

# Evolving Market Structure of the Influenza Vaccine Market

by

Ellen C. Werble  
Class of 2007

A thesis submitted to the  
faculty of Wesleyan University  
in partial fulfillment of the requirements for the  
Degree of Bachelor of Arts  
with Departmental Honors in Economics

## *Contents*

	<i>Acknowledgments</i>	ii
1.	Introduction	1
2.	Model Framework	12
3.	Model Structures	16
4.	Welfare Analysis and Implications in the Current Market	42
5.	Conclusion	54
	<i>Bibliography</i>	58
	<i>Appendix</i>	64

## **Acknowledgements**

Many people have lent their support and encouragement throughout this thesis writing process who I would like to thank. First and foremost, I would like to thank my advisor, Professor John P. Bonin. Without his guidance and insight, this thesis would never have been completed. Also within the Wesleyan community I would like to thank Professor Michael S. Hanson and Professor Manolis Kaparakis for their continued encouragement. I thank Deborah Miller for her conversations with me this past summer concerning pandemic influenza policy, which sparked my interest in the topic and eventually led to this thesis.

David Fox, Bob Helms, Joe Antos, and the GAO Health Care team provided their encouragement through hours spent explaining to me the intricacies of health care policy, without which my interest in the topic may have never arisen. I would also like to thank my friends and fellow thesis writers, especially Tori Santoro, Nick Norvell, Leah Katz, Eric Altneu, Stephen Morris, Kathy Michelmore, and Holly Wheeler for their much-needed support throughout the year. Last and not least, I would like to thank my family for their support and understanding that "school break" really meant "thesis time."

## Chapter 1 Introduction

Seasonal influenza, the flu, is a contagious respiratory illness caused by the influenza virus. Infection hospitalizes 200,000 people and kills 36,000 people a year in the United States (Heinrich, 2006b). The virus's prevalence prompted the development of a vaccine, the best known defense and prevention of the flu (CDC, 2006b). Fortunately, most of the population can decrease their chances of getting the flu as anyone over the age of six months is eligible to receive a flu vaccination.<sup>1</sup> Moreover, the Centers for Disease Control and Prevention (CDC) recommends people at high risk, such as seniors and those with depleted immune systems, for complications from the flu, should receive a vaccine before the flu season every year. This yearly vaccine recommendation is unique but necessary the influenza virus undergoes antigenic drift causing a new strain of the flu to circulate every year.<sup>2</sup> In contrast to most vaccines, a new variation of the influenza vaccine must be developed each year in order to combat the current virus. Influenza vaccines from previous years are not guaranteed to be effective against the new circulating strains. Thus, the seasonal flu presents interesting challenges and obstacles to manufacturers entering the market.

Increasing awareness of the flu and government subsidies for pandemic flu preparations have influenced the expansion of the U.S. influenza vaccine market from three vaccine manufacturing firms participating in 2005 to five firms this year. Rikard

---

<sup>1</sup> People allergic to eggs cannot receive the vaccine since the vaccine production is an egg-based process.

<sup>2</sup> Antigenic drift is a small change in the virus such that the body's immune system will not recognize the new strain (CDC, 2006a). Antigenic drift is differentiated from antigenic shift, which is “the genetic change that enables a flu strain to jump from one animal species to another, including humans.” (NIAID)

Forslid (2005) most recently modeled the influenza vaccine market as a monopoly. However, with the influx of firms and two more waiting to enter in the upcoming seasons the monopoly model no longer accurately reflects the market dynamics. The objective of this paper will be to present an oligopoly model with product differentiation and a two stage demand structure that more closely resembles the influenza vaccine market.

In particular, flu vaccine production is highly complex and uncertain because of the nature of the flu vaccine. As a biologic product, the influenza vaccine is developed from a living organism and regulated by The Food and Drug Administration's (FDA) Center for Biologics Evaluation and Research (CBER). Unlike drugs, biologics are difficult to mass produce, because they are derived from living organisms instead of a defined and measured chemical combination. The influenza virus must be successfully grown in fertilized hen's eggs while excluding the growth of other organisms, which would contaminate the vaccine. Like other biological products, a vaccine is susceptible to heat and microbial contamination. The FDA requires, through adherence to the current Good Manufacturing Practices (cGMP), manufacturers to test for microbial contaminants and maintain strict sterility conditions throughout the production process. The complexity of production and strict adherence to manufacturing regulations renders the production a long, costly and complicated process.

Due to the difficulty present in manufacturing vaccines, two licenses are required to produce a vaccine, unlike the one required in drug development. An Establishment License Application (ELA) is necessary to approve the manufacturing

process and the vaccine production facility and a Product License Application (PLA) is required for the safety and effectiveness of the vaccine (CDC, 2005). Each vaccine must be proven through testing and trials to be a safe and effective product before being released to the public. Thus, no generic biologics exist, unlike the many generic drugs available. Therefore, a regulatory cost saving short cut available to other pharmaceutical products by showing biological equivalence to a previously approved product is not available to vaccines (Salinsky & Werble, 2006).<sup>3</sup> The lack of generic vaccines presents a further complication for profit making firms in the flu vaccine market.

To ensure the safety and effectiveness of the influenza vaccine, the FDA provides the manufacturers with the approved influenza virus strains for mass production. The World Health Organization (WHO) continuously tracks prevalent strains and outbreaks of the flu virus around the world.<sup>4</sup> In late winter the FDA uses the WHO surveillance information and the advice from the National Vaccine Advisory Committee and the CDC to select three flu strains that are most likely to cause serious illness in the upcoming U.S. flu season. The selection for the following year's flu strains must be made early because the manufacturing process takes six to nine months.

Flu vaccine manufacturing is currently an egg-based production process, using fertilized hens' eggs to grow the virus. Eggs for vaccine production go through a different monitoring process than the types of eggs we consume on a daily basis.

---

<sup>3</sup> A drug is a chemical compound and therefore biological equivalence means proving that the drug is the same combination of chemical elements. A vaccine is a biologic which cannot be easily identified or reproduced and therefore the manufacturing process is vital to establishing a safe and effective product.

<sup>4</sup> The flu circulates around the world hitting countries during the winter months.

“They must be specially produced, assuring the health of the laying hens, appropriate sanitation, care in transport, incubation, and other actions as required by the FDA to assure vaccine safety and efficiency” (Lister, 2004). Therefore, egg-based production requires pre-purchasing eggs well in advance of known demand for the lengthy growing and extracting process. The decision on how many eggs to purchase and hence estimated supply is usually made during the previous year’s flu season, presenting a set of obstacles unique to the flu vaccine market supply.

The manufacturing process is susceptible to contamination and requires close monitoring, because “there are numerous points at which the process could fail, and has failed in recent years”(Lister, 2004). The conditions that promote growth of the virus also promote growth of other organisms that could contaminate the batch.

