), $x_{k,lt}$ consists of two parts: assets owned by the plant, and assets rented from others. Assets owned by the plant can be measured as total asset at the beginning of the year ($TAB_{lt}$, in thousands of nominal dollars). Because $TAB_{lt}$ is the book value (the historical cost of the capital minus the aggregate depreciation), it is multiplied by $\frac{NKC_t}{GKH_t}$ to transform $TAB_{lt}$ into market value (i.e., how much the firm would get if it sells the capital in the market), where $NKC_t$ is the NAICS=311 industry level net capital stock in nominal dollars (1992 for example), and $GKH_t$ is the NAICS=311 industry level gross capital stock in book values, both available from the capital stock data published by the Bureau of Economic Analysis (BEA).\textsuperscript{47} Assets rented from others can be measured as total rental payment ($TR_{lt}$), directly from Census of Manufacturers (in thousands of nominal dollars) divided by the rental price $w_{k,t}$. These two parts are then summed together to obtain the quantity of capital stock. Equation (18) illustrates the construction of nominal capital quantity more clearly:

\textsuperscript{45} The deflator is from the NBER productivity database: \url{http://www.nber.org/nberces/}.
\textsuperscript{46} Although we call it “price,” it is just a ratio of rental expenditure to market value of the capital.
\textsuperscript{47} Table 3.1ES and Table 3.3ES from \url{http://www.bea.gov/national/FA2004/SelectTable.asp}
The capital quantity in (18) is in nominal dollars and can be used with the rental price as calculated above to obtain the capital expenditure. In order to obtain the real capital quantity, which will be subsequently used in the productivity calculation, the market value is then deflated to the 4-digit SIC industry-level (in this case, SIC=2015, poultry processing industry) investment price index ($PIINV$) from NBER, to get the deflated dollar value of capital quantity:

\[
x_{k, it, real} = \frac{TAB_{it} * \left(\frac{NKCl}{GKHt}\right) + \frac{TR_{it}}{w_{kt}}}{PIINV_{92}}.
\]

Industry-level cost shares are used to measure input elasticities $\alpha_j$. The implicit assumption behind this is constant returns to the scale. Under this assumption, input elasticities are equal to the corresponding input expenditure shares\(^4^8\). Expenditures for materials, energy and labor are calculated by nominal prices times their corresponding quantities. Capital expenditure is calculated as the product of rental price and nominal capital quantity. Industry-level cost shares $\alpha_j$ can be obtained by dividing nominal expenditure on input $j$ in the industry to total nominal input cost.

\(^{48}\) Production: \(Q = L^\alpha K^\beta\), where \(Q\) is output quantity; \(L\) is labor quantity; \(K\) is capital quantity; \(\alpha\) is input elasticity for labor; \(\beta\) is input elasticity for capital. In production function with constant returns to the scale, \(\alpha + \beta = 1\). Minimize \(C = w_L L + w_K K\), subject to \(Q = L^\alpha K^\beta\), where \(w_L\) is wage for labor; \(w_K\) is rental price for capital. And it can be shown that with optimal labor \(L^* = Q\left(\frac{w_L}{1-\alpha w_K}\right)^{\alpha}\) and capital \(K^* = Q\left(\frac{w_K}{1-\alpha w_L}\right)^{\beta - 1}\),

\[
\frac{w_L L^*}{w_K K^*} = \frac{\alpha}{1-\alpha}.
\]

This implies \(\alpha = \frac{w_L L^*}{w_L L^* + w_K K^*}\) and \(1 - \alpha = \frac{w_K K^*}{w_L L^* + w_K K^*}\).
4.3.2. Measuring Demand-Specific Factors

Of course, demand-specific factors for each plant are unobservable and need to be estimated. We use the following specification for the demand function:

\[ \ln y_{fit} = \alpha_0 + \alpha_1 \ln p_{fit} + \sum_i \beta_i Year_t + \sum_f \gamma_f Firm_f + \mu_{fit}, \]

where \( y_{fit} \) is the physical output of plant \( i \) in firm \( f \) in year \( t \); \( p_{fit} \) is the plant level output price\(^{49} \); \( Year_t \) are yearly dummies; and \( Firm_f \) are firm dummies (we only include firm dummy for firms who have more than 4 plants in our four year sample). Year dummies are included in the regression to account for yearly shock in demand. Firm dummies are included in the regression to account for the firm demand difference. Because plant level price is correlated with the demand-specific factors (see equation (11)), we need to use instrumental variables. Convenient instruments are total factor productivity (TFP) and input prices. Based on the theoretical model, TFP is negatively correlated with output price, input prices are positively correlated with output price (see equation (11)), but neither of them is correlated with the error term \( \mu_{fit} \). So, to estimate demand function (7) we use 2SLS with TFP and raw material prices (that is, deflated \( w_{m,lt} \) discussed in section 3.1) as instruments. Wages and energy price are not used because they are not highly correlated with chicken meat price. The price of capital is not used because it is only observed at the industry level, which makes it perfectly collinear with the time dummy. After estimating the demand equation, the term \( \sum_f \gamma_f Firm_f + \mu_{fit} \) becomes our measure of demand-specific factors for plant \( i \) in firm \( f \) in year \( t \).