“Under optimal conditions the vaccine is produced in batches from August through November, barely making it to market ahead of the annual influenza epidemic” (Lister, 2004).<sup>5</sup> Egg-based production is a long and arduous process such that current technology renders it impossible for production to be increased or the process restarted in the middle of the manufacturing timeline.

The difficulty of producing vaccines, high costs, and regulation related with the process has resulted in a limited number of manufacturing firms in the influenza vaccine market. This trend, however, has recently changed. Up until 2003, firms entered and exited the market with an inactivated injectable vaccine product.<sup>6</sup> In 2003

---

<sup>5</sup> An epidemic outbreak of the flu is different from a pandemic outbreak. An epidemic is confined to a certain region or population. A pandemic is a worldwide outbreak or it is considered an epidemic covering a very large area.

<sup>6</sup> An inactivated injectable vaccine contains the killed virus in a shot.

a firm, MedImmune, entered the market with a live nasal mist vaccine.<sup>7</sup> The decision of the firm to enter the market with a differentiated product licensed for only a cohort of the population presents a new and interesting hybrid product differentiation oligopoly model of the market. Firms still compete in oligopolistic competition in the injectable market, but the firms also compete with the live nasal mist in a cohort of the influenza market.<sup>8</sup> Differentiated products segment the market into injectable and nasal mist populations with some cross over in demand from the nasal mist population for the injectable vaccine.

Firms have exited and entered the influenza vaccine market over the past seven years. In 1999 there were four manufacturers producing 77.9 million doses. Two firms left the U.S. market in 2000 due to citations from the FDA for failure to adhere to cGMP and the high cost of upgrading their facilities. The two firms, Chiron and Aventis, remaining in the market invested in increasing their production capacities of the injectable influenza vaccine. In 2003 MedImmune Vaccines Inc. entered the market with FluMist, the nasal mist vaccine (Danzon, 2005a). Since 2005, GlaxoSmithKline (GSK) and most recently IDBiomedical, a subsidiary of GSK, entered the market with injectable influenza vaccines bringing the total number of firms to five with an estimated supply of 110 million doses for the 2006-2007 flu season (FDA, 2006). With the addition of three firms in four years, the flu vaccine market has undergone a shift that requires examination.

Firms have cited the difficulties of producing the flu vaccine with high fixed costs, low marginal costs and uncertain demand as reasons for leaving the market.

---

<sup>7</sup> A vaccine that is made with live, weakened flu viruses do not cause the flu (CDC, 2006b)

<sup>8</sup> The nasal mist vaccine is not approved for use in all portions of the vaccine market.



Government subsidies are contributing to firms entering the market again. “Faced with low prices and volatile demand, manufacturers have chosen to exit rather than to incur the sizable costs of bringing manufacturing capacity up to the high standards required” (Danzon, Pereira, & Tejwani, 2005). High manufacturing standards increase the fixed costs, but the government is targeting subsidies with pandemic influenza funding towards fixed costs in an attempt to expand the market in preparation for a pandemic.

As an entrant, the nasal mist firm had the choice between two decisions: compete in an oligopoly taking into account the reaction functions of the incumbents or attempt to differentiate their product and capture a niche of the market. This paper will combine the theory of oligopolistic competition with differentiated products with the current market structure to answer the following questions: what does the new product do to competition in the market, and was the differentiated product a smart decision?

A new product entered the market in 2003 suggesting a partially segmented model. The model presented in this paper builds upon a segmented market with product differentiation to a partially segmented market as the current market reflects cross-over between the products. If the entrant had chosen not to enter with a new product, the market would behave as explained by a homogenous product oligopoly model. Using these models the paper will explain how the market reacts to increasing the high risk groups, a change in the severity of the flu, product differentiation, and subsidies.

Based on the market characteristics and an examination of consumer surplus, subsidies, and the Herfindahl index, I explain the market behavior and current interest in expanding the flu vaccine market in the context of the shortage of 2004. The expanding market and product differentiation creates competition and results in higher consumer surplus. A brief examination of the Herfindahl index for the market ending with the shortage in 2004, as explained with a case study of the shortage of 2004, illustrates the dangers associated with only a few producers in a market where supply is uncertain. The shortage scares and threat of a pandemic influenza are currently contributing to the large subsidies aimed at the flu vaccine market. The government's targeted subsidies create an atmosphere where the firms, both incumbents and entrants, are able to make above normal profit and therefore are enticing firms into the once disregarded industry.

A firm may only gain entry into the market through FDA licensure; therefore, entry into the market is limited by the regulator. An economy of scale industry with limited entry suggests a regulated monopoly model. However, the existence of product differentiation violates the key assumption of a homogenous product for a regulated monopoly model. If I were to treat both the vaccines, the nasal mist and the injectable, as a homogenous flu preventing product, the regulated model assumptions about the regulator are still violated in the flu vaccine market. Besanko and Baron (1984), Besanko and Sappington (1987), and Sappington and Stiglitz's (1987) variations on a simple regulated monopoly model do not coincide with the flu vaccine market characteristics.

Besanko and Baron (1984) attribute market imperfections to an informational asymmetry, in which the regulator by obtaining the information can force the first-best outcome (Baron & Besanko, 1984). In the flu vaccine market, the constraints of the production process prohibit any active regulatory actions even if the regulator could obtain information. The interactions between the FDA and manufacturers consist of biannual audits and regularly timed product testing. The regulator, the FDA, does not actively make decisions that affect production or costs not already anticipated by the firms. The biannual audits might result in fines for failure to adhere to cGMP, but the firm can include the auditing costs as a part of the fixed costs associated with maintaining their facilities and license. If the FDA were to acquire complete information, they would not be able to induce the first-best outcome because there are no points in the production process or distribution that allow for a change in production output besides withdrawing the firm's entire supply.

Besanko and Sappington (1987) assume the regulated monopolist is endowed with private information from the beginning, and the regulator's task is to set prices and taxes such that the regulator is able to control the firm's rents from the superior knowledge (Besanko & Sappington, 1987). The FDA does not have the legal authority to set prices, nor do they have complete and comprehensive information, and the regulator in the broad sense as the U.S. government is not a large enough purchaser of the vaccine to set prices by exerting its buying power.<sup>9</sup> Manufacturers distribute the vaccine through competitive bids to physicians, hospitals, drug stores

---

<sup>9</sup> Through the Commerce Clause in the Constitution the federal government is responsible “for the safety and efficacy of the vaccines in commerce in the United States, but this authority does not extend to controlling the distribution or administration of the product.” (Sarah A. Lister, 2004)

and other suppliers of the flu vaccine. “Thus, manufacturing prices reflect competition rather than regulation” (Danzon, Pereira, & Tejwani, 2005). The FDA does not-and cannot-set prices such that the Besanko and Sappington 1987 regulation model does not accurately reflect the market dynamics.