\(^{49}\) Plant-level output price is computed as the plant-level value of shipments divided by the plant-level output quantity.
4.4. Estimation Models

In order to study the determinants of survival and ownership change, we explore the roles of physical productivity and demand-specific factors. The approach is based on estimating the simple probit and logit models and the multinomial logistic model.

In simple probit and logit models, dependent variable \( y_{it} \) is a binary variable (\( y_{it} \) can only take value of 0 or 1). \( y_{it}^* \) is the index variable, which is a linear function of independent variables. There are two models in our study: survival model and ownership change model. In the survival model, the dependent variable \( y_{it} = 1 \) if the plant is in the first group (exit); otherwise, \( y_{it} = 0 \). In the ownership change model, the dependent variable \( y_{it} = 1 \) if the plant is in the third group (acquired); otherwise \( y_{it} = 0 \). Both the survival model and the ownership change model have the same structure specified in equations (21) and (22) where the independent variables \( (X_{it-5}) \) are year dummies, physical productivity and demand-specific factors with or without control for the capital stock. The purpose of including the capital stock in the specification is to separately measure the short- and long-run components of plant survival.\(^{50}\)

\[
(21) \quad y_{it}^* = X_{it-5} \beta + \epsilon_{it},
\]

\[
(22) \quad y_{it} = \begin{cases} 
0 & \text{if } y_{it}^* < 0 \\
1 & \text{if } y_{it}^* > 0 
\end{cases}.
\]

In the simple probit model, the error term \( \epsilon_{it} \) follows the standard normal distribution, while in the simple logistic model, \( \epsilon_{it} \) follows the logistic distribution. \( \beta \) is vector of

\(^{50}\) According to Ollegy and Pakes (1996), a plant’s capital stock reflects persistent components of survival.
parameters that need to be estimated. Let $\beta_j$ and $X_{it - 5j}$ are the $j$ th element of $\beta$ and $X_{it - 5}$ respectively. A positive (negative) $\beta_j$ means $X_{it - 5j}$ will increase (decrease) the probability of $y_{it} = 1$. For simple probit model, $P(y_{it} = 1) = \Phi(X_{it - 5}\beta)$, and the marginal effect of $X_{it - 5j}$ on $P(y_{it} = 1)$ is $\Phi(X_{it - 5}\beta)\beta_j$. $\phi(.)$ is the probability density function of normal distribution.

For simple logit model, $P(y_{it} = 1) = \frac{e^{x_{it - 5}\beta}}{1 + e^{x_{it - 5}\beta}}$, and the marginal effect of $X_{it - 5j}$ on $P(y_{it} = 1)$ is $\frac{e^{x_{it - 5}\beta}}{(1 + e^{x_{it - 5}\beta})^2} \beta_j$.

In the multinomial logistic model, dependent variable $y_{it}$ is nominal ($y_{it}$ can be 0, 1, 2 ..., but the order of $y_{it}$ does not matter). The advantages of the multinomial logistic model are that the probabilities for dependent variable of taking each value are positive without further restrictions and that the dependent variable need not to be ordered. The probability of $y_{it}$ taking the value of $m$ can be expressed as follows:

\begin{align*}
(23) & \quad P(y_{it} = 1) = \frac{1}{1 + \sum_{r=2}^{M} \exp(x_{it - 5}\beta_r)}, \\
(24) & \quad P(y_{it} = m) = \frac{\exp(x_{it - 5}\beta_m)}{1 + \sum_{r=2}^{M} \exp(x_{it - 5}\beta_r)}, \text{ for } m = 2, 3, \ldots,
\end{align*}

where $\beta_r$ is a vector of parameters to be estimated for $r = 2$ to $M$. In this study, I will let $y_{it} = 1$ if plant $i$ belongs to the first group at year $t$, $y_{it} = 2$ if plant $i$ belongs to the second group at year $t$, $y_{it} = 3$ if plant $i$ belongs to third group at year $t$. The marginal effects could be obtained by the following formulas:

\begin{align*}
(25) & \quad \frac{\partial P(y_{it} = 1)}{\partial x_{it - 5j}} = -\frac{\sum_{r=2}^{M} \exp(x_{it - 5}\beta_r)\beta_{rj}}{(1 + \sum_{r=2}^{M} \exp(x_{it - 5}\beta_r))^2}, \\
(26) & \quad \frac{\partial P(y_{it} = m)}{\partial x_{it - 5j}} = \frac{\exp(x_{it - 5}\beta_m)\beta_{mj}}{1 + \sum_{r=2}^{M} \exp(x_{it - 5}\beta_r)} - \exp(x_{it - 5}\beta_m) \frac{\sum_{r=2}^{M} \exp(x_{it - 5}\beta_r)\beta_{rj}}{(1 + \sum_{r=2}^{M} \exp(x_{it - 5}\beta_r))^2}
\end{align*}
4.5. Results

The summary statistics for the variables used to calculate physical productivity and demand-specific factors are listed in Table 4.1. The physical productivity for each plant was calculated based on expression (16). The summary statistics are provided in the left panel of Table 4.2.

From Table 4.2, it can be seen that plants in the survival group have the lowest average physical productivity, whereas the productivities of plants in the exit and acquired group are higher. The reason the exit and acquired groups have higher average productivities is that a large portion of plants in these groups are from the most recent period (2002 to 2007 period). Because productivity grows over time, including large portion of recent years’ plants in the group tends to increase the means of the group. So including year dummies in the selection models could address this issue.

Next, the demand function is estimated in equation (20) to obtain the demand-specific factors for each plant. As mentioned above, the productivity and the price of intermediate materials (live chickens) are used as the instrumental variables for the chicken price. In order to check whether these variables are good instruments, the weak IV test\(^{51}\) and the over-identification test\(^{52}\) are performed. The estimation results are shown in Table 4.3. The over-

---

\(^{51}\) In order to evaluate the correlation between instrumental variables and exogenous variables, we run a regression of the endogenous variable on instrumental variables and other exogenous variables and test the significance of the instrumental variables with F test. The null hypothesis is that the instrumental variables are not correlated with the endogenous variable. The alternative hypothesis is that instrumental variables are correlated with the endogenous variable. A significant test statistic indicates a good instrumental variable.

\(^{52}\) We use Basmann’s test for overidentification test. The null hypothesis is that the instrumental variables have zero correlations with error terms. The alternative hypothesis is that at least one of the assumed zero coefficients is nonzero. Formula for Basmann’s test is: 

\[
B_l = \frac{\hat{\sigma}^2(z'z)^{-1}z'\hat{\Omega}/(l-k)}{\hat{\sigma}^2(l-z(z'z)^{-1}z')/\left((n-l)\right)}
\]

where \(N\) is total number of observations; \(L\) is number of instrumental variables; \(K\) is number of right-hand side (RHS) endogenous variables; \(\hat{\Omega}\) is \(N \times 1\)
identification test and weak IV test show that productivity and the price of materials are highly correlated with chicken price, but are not correlated with the error term in the demand equation (20). This implies we can use productivity and the price of materials as instruments for chicken meat price.

Using estimated coefficients, demand-specific factors for each plant in the sample were calculated. The summary statistics are presented in the right panel of Table 4.2. From Table 4.2, it can be seen that the group of acquired plants has the highest average demand-specific factors, and the group of exit plants has the lowest average demand-specific factors. This means that plants with lower demand-specific factors are less likely to survive or be acquired. Plants with higher demand-specific factors are more likely to become target of mergers and/or acquisitions.

**4.5.1 Plant-Level Analysis**

The obtained estimates of productivities and demand specific factors are used to estimate the probability models. The parameter and marginal effects are estimated with the method mentioned above. The standard error for the parameter estimates and marginal effects are estimated using bootstrapping\(^{53}\).

\(^{53}\)Our original data consist of 471 plants coming from 4 years. Each bootstrap sample is obtained by sampling the original dataset with replacement by year. For each bootstrap sample, I estimate the demand curve and then estimate the probit, logit and multinomial models and then calculate marginal effects (4.3.2 and 4.4). This process is repeated 1,000 times. By doing this, I get 1000 estimates for each parameter and each marginal effects, standard errors for these parameters and marginal effects are then calculated from the standard deviations of the estimates.
The estimation results for the probability of a plant exiting the industry are shown in Table 4.4. Each probit and logit model is estimated in two versions, where the second version controls for the size of capital. As mentioned above, the purpose of including the capital stock in the specification is to separately measure the short- and long-run components of plant survival. All specifications include year dummies. The panel A of Table 4.4 shows that the estimates obtained with either the probit or logit model is similar. Results show that higher productivity increases the probability of exit, but the effect is not significant. As expected, higher demand-specific factors will decrease the probability of exit. The marginal effects of a one-standard-deviation increase in each variable are listed in panel B. Although the parameter estimates for the effect of physical productivity are not significant, the marginal effects of one standard deviation increase of productivity are significant with probit models and logit model with control of capital (it is not significant using logit model without control of capital). The marginal effects of demand-specific factor calculated from all four models are significant. On average, a one-standard-deviation increase in demand-specific factors corresponds to a decline in exit probabilities of 6.86 percentage points (average of 0.0659 and 0.0713) with the probit model and 6.16 percentage points (average of 0.0598 and 0.0634) with the logit model. The specifications controlling for plant capital stock increase the magnitude of demand-specific factors effect, but also increase the standard error of the effect.

Similarly, the probability of ownership change is modeled, and the results are shown in Table 4.5. Panel A of Table 4.5 shows that higher demand-specific factors will increase the probability of ownership change. This is because plants with higher demand-specific factors
are more likely to be a target for acquisitions. Higher productivity will decrease the probability of ownership change, but the effect is not significant. The marginal effects of a one-standard-deviation increase in each variable are listed in panel B. Marginal effects of physical productivity are positive but not significant. While marginal effects of demand-specific factors are all positive and significant. On average, a one-standard-deviation increase each in demand-specific factor corresponds to increase in ownership change probabilities of 6.67 percentage points (average of 0.064 and 0.0619) with the probit model and 5.86 percentage points (average of 0.0562 and 0.0609) with the logit model. The specifications controlling for plant capital stock makes the marginal effect of demand-specific factors less significant.