Sappington and Stiglitz's (1987) principal-agent problem stresses the importance of who knows what information, and when the information is known in their regulation model. The regulator in the Sappington and Stiglitz model maximizes the regulator's expected utility as a function of output, price, the regulated firm's utility, and a set of the regulator's actions for a given level of information (Sappington & Stiglitz, 1987). However, there are no points in the production process where the regulator can make active decisions based on information inducing a change in output. Therefore, there are no possible regulator actions and firm reaction variables. Hence, instead of an action-reaction interplay between the regulator and the regulated, the firms factor the regulator's fixed actions as a step in their production process that affects fixed costs. Therefore, the main relevant regulation models all fail to recognize the unique interplay between the FDA and manufacturers explaining that while the flu vaccine industry is highly regulated, the behavior of the firms cannot accurately be explained with a regulation model.

The models presented in this paper depend on the outbreak of the flu virus and its effect on the demand structure, such that a two stage demand, segmented model with product differentiation outline the framework for a segmented model, a partially segmented model, and a homogenous product oligopoly model presented in this

paper. The outbreak of the flu virus distinguishes the divide between the two demand periods as simplified in Table 1.

**Table 1: Overview of the Market Structure:**

<b>Ex-Ante:</b> Vaccine Production In-Process		<b>Flu Virus Outbreak</b>	<b>Ex-Post:</b> Vaccine Production Fixed	
<b>Demand:</b>	<b>Supply:</b>		<b>Demand:</b>	<b>Supply:</b>
<ul style="list-style-type: none"> <li>• High-Risk Population</li> </ul>	<ul style="list-style-type: none"> <li>• Injectable Vaccine Firms</li> </ul>		<ul style="list-style-type: none"> <li>• Residual High-Risk from Ex-Ante</li> <li>• Low-Risk Population Not Infected</li> </ul>	<ul style="list-style-type: none"> <li>• Injectable Vaccine Firms</li> <li>• Nasal Mist Firms</li> </ul>

In a segmented model, I simplify the market demand and treat the post-flu outbreak, ex-post, period as a strictly segmented market with no cross-over in demand from the low risk and the high risk populations. In a partially segmented model, I allow for cross-over between the low risk and the high risk populations such that the injectable vaccine supplies both the low risk and the high risk populations in the ex-post period. In both the segmented and partially segmented models the pre-flu outbreak, ex-ante, period demand for the vaccine is exclusively from the high risk population. Therefore, only the injectable vaccine can participate in the ex-ante period. In a homogenous product oligopoly model, I address the question of how the market would look if the entrant did not choose to differentiate their product and entered with an injectable vaccine.

These three models set up the basis for welfare analysis and allow me to explain why firms are entering the market, when we previously experienced firms exiting the market due to regulatory costs. A case study of the 2004 shortage illustrates the importance of subsidies, consistent with the Second Theorem of

Welfare Economics, to increase the number of firms in the market since production uncertainty and a limited number of firms in the market cause a social welfare decreasing concentration in the industry.

## Chapter 2 Model Framework

The influenza market is characterized as a separate market from other vaccines with high fixed costs, low marginal costs, product differentiation, uncertain demand and uncertain supply. The manufacturing process for each vaccine is licensed as well as the product. Therefore, there is no direct substitution between different vaccines such that “the product market for the vaccine industry really consists of a number of markets, one for each specific vaccine” (Pauly, 1996, p. 9). Since each vaccine is considered to have its own market, this paper will focus entirely on the influenza vaccine market.

Sterile facilities and fixed regulatory monitoring imply high fixed costs and lower marginal costs than average costs. According to Mercer Management Consulting, sixty percent of vaccine production costs are fixed independent of the volume produced and twenty-five percent are semi-variable (*Lessons Learned: New Procurement Strategies for Vaccines*, 2002). The manufacturing facilities have to adhere to tight federal regulations increasing the fixed costs of obtaining and maintaining appropriate manufacturing plants. “Fixed research costs, production setup costs, costs of getting and maintaining FDA approval all result in marginal costs that fall below average cost” (Pauly, 1996, p. 7). The FDA regulates the manufacturers on a fixed schedule such that the product cannot be sold unless it passes FDA inspection. This implies that the regulation can be treated as a fixed cost.

The vaccine supply depends not only on the number of firms in the market, but also on the natural yield of the vaccine, which being derived from a living organism is uncertain. The risks of contamination coupled with an uncertain yield

leads to an uncertain supply each year. Demand is also uncertain since the demand for the vaccine occurs about a year after quantity decisions are made and manufacturing begins. The prevalent influenza virus strains are approved by the FDA between February and March (Danzon, 2005a). The strains are sent to the manufacturers who must culture and produce a vaccine by October in order to hit the peak flu season, November-March. Therefore, manufacturers must determine their estimated supply almost a year before its distribution based on uncertain demand.

Stockpiling is not a viable option for ensuring demand is satisfied, because the influenza vaccine is an “extreme case of limited storability” (Danzon, Pereira, & Tejwani, 2005). The influenza virus undergoes antigenic drift, which leads to different strains appearing every year. Hence, last year’s vaccine will not be appropriate for this year’s influenza virus eliminating the option of stockpiling.

The CDC recommends a portion of the population identified as high risk individuals receive the flu vaccine before the flu season begins. The injectable vaccine is the only product licensed to supply the population identified as high risk. Depending on the severity of the flu in a particular season, individuals not listed or ordinarily not willing to receive a vaccine will demand a vaccine once the information about the severity of the flu is available. As a result, demand can be described in two-stages: a pre-influenza outbreak targeting high risk individuals and post-influenza outbreak including individuals from the general healthy population. The individuals recommended receiving the vaccine do not all receive the vaccine in the pre-outbreak stage, which suggests that their demand stretches across both



periods. With an uncertain demand and an uncertain supply, shortages and surpluses occur.

In 2002 there were two incumbent firms remaining in the vaccine market for the next year, Chiron Corporation and Aventis Pasteur. Both firms produced an injectable vaccine suggesting a duopoly with a homogenous product.<sup>10</sup> In 2003 MedImmune entered the market with a nasal mist vaccine. The nasal mist is licensed for distribution to the healthy, 5-49 year old population. The nasal mist differentiated itself from the injectable vaccine through a new delivery system, a nasal spray instead of an injection. The injectable is licensed for all users over six months old in various dosages from infants to adults, while the nasal mist is only licensed for a cohort of the injectable population. In 2002 the market could be modeled as a duopoly, but after the entrance of the nasal mist the market segmented with the product differentiation. Due to the nature of the demand, the market can be modeled as a two stage game with duopoly quantity competition in the first stage and a differentiated duopoly/oligopoly price competition model in the second stage.