Finally, the estimation results for multinomial model are presented in Table 4.6. The reference group in our model is the exit group. Generally speaking, the effects of productivity are not significant and demand-specific factors have positive parameters. As mentioned before, the direction of change in $P(y_{lt} = m)$ for a small change in $x_{lt-5j}$ cannot be inferred for the sign of $\beta_{mj}$, because in a multinomial model, a change in the value of a variable affects the probability of every outcome. The magnitude of the change could be obtained by equations (25) and (26). The results are listed in Table 4.7. Marginal effects are not significant for all variables.

4.5.2 Firm-Level Analysis
This section will analyze the firm-level expansion. Given the fact that the total production of poultry industry has almost doubled during the studied period while the number of firms in the industry has remained relatively stable, we want to study the effects of physical
productivity and demand-specific factors on the probability of the firms’ expansion. In order to carry out the analysis at the firm level, the plant-level variables need to be aggregated to the firm-level. The sum of the plant-level output is used as firm-level output, the output-weighted average plant-level productivity is used as the firm-level physical productivity, the output-weighted average plant-level output price is used as the firm-level output price, and the input-weighted average plant-level input prices is used as the firm-level input prices. The precise calculations of the firm level aggregates are given by the following set of formulas:

\( y_{ft} = \sum_{i=1}^{n_f} y_{fit}, \)

\( tf p_{ft} = \frac{\sum_{i=1}^{n_f} y_{fit} t f p_{fit}}{y_{ft}}, \)

\( P_{ft} = \frac{\sum_{i=1}^{n_f} y_{fit} P_{fit}}{y_{ft}}, \)

\( w_{s,ft} = \frac{\sum_{i=1}^{n_f} x_{s,fit} w_{s,fit}}{\sum_{i=1}^{n_f} x_{s,fit}}, \)

where \( y_{ft} \) is the firm-level output quantity for firm \( f \) at year \( t \); \( n_f \) is number of plants belonging to firm \( f \) at year \( t \); \( tf p_{ft} \) is the natural logarithm of the physical productivity of firm \( f \) at year \( t \); \( P_{ft} \) is the output price of firm \( f \) at year \( t \); \( w_{s,ft} \) is the input price of firm \( f \) at year \( t \). The variable \( s = l, k, m, e \) denotes various inputs, in particular labor, capital, materials and energy respectively.

An expanding firm at year \( t \) is defined as the one which has opened at least one new plant or has acquired at least one plant from other firms between year \( t - 4 \) and \( t \) (including \( t \)). The analysis starts with the productivity calculations. Using equation (28), the firm-level
productivity is calculated with plant-level productivity and output quantity. The summary statistics for the firm-level physical productivity are listed in the left panel of Table 4.8, which shows that expanding firms have slightly lower productivity compared to other firms.

Next, by using the firm-level variables calculated above, the firm-level demand-specific factors can be estimated by equation below:

\[(31) \quad \ln y_{ft} = \alpha_0 + \alpha_1 \ln p_{ft} + \sum \beta_t Year_t + \gamma Single_{ft} + \mu_{ft},\]

where \(\mu_{ft}\) is the error term which will be subsequently used as the estimate of the firm-level demand-specific factors, and \(Single_{ft}\) is the dummy variable identifying the single-plant firms. The estimation results are listed in Table 4.9. They are similar to plant-level demand equation: instrumental variables (firm-level productivity and firm-level live chicken price) are highly correlated with output price but not correlated with the error term in equation (31). Parameters are estimated using 2SLS. Based on the firm-level demand equation estimates, the estimate of the firm-level demand-specific factors can be obtained. The summary statistics of the firm-level demand-specific factors are listed in the right panel of Table 4.8. As can be seen, expanding firms have higher demand-specific factors.

The probability of a firm’s expanding is analyzed by using simple probit and logit models. The dependent variable is defined as \(y_{it} = 1\) if the firm is expanding and \(y_{it} = 0\) otherwise. The top portion of Table 4.10 presents the parameter estimators. It can be seen that lower productivity and higher demand-specific factors will increase the probability of firms’ expanding, but both productivity and demand-specific factors effects are not significant. The magnitude of the increase in probability of firms’ expanding associated with
one-standard-deviation increase in each productivity, demand-specific factors and capital stock are listed in the bottom portion of Table 4.10. Although all parameter estimators are not significant, the marginal effect of demand-specific factor is significant. Take probit model without control of capital as an example, one standard deviation increase in demand-specific factors will increase the probability of expanding by 9.45%. Marginal effects of capital are estimated to be negative and significant. This implies that firms already have large capital stock, are less likely to expand.

4.6. Conclusions

This chapter presented a study of the effects of physical productivity and demand-specific factors on plants’ and firms’ performance in the U.S. broiler industry. The use of the Census data enabled the observation of plant-level quantities; hence, physical productivity and demand-specific factors could be separately measured. Overall, the influence of physical productivity turns out to be an insignificant determinant of industry dynamics either at the plant-level or at the firm-level. This means that previous studies using traditional productivity measures only overstated the importance of productivity on selection of plants, especially in narrowly-defined industries. On the other hand, plants with higher demand-specific factors are less likely to exit, more likely to survive, and more likely to be acquired. The same is true for firms where those with higher demand-specific factors are more likely to expand.