The demand can be modeled in two stages, before the flu outbreak and after the flu outbreak, respectively called ex-ante and ex-post demand. Before the flu virus reaches the United States the CDC recommends that the high risk population receive the influenza vaccine. For simplicity, I am going to assume that only the high risk individuals seek vaccination in the ex-ante period. In the ex-post period, there will be a mixture of individuals demanding the vaccine: high risk individuals that did not receive a vaccine in the first period and low risk individuals seeking vaccination. In

---

<sup>10</sup> Each vaccine on the market must contain the three strains of the influenza virus as specified by the FDA, such that there is no discernable difference in the effectiveness of the injectable vaccines produced by different manufacturers.

the ex-post period the number of people demanding the vaccine also depends on the severity of the flu, which is represented by the proportion of the U.S. population infected with the virus,  $\delta$  (Forslid, 2005).

### Chapter 3 Model Structures

The outbreak of the flu divides the market structure of each model into an ex-ante and ex-post period with the injectable firms participating in both periods and the nasal mist participates exclusively in the ex-post period. As outlined in Table 2, the market structure for each model changes in the ex-post period:

**Table 2: Summary of Models and Market Structure:**

<b>Ex-Ante</b>			
<b>Models</b>		<b>Firms</b>	<b>Market Structure</b>
<b>A. Segmented</b>	Free Entry	Injectable	$Q_0 = \theta N - P_0$
<b>B. Partially Segmented</b>	Free Entry	Injectable	$Q_0 = \theta N - P_0$
<b>C. Homogenous Product</b>	Free Entry	Injectable	$Q_0 = \sum_{i=1}^3 q_i = \theta N - P_0$
	Limit Entry	Injectable	Zero profit Condition for Entrant $\Pi_3 = 0$
<b>Ex-Post</b>			
<b>Models</b>		<b>Firms</b>	<b>Market Structure</b>
<b>A. Segmented</b>	Free Entry	Injectable, Nasal Mist	$Q_1^{IN} = \theta(N(1-\delta) - \eta[\delta]) - P_1^{IN}$ $Q_1^S = (1-\theta)(N(1-\delta)) - P_1^S$
<b>B. Partially Segmented</b>	Free Entry	Injectable, Nasal Mist	$Q_1^{IN} = N(1-\delta) - \eta[\delta] - P_1^{IN}$ $Q_1^S = (1-\theta)(N(1-\delta)) - P_1^S - P_1^{IN}$
	Limit Entry	Injectable, Nasal Mist	Zero profit Condition for Entrant $\Pi_3 = 0$
<b>C. Homogenous Product</b>	Free Entry	Injectable	$Q_1 = N(1-\delta) - \eta[\delta] - P_1$ $Min(Q_1, \bar{Q}_1 - \eta[\delta])$
	Limit Entry	Injectable	Zero profit Condition for Entrant $\Pi_3 = 0$

Models A, B, and C present and explore a segmented, a partially segmented, and a homogenous product oligopoly model with free entry and limited entry conditions when applicable.

### A. Segmented Market:

#### *Ex-Ante Period:*

The optimal period for vaccination for people at higher risk for complications from the flu virus is prior to the outbreak. Hence, I assume only the high risk individuals shape the demand in the ex-ante period. The ex-ante demand can be represented as the U.S. population,  $N$ , times the portion of the population deemed at high risk by the CDC,  $\theta$ , minus the price in the ex-ante period,  $P_0$ . Therefore, the ex-ante demand can be written as

$$Q_0 = \theta N - P_0 \quad (3.A.1)$$

Since the injectable vaccine is the only vaccine licensed for the high risk population, the two firms in the injectable market compete for  $Q_0$  in the ex-ante period, and the entrant with product differentiation is excluded from the ex-ante market. I will assume constant marginal costs,  $c_i$ ,  $i = 1, 2$ , marginal costs are nontrivial for firms one and two, and firms incur fixed costs,  $F_i > 0$ ,  $i = 1, 2$ , associated with the regulatory costs of manufacturing a vaccine under cGMP. Therefore, each firm earns profit  $\Pi_i = Pq_i - c_i q_i - F_i$ ,  $i = 1, 2$ . Each firm maximizes profit assuming the firm recognizes the other firm's output decisions in a simple Stackelberg leader duopoly problem. I use a Stackelberg leader model instead of a simple Cournot model because the production processes are fixed by regulation, and demand is limited such that any output decision made by competing firms directly affects the firm's output. Hence, I can assume that  $\partial q_i / \partial q_j \neq 0$  for  $i \neq j$ , and therefore the Cournot assumption is violated and the Stackelberg leader model is more appropriate. Profit for the ex-ante

period can be represented as  $\Pi_i = [\theta N - q_i - q_j]q_i - c_i q_i - F_i$ . The Stackelberg leader model solution can be solved with the associated first-order conditions for firms one, and two:

$$\begin{aligned}\frac{d\Pi_1}{dq_1} &= \theta N - 2q_1 - \bar{q}_2 - c_1 = 0 \\ \frac{d\Pi_2}{dq_2} &= \theta N - 2q_2 - \bar{q}_1 - c_2 = 0\end{aligned}\quad (3.A.2)$$

Solving the first-order conditions for the equilibrium quantities, I obtain<sup>11</sup>:

$$\begin{aligned}q_1 &= \frac{\theta N + c_2 - 2c_1}{3} \\ q_2 &= \frac{\theta N + c_1 - 2c_2}{3}\end{aligned}\quad (3.A.3)$$

Therefore, each firm earns profit equal to<sup>12</sup>:

$$\begin{aligned}\Pi_1 &= \frac{(\theta N)^2 - \theta N c_2 - 4\theta N c_1 - 2c_2 c_1 + 8c_1^2}{9} - F_1 \\ \Pi_2 &= \frac{(\theta N)^2 - \theta N c_1 - 4\theta N c_2 - 2c_2 c_1 + 8c_2^2}{9} - F_2\end{aligned}\quad (3.A.4)$$

Assuming the cost structures are the same, the two injectable firms split the market and make equal profit such that the total quantity supplied equal

$$q_1 + q_2 = \frac{2\theta N - c_1 - c_2}{3} \text{ and price equals } P_0 = \frac{\theta N + c_1 + c_2}{3}.$$

*Ex-Post Period:*

If the entrant chooses to differentiate its product from the incumbents and produce a nasal mist vaccine, the ex-post market demand can be represented by two

---

<sup>11</sup> See Appendix A.1 for derivation

<sup>12</sup> Ibid A.2

separate demand equations: the demand for the injectable, and the demand for the nasal mist. The demand function for the ex-post period differs from the ex-ante period due to the entrance of an additional firm and to market segmentation from the product differentiation. Therefore, ex-post demand depends on two prices, the injectable(s) and the nasal mist prices. However, the nasal mist vaccine is licensed only for a cohort of the injectable population, the low risk population, such that the ex-post market is also segmented into a high risk market and a low risk market. Still assuming that the two injectable firms have the same costs, and as a result split the ex-ante demand, the ex-post demand for the injectable vaccine will be the residual demand from the ex-ante period. Hence, the ex-post demand is also dependent on the capacity constraints of the injectable vaccines, but on the capacity of the nasal mist vaccine, which only produces for the ex-post period.