The extension of the analysis of industry dynamics by measuring the demand-specific factors also shows that treating acquired plants the same as exiting or surviving plants is not
appropriate. The results strongly indicate that acquired plants have significantly higher demand-specific factors than either the surviving or exiting plants.

Table 4.1: Summary Statistics for Variables Used to Calculate Physical Productivity and Demand Specific Factors (1987-2002)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (Standard Deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Quantity</td>
<td>153520.41 (99800.36)</td>
</tr>
<tr>
<td>Output Price</td>
<td>0.7766 (0.21)</td>
</tr>
<tr>
<td>Material</td>
<td>183571.25 (104179.22)</td>
</tr>
<tr>
<td>Capital</td>
<td>32009.09 (26777.29)</td>
</tr>
<tr>
<td>Labor</td>
<td>1574.59 (968.22)</td>
</tr>
<tr>
<td>Energy</td>
<td>23224.64 (19382.47)</td>
</tr>
</tbody>
</table>
Table 4.2: Summary Statistics for Plant-Level Physical Productivity and Demand Specific Factors (1987-2002)

<table>
<thead>
<tr>
<th>Group</th>
<th>Physical Productivity</th>
<th>Demand-specific Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exit</td>
<td>59</td>
<td>2.7297</td>
</tr>
<tr>
<td>Survival</td>
<td>359</td>
<td>2.5468</td>
</tr>
<tr>
<td>Ownership</td>
<td>53</td>
<td>2.7243</td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>471</td>
<td>2.5904</td>
</tr>
</tbody>
</table>

Notes: N indicates the number of plants in the group; Mean is the mean of the variable; Std. Dev. means standard deviation. Physical Productivity is calculated from equation (16); Demand-specific factors are estimated from equation (20). Definitions of groups (Exit, Survival and Ownership Change) can be found in Part 3.
Table 4.3: Plant-level Demand Estimation Results Using 2SLS

<table>
<thead>
<tr>
<th></th>
<th>Estimates</th>
<th>Standard Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>10.5453***</td>
<td>0.1010</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Price</td>
<td>-1.3179***</td>
<td>0.2237</td>
<td>0.0003</td>
</tr>
<tr>
<td><strong>Tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over identification</td>
<td>1/469</td>
<td>0.62</td>
<td>0.4297</td>
</tr>
<tr>
<td>Weak IV</td>
<td>2/444</td>
<td>138.36</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Notes: estimation of equation (20) using pooled sample of 471 plant-year observations. Dependent variable is output quantity; independent variables are year dummies, firm dummies and output price. Because output price is endogenous, we use material price and physical productivity as instrumental variables. Basmann’s test is used to test over-identification. A regression of output price on exogenous variables is used to test weak IV. *** means significant at 1% level.
Table 4.4: Probability of Plant Exit

A. Parameters estimates

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Probit (1)</th>
<th>Probit (2)</th>
<th>Logit (1)</th>
<th>Logit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>0.1296 (0.11)</td>
<td>0.1342 (0.11)</td>
<td>0.1966 (0.21)</td>
<td>0.2020 (0.21)</td>
</tr>
<tr>
<td>Demand-specific factors</td>
<td>-0.3435***</td>
<td>-0.3712***</td>
<td>-0.6028***</td>
<td>-0.6369***</td>
</tr>
<tr>
<td>(0.09)</td>
<td>(0.11)</td>
<td>(0.17)</td>
<td>(0.22)</td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>0.0593 (0.13)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Marginal effects of one-standard-deviation increase

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Probit (1)</th>
<th>Probit (2)</th>
<th>Logit (1)</th>
<th>Logit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>0.0249**</td>
<td>0.0258**</td>
<td>0.0195</td>
<td>0.0201*</td>
</tr>
<tr>
<td></td>
<td>(1.23E-2)</td>
<td>(1.20E-2)</td>
<td>(1.37E-2)</td>
<td>(1.13E-2)</td>
</tr>
<tr>
<td>Demand-specific factors</td>
<td>-0.0659***</td>
<td>-0.0713***</td>
<td>-0.0598***</td>
<td>-0.0634***</td>
</tr>
<tr>
<td></td>
<td>(1.47E-2)</td>
<td>(1.53E-2)</td>
<td>(1.14E-2)</td>
<td>(1.41E-2)</td>
</tr>
<tr>
<td>Capital</td>
<td>0.0114</td>
<td></td>
<td>0.0079</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.77E-2)</td>
<td></td>
<td>(1.74E-2)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The sample used is the pooled sample of 471 plant-year observations. All specifications include year dummies. * means significant at 10% level. ** means significant at 1% level. *** means significant at 1% level. Numbers in () are standard errors.
Table 4.5: Probability of Ownership Change

A. Parameters estimates

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Probit (1)</th>
<th>Probit (2)</th>
<th>Logit (1)</th>
<th>Logit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>-0.0306 (0.09)</td>
<td>-0.0397 (0.09)</td>
<td>-0.0770 (0.16)</td>
<td>-0.0928 (0.16)</td>
</tr>
<tr>
<td>Demand-specific</td>
<td>0.4341*** (0.09)</td>
<td>0.4747*** (0.13)</td>
<td>0.7792*** (0.17)</td>
<td>0.8510*** (0.24)</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.0487 (0.12)</td>
<td>-0.0818 (0.22)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Marginal effects of one-standard-deviation increase

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Probit (1)</th>
<th>Probit (2)</th>
<th>Logit (1)</th>
<th>Logit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>-0.0045 (2.42E-2)</td>
<td>-0.0058 (2.53E-2)</td>
<td>-0.0056 (3.00E-2)</td>
<td>-0.0066 (2.74E-2)</td>
</tr>
<tr>
<td>Demand-specific</td>
<td>0.0642*** (2.63E-2)</td>
<td>0.0691* (3.98E-2)</td>
<td>0.0562** (2.61E-2)</td>
<td>0.0609 (4.59E-2)</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.0071 (3.22E-2)</td>
<td>-0.0059 (3.42E-2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: The sample used is the pooled sample of 471 plant-year observations. All specifications include year dummies. * means significant at 10% level. ** means significant at 5% level. *** means significant at 1% level. Numbers in () are standard errors.
Table 4.6: Estimation Results for Multinomial Model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity 2 vs. 1</td>
<td>0.2043 (0.21)</td>
</tr>
<tr>
<td>Productivity 3 vs. 1</td>
<td>-0.0691 (0.17)</td>
</tr>
<tr>
<td>Demand-specific 2 vs. 1</td>
<td>-0.5948*** (0.22)</td>
</tr>
<tr>
<td>Demand-specific 3 vs. 1</td>
<td>0.7777*** (0.26)</td>
</tr>
<tr>
<td>Intercept 2 vs. 1</td>
<td>-1.9441*** (0.27)</td>
</tr>
<tr>
<td>Intercept 3 vs. 1</td>
<td>-2.3322*** (0.23)</td>
</tr>
<tr>
<td>Capital 2 vs. 1</td>
<td>0.0922 (0.27)</td>
</tr>
<tr>
<td>Capital 3 vs. 1</td>
<td>-0.0673 (0.23)</td>
</tr>
</tbody>
</table>

Notes: The sample used is the pooled sample of 471 plant-year observations. All specifications include year dummies. *** means significant at 1% level. Numbers in () are standard errors.
### Table 4.7: Marginal Effects of One-Standard-Deviation Increase

<table>
<thead>
<tr>
<th>Variables</th>
<th>Productivity</th>
<th>Demand-specific Factor</th>
<th>Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exit</td>
<td>0.0215 (2.84E-2)</td>
<td>-0.0677 (4.74E-2)</td>
<td>0.0100 (3.58E-2)</td>
</tr>
<tr>
<td>Survival</td>
<td>-0.0147 (1.12E-2)</td>
<td>0.0063 (1.51E-2)</td>
<td>-0.0043 (1.67E-2)</td>
</tr>
<tr>
<td>Ownership Change</td>
<td>-0.0068 (3.43E-2)</td>
<td>0.0615 (5.95E-2)</td>
<td>-0.0057 (4.14E-2)</td>
</tr>
</tbody>
</table>

Notes: The sample used is the pooled sample of 471 plant-year observations. All specifications include year dummies. Numbers in () are standard errors.

### Table 4.8: Firm-level Physical Productivity and Demand-specific Factors (1987-2002)

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Productivity</th>
<th>Demand-specific Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Expanding Firms</td>
<td>27</td>
<td>2.3977</td>
<td>0.46</td>
</tr>
<tr>
<td>Other Firms</td>
<td>138</td>
<td>2.5667</td>
<td>1.10</td>
</tr>
<tr>
<td>Total</td>
<td>165</td>
<td>2.5389</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Notes: N indicates the number of plants in the group; Mean is the mean of the variable; Std. Dev. means standard deviation. Physical Productivity is calculated from equation (28); Demand-specific factors are estimated from equation (31).
### Table 4.9: Firm-level Demand Estimation Results with 2SLS

<table>
<thead>
<tr>
<th></th>
<th>Estimates</th>
<th>Standard Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>12.9076***</td>
<td>0.2315</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Price</td>
<td>-1.2157***</td>
<td>0.4977</td>
<td>0.0157</td>
</tr>
<tr>
<td>Single-Plant dummy</td>
<td>-2.2082***</td>
<td>0.1592</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over identification</td>
<td>1/158</td>
<td>2.61</td>
<td>0.1084</td>
</tr>
<tr>
<td>Weak IV</td>
<td>2/157</td>
<td>59.55</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Notes: estimation of equation (31) use pooled sample of 165 firm-year observations. Dependent variable is output quantity; independent variables are year dummies, single-firm dummy and output price. Because output price is endogenous, we use material price and physical productivity as instrumental variables. Basmann’s test is used to test overidentification. A regression of output price on exogenous variables is used to test weak IV. *** implies significant at 1% level.
Table 4.10: Probit and Logit Model Estimates of the Probability of Firms Expanding