The demand also changes post-outbreak of the flu due to the severity of the flu and the number of individuals not already infected with the virus. The severity of the flu as measured by Forslid (2006) is the percent of the U.S. population infected with the influenza virus,  $\delta$ . Therefore, the viable population to receive the flu vaccine is the population minus the number of people infected with the virus,  $N(1-\delta)$ . If I assume that the entire low risk population prefers to consume the nasal mist, the ex-post demand is a segmented market with an injectable demand,  $Q_1^{IN}$ , and a nasal mist demand,  $Q_1^S$ . Therefore, the ex-post demand can be specified as:

$$\begin{aligned} Q_1^{IN} &= \theta(N(1-\delta) - \eta[\delta]) - P_1^{IN} \\ Q_1^S &= (1-\theta)(N(1-\delta)) - P_1^S \end{aligned} \tag{3.A.5}$$

In (3.A.5),  $\eta$  represents the demand satisfied from  $Q_0$  in the ex-ante period.

Furthermore,  $\eta$  is dependent on the consumer's expectation of  $\delta$ , since  $\delta$  is the measure of the severity of the U.S. flu, which is not realized until the ex-post period. I simplify demand to capture the effect of the entrance and exit of firms in the market that do not affect the microeconomic determinants of the consumer's vaccination choices because I am looking at the market from the firm's point of view. The firm cares about the magnitude of  $\eta$  in the ex-post period but cannot recognize the consumer's expectations of  $\delta$ . Therefore, I treat  $\eta$  as an exogenous variable throughout this paper.

The flu vaccine has already been produced or is in the end stages of production by the ex-post period, and as discussed in the introductory section, production is time constrained so that supply cannot be increased after the production process has begun. Therefore, there is a capacity constraint on the ex-post injectable demand. The capacity constraints indicate that ex-post consumption cannot exceed a maximum,  $\bar{Q}_1$ , equal to the quantity produced by the manufacturers minus the quantity supplied in the ex-ante period. Therefore the quantity supplied in the ex-post period will be the minimum of the quantity demanded, and the capacity constrained quantity:  $Min[Q_1, \bar{Q}_1]$ .

The nasal mist firm produces only for the ex-post period so it is not capacity constrained because its quantity decisions are based purely on the ex-post period demand. Since the nasal mist captures the entire demand for the low risk population,  $Q_1^s$ , I assume the nasal mist firm will follow a monopoly price setting scheme.

Maximizing profit for the nasal mist firm with respect to quantity results in the quantity supplied<sup>13</sup>:

$$Q_1^S = q_3 = \frac{1}{2} \left[ (N(1 - \delta - \theta + \delta\theta)) - c_3 \right] \quad (3.A.6)$$

$$\begin{aligned} \frac{\delta q_3}{\delta \delta} &= \frac{\delta P_1^S}{\delta \delta} = \frac{1}{2} (N(\theta - 1)) < 0 \text{ if } \theta \neq 1 \\ \frac{\delta q_3}{\delta \theta} &= \frac{\delta P_1^S}{\delta \theta} = -\frac{1}{2} (N(1 - \delta)) < 0 \text{ if } \delta \neq 1 \end{aligned} \quad (3.A.7)$$

From the above equation the comparative statics, (3.A.7), imply that the effect of a change in  $\delta$  on the nasal spray price is contrary to Forslid's positive result of an increase in  $\delta$  on the profit maximizing price (Forslid, 2005). However, Forslid allows the firm to control for  $\delta$ , which I am treating as an exogenous variable, and Forslid includes a variable dependent on  $\delta$  measuring the willingness of consumers to purchase the vaccine. The firm cannot control the spread of the virus, because they cannot force vaccination on individuals to control the spread of the virus. Therefore, I treat  $\delta$  as exogenous in this model. However, the impact of a change in  $\delta$  on profit is important, since  $\delta$  changes from year to year. As the virus spreads,  $\delta$  increases, and the question arises what happens to profit. Forslid argues that as  $\delta$  increases, severity is increasing and people might be more willing to pay for a vaccine, implying that the price will also increase and it is more profitable for the firm to allow the disease to spread. However, in my model since demand for the vaccine decreases as  $\delta$  increases, an inward shift of the demand, I do not expect price to increase in my model. The comparative static result (3.A.7) claims that the decrease in demand decreases price as  $\delta$  increases, which suggests that the model does not capture an important change in

---

<sup>13</sup> See Appendix A.3 for derivation



the consumer's behavior with respect to a change in  $\delta$  on the price elasticity of demand.

A change in  $\theta$  has a negative impact on the nasal mist quantity and price, which coincides with the fact that the higher are the number of people in the high risk population the lower are the number of people that qualify for the nasal mist vaccine. If the population qualifying to receive the nasal mist vaccine decreases, demand will decrease and hence the price will decrease, as shown in (3.A.7). Assuming that  $\delta$  is not equal to one is reasonable, because there is a maximal natural spread of a disease, such that the entire population is rarely ever infected (Forslid, 2005). If  $\theta$  were equal to one, there would be no demand for the nasal mist vaccine, and the entire population would be considered at high risk for complications, which is an unreasonable assumption.

The profit earned by the nasal mist firm and the comparative statics are equal to<sup>14</sup>:

$$\Pi_3 = \frac{1}{4} \left( \left[ (N(1-\delta-\theta+\delta\theta)) - c_3 \right] \right)^2 - F_3 \quad (3.A.8)$$

$$\begin{aligned} \frac{d\Pi_3}{d\delta} &= \frac{1}{2} (N(1-\delta)(1-\theta) - c_3) (N(\theta-1)) < 0 \\ \frac{d\Pi_3}{d\theta} &= \frac{1}{2} (N(1-\delta)(1-\theta) - c_3) (N(\delta-1)) < 0 \end{aligned} \quad (3.A.9)$$

In Forslid's monopoly model, as  $\delta$  increases profit unambiguously increases. As (3.A.9) shows, the change in profit with respect to changes in  $\delta$  and  $\theta$  is unambiguously negative if we assume that  $N(1-\delta)(1-\theta) > c_3$ . This is a reasonable assumption since  $N$  is about three-hundred million,  $\delta$  on average ranges from ten to

---

<sup>14</sup> See Appendix A.4 for derivation

twenty percent (HHS, 2007), and the recommended population proportion for low and high risk groups together this year was seventy-three percent (Werble, 2006). Marginal costs are assumed to be of much smaller magnitude than  $N(1-\delta)(1-\theta)$ , which ranges from the above estimations from 64.8 to 72.9 million. As a result, the comparative statics listed in (3.A.9) are all negative in sign.