A. Parameters estimates

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Probit (1)</th>
<th>Probit (2)</th>
<th>Logit (1)</th>
<th>Logit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>-0.2167 (0.65)</td>
<td>-0.1864 (5.21)</td>
<td>-0.4023 (1.40)</td>
<td>-0.3422 (15.74)</td>
</tr>
<tr>
<td>Demand-specific</td>
<td>0.4210 (4.30)</td>
<td>0.6543 (18.02)</td>
<td>0.7300 (13.96)</td>
<td>1.1459 (58.74)</td>
</tr>
<tr>
<td>Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>-0.2920 (4.01)</td>
<td></td>
<td></td>
<td>-0.4915 (12.89)</td>
</tr>
</tbody>
</table>

B. Marginal Effects on Probability of One-standard-deviation Increase

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Probit (1)</th>
<th>Probit (2)</th>
<th>Logit (1)</th>
<th>Logit (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>-0.0486 (3.42E-2)</td>
<td>-0.0402 (3.15E-2)</td>
<td>-0.0512* (2.99E-2)</td>
<td>-0.0389 (2.57E-2)</td>
</tr>
<tr>
<td>Demand-specific</td>
<td>0.0945*** (3.65E-2)</td>
<td>0.1412*** (5.81E-2)</td>
<td>0.0928*** (2.88E-2)</td>
<td>0.1302*** (4.81E-2)</td>
</tr>
<tr>
<td>Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>-0.0630* (3.30E-2)</td>
<td></td>
<td>-0.0558** (2.70E-2)</td>
<td></td>
</tr>
</tbody>
</table>

Note: The estimation includes year dummies and is based the pooled sample of 165 firm-year observations. Numbers in () are standard errors.
CHAPTER 5: CONCLUSION

The US chicken industry is almost vertically integrated and is experiencing active horizontal mergers and acquisitions. Vertically, the only stage of production which is not integrated with processors is chicken growers. More than 90% of broiler production is coming from chicken grown by farmers who contact with processing plants. Horizontally, the US broiler industry is more and more concentrated because of reallocation, exit and expansion. The Herfindahl index (HHI) of poultry processing industry increased from 735 to 1224 from 1992 to 2007. The industry's Top-4 concentration ratio increased from 44.24% in 1992 to 58.52% in 2007, and its Top-8 concentration ratio increased from 60.30% to 72.14% during the same time period. About 11.25% of the broiler processing plants changed ownership during the period 1987 to 2007, and about 12.53% of the broiler processing plants exited the industry during the same period (see Table 4.2 in Chapter 4). In addition, about 19.57% of the firms increased the total number of plants through acquiring plants from other firms or building up new plants. Chapter 2 presented the brief history of the US broiler industry, described the most recent developments in the broiler industry, and finally showed the industry structure and dynamics. The details of features described above are also included in Chapter 2.

Chapter 3 showed the welfare effect of the higher concentration in the US broiler industry. Theoretically, higher concentration could decrease the social welfare because of higher market power, or increase the social welfare because of increased efficiency. By estimating a cost function using data from Census of Economics and estimating demand function using data from USDA-ERS, I calculated the changes in consumer surplus and

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changes in producer surplus, and hence showed changes in social welfare during the our study time period. The results show that HHI increased in periods 1992-1997, 1997-2002, and decreased in period 2002-2007. Consumer surplus increased in all three periods. Producer surplus was positively correlated with HHI; that is, producer surplus increased when HHI increased and decreased when HHI decreased. The overall social welfare increased during the HHI’s increasing period (1992-2002), while social welfare decreased during the HHI’s decreasing period (2002 to 2007). These results show that society benefited from higher concentration in the poultry industry, while it was worse off from lower concentration in the poultry industry.

Chapter 4 studied the effect of productivity and demand-specific factors on broiler processing plants’ survival and ownership change. Previous studies generally used revenue productivity instead of physical productivity because of the availability of data. Following Foster, Haltiwanger and Syverson’s (2008) method, I divided revenue productivity into physical productivity and demand-specific factors. Unlike Foster, Haltiwanger and Syverson (2008) and most previous researchers who treat ownership change as an exit, I studied the effect of physical productivity and demand-specific factors on exit and ownership change separately. I made a distinction between the plants that are acquired by other firms from plants that truly exited the industry, mainly because plants that completely exited the industry could be fundamentally different from plants that were acquired by other firms. The difference may be because the acquired plants needed to be good enough to attract other buyers. This study’s results show that higher demand-specific factors decrease the probability of exit, increase the probability of ownership change, and increase the probability of survival.
The effect of physical productivity on the probability of exit or ownership change is generally insignificant. One the other hand, given the fact that the poultry industry’s volume of production has almost doubled during the studied time period, I also analyzed the firm-level expansion. The results also show that firms with higher demand-specific factors have a higher probability of expanding their businesses.

There are several improvements possible to this paper. Firstly, because of the availability of data, the measurement of plant-level rental price may be problematic. A better measurement would be plant-level interest rate if possible. Secondly, as mentioned before, grower is the only stage which is not integrated with processor in broiler production, so one area for future research is to analyze the welfare implications of mergers and acquisitions on contract growers, which I did not study in this paper. Third, in chapter 4, we show that plants which change ownership and plants which exit are significantly different from each other. It would be nice if we could improve the theoretical model in chapter 4 to include plants which enter the industry, and then acquired by other firms.
REFERENCES


Bergin, James and Dan Bernhardt. 1996. Industry dynamics over the Business Cycles. Working Papers 935, Queen's University, Department of Economics.


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Appendix A: Proof of Result 1

When only the price for chicken changes between year $t_1$ and year $t_2$ and the prices for other goods remain the same, (12) can be re-written as:

$$e(u_{t_1}, p_{t_2}) = \exp \left\{ \alpha_0 + \sum_k \alpha_k \log p_{kt_1} + 0.5 \sum_k \sum_j y_{kj} \log p_{kt_1} \log p_{j1} + u_{t_1} \beta_0 \prod_k p_{kt_1}^{\beta_k} + \alpha_c (\log p_{ct_2} - \log p_{ct_1}) + \sum_j y_{cj} \log p_{j1} (\log p_{ct_2} - \log p_{ct_1}) + 0.5 y_{cc} \left[ (log p_{ct_2})^2 - (log p_{ct_1})^2 \right] + u_{t_1} \beta_0 \prod_k p_{kt_1}^{\beta_k} \left[ \left( \frac{p_{ct_2}}{p_{ct_1}} \right)^{\beta_c} - 1 \right] \right\}.$$

(12) also implies that,

$$u_{t_1} \beta_0 \prod_k p_{kt_1}^{\beta_k} = (\log e_{t_1} - \alpha_0 - \sum_k \alpha_k \log p_{kt_1} - 0.5 \sum_k \sum_j y_{kj} \log p_{kt_1} \log p_{j1}).$$

Plugging (A.2) into (A.1) yields,

$$e(u_{t_1}, p_{t_2}) = e_{t_1} \exp \left\{ \alpha_c (\log p_{ct_2} - \log p_{ct_1}) + \sum_j y_{cj} \log p_{j1} (\log p_{ct_2} - \log p_{ct_1}) + 0.5 y_{cc} \left[ (log p_{ct_2})^2 - (log p_{ct_1})^2 \right] + \log e_{t_1} - \alpha_0 - \sum_k \alpha_k \log p_{kt_1} - 0.5 \sum_k \sum_j y_{kj} \log p_{kt_1} \log p_{j1} \left[ e^{\beta_c (\log p_{ct_2} - \log p_{ct_1})} - 1 \right] \right\}.$$

Therefore, CV can be written as,

$$CV = e(u_{t_1}, p_{t_2}) - e(u_{t_1}, p_{t_1}) = e_{t_1} \left\{ \exp \left\{ F_{t_1} \Delta \log p_c + 0.5 y_{cc} \Delta (\log p_c)^2 + \left[ e^{\beta_c (\log p_{ct_2} - \log p_{ct_1})} - 1 \right] (F_{t_1} - \alpha_0) \right\} - 1 \right\},$$

where $\Delta \log p_c = \log p_{ct_2} - \log p_{ct_1}$, $\Delta (\log p_c)^2 = (\log p_{ct_2})^2 - (\log p_{ct_1})^2$, $E_{ct_1} = \alpha_c + \sum_j y_{cj} \log p_{j1}$ and $F_{t_1} = \log e_{t_1} - \sum_k \alpha_k \log p_{kt_1} - 0.5 \sum_k \sum_j y_{kj} \log p_{kt_1} \log p_{j1}.$

When $\beta_c (\log p_{ct_2} - \log p_{ct_1})$ is small and close to zero, $e^{\beta_c (\log p_{ct_2} - \log p_{ct_1})} - 1$ can be approximated by $\beta_c (\log p_{ct_2} - \log p_{ct_1})$. Then (A.3.a) can be rewritten as:
(A.3.b). \( e(u_t, p_{t_2}) = e_{t_1} \exp \{ \alpha_c (\log p_{ct_2} - \log p_{ct_1}) + \sum_j \gamma_{cj} \log p_{jt_1} (\log p_{ct_2} - \log p_{ct_1}) + 0.5 \gamma_{cc} \left[ (\log p_{ct_2})^2 - (\log p_{ct_1})^2 \right] + (\log e_{t_1} - \alpha_0 - \sum_k \alpha_k \log p_{kt_1} - 0.5 \sum_k \sum_j \gamma_{kj} \log p_{kt_1} \log p_{jt_1}) \} = e_{t_1} \exp \{ [\alpha_c + \sum_j \gamma_{cj} \log p_{jt_1} + \beta_c (\log e_{t_1} - \alpha_0 - \sum_k \alpha_k \log p_{kt_1} - 0.5 \sum_k \sum_j \gamma_{kj} \log p_{kt_1} \log p_{jt_1})] (\log p_{ct_2} - \log p_{ct_1}) + 0.5 \gamma_{cc} \left[ (\log p_{ct_2})^2 - (\log p_{ct_1})^2 \right] \}.

Notice

\[ \alpha_c + \sum_j \gamma_{cj} \log p_{jt_1} + \beta_c (\log e_{t_1} - \alpha_0 - \sum_k \alpha_k \log p_{kt_1} - 0.5 \sum_k \sum_j \gamma_{kj} \log p_{kt_1} \log p_{jt_1}) \] is actually \( s_{ct_1} \), then (A.4) can be expressed as:

(A.5). \( CV = e_{t_1} \{ \exp \{ s_{ct_1} \Delta \log p_c + 0.5 \gamma_{cc} \Delta (\log p_c)^2 \} - 1 \} \).