The demand from the high risk population for the injectable vaccine will be the residual demand from the ex-ante period. Assuming that firms one and two have produced enough vaccine to cover the entire high risk population, price competition in the ex-post period will result in the two firms splitting the market. I assume that the two firms compete in a Bertrand duopoly in the ex-post high risk individuals market, because supply is fixed due to the long production process. Firms make supply decisions a year before the demand is known. In the segmented model, I assume the injectable firms make their output decisions based on  $\theta$ , and therefore must produce in order to meet the expected ex-ante demand and the expected ex-post demand. Firms make their output decisions based on the knowledge that there will be an ex-post period and adjust their output for a second period demand. Therefore, the firm makes its pricing decisions based on the fixed residual supply from the ex-ante period and chooses to maximize profit with respect to the choice variable price such that the associated first-order conditions for profit maximization are<sup>15</sup>:

$$\begin{aligned}\frac{\partial \Pi_1}{dP_1^{IN}} &= (\theta(N(1-\delta) - \eta[\delta]) + c_1 - \bar{q}_2) - 2P_1^{IN} = 0 \\ \frac{\partial \Pi_2}{dP_1^{IN}} &= (\theta(N(1-\delta) - \eta[\delta]) + c_2 - \bar{q}_1) - 2P_1^{IN} = 0\end{aligned}\tag{3.A.10}$$

---

<sup>15</sup> See Appendix A.5 for derivation

The manufacturing process limits the firms to the amount produced in the ex-ante period; hence, the firms will choose to maximize their profit with respect to price in the ex-post period and supply the  $Min[q_i, \tilde{q}_i]$ ,  $i = 1, 2$  where  $\tilde{q}_i$  is the quantity produced in the ex-ante period minus the quantity supplied in the ex-ante period.

Solving (3.A.10) for firm one, I obtain the resulting price:

$$P_1^{IN} = \frac{(\theta(N(1-\delta) - \eta[\delta]) + c_1 - \bar{q}_2)}{2} \quad (3.A.11)$$

Firms one and two collectively produce<sup>16</sup>:

$$q_1 + q_2 = \frac{(\theta(N(1-\delta) - \eta[\delta]) + c_1 - \bar{q}_2)}{2} \quad (3.A.12)$$

The equilibrium quantities, price and resulting profit equal:

$$\begin{aligned} q_1 &= -\frac{1}{5}((N(\delta-1) + \eta)\theta + 2c_1 - 3c_2) \\ q_2 &= -\frac{1}{5}((N(\delta-1) + \eta)\theta - 3c_1 + 2c_2) \end{aligned} \quad (3.A.13)$$

$$P_1^{IN} = \frac{1}{5}(-2(N(\delta-1) + \eta)\theta + c_1 + c_2)$$

$$\begin{aligned} \Pi_1 &= \frac{1}{25}((N(\delta-1) + \eta[\delta])\theta + 2c_1 - 3c_2)^* \\ &\quad (2(N(\delta-1) + \eta[\delta])\theta + 4c_1 - c_2) - F_1 \end{aligned} \quad (3.A.14)$$

$$\begin{aligned} \frac{d\Pi_1}{d\delta} &= \frac{1}{25}\theta(8c_1 - 7c_2 + 4\theta(N(\delta-1) + \eta[\delta]))\left(N + \frac{d\eta[\delta]}{d\delta}\right) \\ \frac{d\Pi_1}{d\theta} &= \frac{1}{25}(N(\delta-1) + \eta[\delta])(8c_1 - 7c_2 + 4\theta(N(\delta-1) + \eta[\delta])) \end{aligned} \quad (3.A.15)$$

The change in profit with respect to  $\delta$  and with respect to  $\theta$  is ambiguous. I would expect the comparative static for a change in profit with an increase in  $\delta$  to be negative because demand decreases as  $\delta$  increases. If  $c_1 + 4\theta(N(\delta-1) + \eta[\delta]) < 0$ ,

---

<sup>16</sup> Ibid A.6

which is a reasonable assumption given that  $(\delta - 1)$  is negative and the magnitude of  $\eta$  is at least a fraction of  $\theta N$ , because  $\eta$  is the number of high risk people that received the vaccine in period one. The magnitude of  $N$  and  $\eta$  render the addition of marginal cost insignificant such that the comparative static depends on the magnitude of  $\eta$  compared to  $N(\delta - 1)$ . However,  $\eta$  depends on the expectation of  $\delta$ , and as  $\delta$  increases then the expectation of  $\delta$  should also increase and high risk individuals will consume more in the first period;  $\eta$  will increase. Thus, the change in profit with respect to  $\delta$  is ambiguous, which contradicts Forslid's result of an unambiguous increase in profit if  $\delta$  increases. Forslid included a variable to predict the willingness of individuals to receive a vaccine as  $\delta$  changes, which increases as  $\delta$  increases. Therefore, Forslid's change in profit as  $\delta$  increases unambiguously increases. The change in profit with respect to  $\theta$  is also ambiguous and dependent on the magnitude of  $\eta$ . If the assumption made above for the magnitude of  $\eta$  and the population size is correct then the change in profit with respect to  $\delta$  will be negative, and the change in profit with respect to  $\theta$  will be positive. As  $\theta$  increases, demand increases, and I expect profits to increase as well.

For the ex-post period, the price elasticity of demand can be expressed as:

$$\begin{aligned}\xi_{P_1^{IN}} &= (-1) \left( \frac{P_1^{IN}}{\theta(N(1-\delta) - \eta[\delta]) - P_1^{IN}} \right) \\ \xi_{P_1^S} &= (-1) \left( \frac{P_1^S}{(1-\theta)(N(1-\delta)) - P_1^S} \right)\end{aligned}\tag{3.A.16}$$

A change in the price elasticity of demand with respect to  $\delta$  would indicate how an increase in  $\delta$  would affect the change in the flu vaccine's price on the demand for the vaccine. As  $\delta$  increases, the population available to receive the vaccine decreases.

However, the change in the price elasticity with respect to  $\delta$  would help to answer the question of are people sensitive to a price increase with the threat of a more severe flu outbreak. Hence, I consider the following comparative statics:

$$\frac{\partial \xi_{P_1^{IN}}}{\partial \delta} = \frac{-P_1^{IN} \left( \theta \left( N - \frac{\delta \eta}{\delta} \right) \right)}{\left[ \theta (N(1-\delta) - \eta[\delta]) - P_1^{IN} \right]^2} < 0$$

$$\frac{\partial \xi_{P_1^S}}{\partial \delta} = \frac{-(1-\theta)NP_1^S}{\left[ (1-\theta)(N(1-\delta)) - P_1^S \right]^2} < 0$$
(3.A.17)

From (3.A.17), both price elasticities with respect to an increase in  $\delta$  decrease. Since the price elasticities are already negative, a negative change with respect to an increase in  $\delta$  suggests that the price elasticity in absolute value increases. If in absolute value the price elasticity of demand is increasing, it is becoming more elastic. Intuition suggests that the willingness to pay increasingly does not depend on price as  $\delta$  increases, because if the severity of the flu is very high those uninfected remaining may be willing to prevent the flu at any cost. However, (3.A.17) implies that as  $\delta$  increases, the price elasticity of demand becomes more elastic; consumers are more sensitive to price changes. The counterintuitive result, (3.A.17), suggests that the model may not be a good abstraction of the changes of demand with respect to a change in price as  $\delta$  changes. Forslid includes a variable describing the willingness of consumer's to purchase the vaccine as  $\delta$  changes (Forslid, 2005). As  $\delta$  increases, consumer's willingness to purchase a flu vaccine increases; therefore, Forslid's model was able to capture the change in consumer's behavior with respect to a change in the severity of the flu. I did not include such a variable in my model

because I have simplified demand to focus on the dynamics associated with entry and product differentiation in the market.

## **B. Partial Market Segmentation:**

### *Free Entry:*

Assuming that the entrant chooses a differentiated product, the ex-ante period results will be the same as in the segmented market model, (3.A.3). If I use a Bertrand product differentiation duopoly model, there will be partial market segmentation in the ex-post period. Since the nasal spray is licensed only for a subset of the population there are two demand equations and two prices. The injectable firm maximizes its profit with respect to the injectable price while the nasal mist firm must factor in the price of the injectable as well as its own price due to the cross-over in demand in the low risk population for the nasal mist and the injectable vaccines. Let  $\Pi^{IN}$  represent the total profit for the injectable market. For simplicity, I assume that the two incumbents in the injectable market are one firm for the following duopoly analysis. Due to the product differentiation and partial market segmentation, the respective firms maximize  $\Pi^{IN}(P_1^{IN})$ , and  $\Pi_3(P_1^{IN}, P_1^S)$ .

The demand changes from the segmented market such that the injectable demand now includes the entire population not already infected or vaccinated, and the nasal mist demand,  $Q_1^S$ , includes the price of the injectable. The quantity  $Q_1^S$  still excludes the portion of the high risk population since the license for their product prohibits them from supplying the high risk groups. Hence, the partially segmented

model demand equals:

$$\begin{aligned} Q_1^{IN} &= q_1 + q_2 = N(1-\delta) - \eta[\delta] - P_1^{IN} \\ Q_1^S &= q_3 = (1-\theta)(N(1-\delta)) - P_1^S - P_1^{IN} \end{aligned} \quad (3.B.1)$$

Using a Bertrand duopoly model, the injectable firm maximizes profit with respect to price with the resulting first-order condition.<sup>17</sup>

$$\frac{\partial \Pi^{IN}}{\partial P_1^{IN}} = (N(1-\delta) - \eta[\delta] + c_1) - 2P_1^{IN} = 0 \quad (3.B.2)$$

The price and quantity solved from (3.B.2) are equal to:

$$\begin{aligned} P_1^{IN} &= \frac{1}{2}(N(1-\delta) - \eta[\delta] + c_1) \\ Q_1^{IN} &= q_1 + q_2 = \frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1) \end{aligned} \quad (3.B.3)$$

From (3.B.3), profits for the injectable firm are equal to:

$$\begin{aligned} \Pi_1^{IN} &= \frac{1}{4}(N^2(1-\delta)^2 - 2\eta[\delta](N(1-\delta)) + \eta[\delta]^2 + c_1^2) \\ &\quad - c_1 \left( \frac{1}{2}(N(1-\delta) - \eta[\delta]) \right) - F_1 \end{aligned} \quad (3.B.4)$$

The entrant's reaction function includes the price of the injectable vaccine since the population for the nasal mist can choose to consume the injectable or the nasal mist such that the first-order condition, (3.B.5), and resulting reaction function includes the price of the injectable.<sup>18</sup>

$$\frac{\partial \Pi_3}{\partial P_1^S} = (1-\theta)(N(1-\delta)) - \bar{P}_1^{IN} + c_3 - 2P_1^S = 0 \quad (3.B.5)$$

---

<sup>17</sup> See Appendix B.1 for derivation

<sup>18</sup> See Appendix B.2 for derivation

The solution to maximizing profit for the nasal mist price,  $P_1^S$ , and quantity,  $Q_1^S$ , are:

$$\begin{aligned} P_1^S &= \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - \bar{P}_1^{IN} + c_3 \right) \\ Q_1^S &= \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - c_3 \right) - \frac{3}{2} \bar{P}_1^{IN} \end{aligned} \quad (3.B.6)$$

From (3.B.6), profit for the nasal mist firm is equal to:

$$\begin{aligned} \Pi_3 &= \frac{1}{4} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 \\ &\quad - c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) - F_3 \end{aligned} \quad (3.B.7)$$

From the following comparative statics, and a few assumptions, I can sign the change in the injectable price and quantity with respect to an increase in  $\delta$ <sup>19</sup>:

$$\begin{aligned} \frac{\delta P_1^{IN}}{\delta \delta} &= \frac{\delta Q_1^{IN}}{\delta \delta} = -\frac{1}{2} \left( N - \frac{\delta \eta[\delta]}{\delta \delta} \right) < 0 : \text{if } \frac{\delta \eta[\delta]}{\delta \delta} < N \\ \frac{\delta \Pi_1^{IN}}{\delta \delta} &= \frac{1}{2} \left( -N^2(1-\delta) - 2 \frac{\delta \eta[\delta]}{\delta \delta} (N(1-\delta)) + 2\eta[\delta]N + 2\eta[\delta] \frac{\delta \eta[\delta]}{\delta \delta} \right) \\ &\quad - c_1 \left( \frac{1}{2} \left( -N - \frac{\delta \eta[\delta]}{\delta \delta} \right) \right) \end{aligned} \quad (3.B.8)$$

From (3.B.8), if the change in  $\eta$  with respect to an increase in delta is less than N a change in price and quantity with respect to an increase in  $\delta$  is negative. Since  $\eta$ , is the number of individuals that received a vaccine in the ex-ante period, I expect

$\frac{\delta \eta[\delta]}{\delta \delta} > 0$ . The risk of getting the flu increases as a greater portion of the population is

infected; therefore, the high risk population is at greater risk of becoming infected

with the flu virus. Although  $\frac{\delta \eta[\delta]}{\delta \delta} > 0$ , the comparative static,  $\frac{\delta \eta[\delta]}{\delta \delta}$ , should be less

than the magnitude of the U.S. population because  $\eta$  is a portion of  $\theta N$ . Therefore, a

change in  $\eta$  with respect to an increase in  $\delta$  should be less than N. If both

---

<sup>19</sup> Ibid B.3



$\frac{\delta P_1^{IN}}{\delta \delta}, \frac{\delta Q_1^{IN}}{\delta \delta} < 0$  then I would expect  $\frac{\delta \Pi_1^{IN}}{\delta \delta}$  to also be less than zero since both price

and quantity decrease with an increase in  $\delta$ . However,  $\frac{\delta \Pi_1^{IN}}{\delta \delta}$  is ambiguous, and the

intuition cannot be supported by the math. While also ambiguous, the change in the nasal mist firm's profit under a few assumptions can be signed with respect to an increase in  $\delta$  and an increase in  $\theta$ , which is equal to<sup>20</sup>:

$$\begin{aligned}\frac{\delta \Pi_3}{\delta \delta} &= -\frac{1}{2}((1-\theta)N)((1-\theta)N(1-\delta) - P_1^{IN} - c_3) \\ \frac{\delta \Pi_3}{\delta \theta} &= -\frac{1}{2}(N(1-\delta))((1-\theta)(N(1-\delta)) - P_1^{IN} - c_3)\end{aligned}\tag{3.B.9}$$

I expect the change in the nasal mist firm's profit with respect to the parameters  $\delta$  and  $\theta$  to both be negative since the magnitude of  $N$  is in the hundred millions which even small fractions of which should be larger than the sum of the injectable price and the marginal cost.<sup>21</sup> Since the U.S. population is on the magnitude of ten to the eighth and, the marginal cost of producing a vaccine is very low, I can assume that  $((1-\theta)(N(1-\delta)) - P_1^{IN} - c_3)$  is positive which generates negative signs for the comparative statics.

The nasal mist's quantity should be negatively correlated with an increase in  $\theta$  since an increase in  $\theta$  indicates a decrease in the nasal mist's demand, as does an increase in  $\delta$ . If more people are infected with the virus, there are fewer candidates

<sup>20</sup> See Appendix B.3 for derivation

<sup>21</sup> The injectable vaccine has ranged from two to ten dollars over the past seven years (CDC).

who are able to receive the vaccine as given by the negative comparative statics:

If  $\theta, \delta < 1$

$$\frac{\delta P_1^S}{\delta \delta} = \frac{\delta Q_1^S}{\delta \delta} = -\frac{1}{2}N(1-\theta) < 0 \quad (3.B.10)$$

$$\frac{\delta P_1^S}{\delta \theta} = \frac{\delta Q_1^S}{\delta \theta} = -\frac{1}{2}N(1-\delta) < 0$$

$$\frac{\delta Q_1^S}{\delta P_1^{IN}} = -\frac{3}{2} < 0 \quad (3.B.11)$$

If  $\theta$  and/or  $\delta$  is equal to one, the comparative statics on the nasal mist are trivial since the population available to receive the vaccine would be zero. Hence, I assume that  $\theta$  and  $\delta$  are not equal to one. If  $\theta$  and  $\delta$  are not equal to one, increasing  $\theta$  or  $\delta$  results in a decrease in the nasal mist's quantity and price, because the population available to receive the vaccine decreases.

*Limited Entry:*

If the incumbent firms know that the entrant will produce a product that can only be marketed in the ex-post period, the incumbents can estimate what price is necessary to force the entrant to zero profit in the ex-post period, and price slightly below the ex-post zero profit condition. For the partially segmented market the ex-post zero profit condition for the entrant is<sup>22</sup>:

$$P_1^S = \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) \pm \frac{1}{2} \sqrt{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)} \quad (3.B.12)$$

---

<sup>22</sup> See Appendix B.4 for derivation

Solving (3.B.12) the injectable price is equal to<sup>23</sup>:

$$P_1^{IN} = \frac{F_3 + P_1^S (N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S)}{(N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S)} \quad (3.B.13)$$

If the incumbents lowered the injectable price an epsilon below (3.B.13) assuming all else held constant, the incumbents would deter entry by the nasal spray firm, which would make below normal profits. Since the injectable firms also participate in the ex-ante period, they could make negative profit in the ex-post period in order to deter entry from the nasal mist as long as across both periods the injectable firms make at least normal profit.

As  $\delta$  changes the change in price for the nasal mist at the zero profit condition is<sup>24</sup>:

$$\frac{\delta P_1^S}{\delta \delta} = -\frac{N}{2}(1-\theta) \pm \frac{((1-\theta)(N(1-\delta)) - P_1^{IN} - c_3)N(1-\theta)}{\sqrt{((1-\theta)(N(1-\delta)) - P_1^{IN} + c_3)^2 - 4(c_3((1-\theta)(N(1-\delta)) - P_1^{IN}) + F_3)}} \quad (3.B.14)$$

The effect of a change in  $\delta$  on the nasal mists price in the ex-post period is ambiguous. However, if the denominator of the fraction,

$\sqrt{((1-\theta)(N(1-\delta)) - P_1^{IN} + c_3)^2 - 4(c_3((1-\theta)(N(1-\delta)) - P_1^{IN}) + F_3)}$  is greater than

$((1-\theta)(N(1-\delta)) - P_1^{IN} - c_3)N(1-\theta)$ , an increase in  $\delta$  will result in a decrease in

price for the nasal mist. Hence, the price decreases and *ceteris paribus* profits

decrease. Therefore, the nasal mist firm will exit the market since they are already

operating at the zero profit margin. Since the nasal mist does not supply a product

---

<sup>23</sup> Ibid B.5

<sup>24</sup> Ibid B.6

during both demand periods, the firm must make at least zero profit in the ex-post period. If the nasal mist is not going to make zero profit the firm should not enter the market. An increase in  $\delta$  also results in a decrease in price for the injectable firm, as shown in the comparative static (3.B.15).

$$\frac{\delta P_1^{IN}}{\delta \delta} = \frac{N(\theta - 1)F_3}{(N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S)^2} < 0 \quad (3.B.15)$$

In the zero profit condition the price of the injectable decreases with an increase in  $\delta$  as it did in the free entry partially segmented model. Similar reasoning indicates that, as  $\delta$  increases, the quantity demanded decreases and therefore price decreases. Therefore, as  $\delta$  increases, both prices, the injectable and the nasal mist, decrease and *ceteris paribus* profits decrease for all the vaccine firms. Hence, I conclude that it is more profitable for the firms if  $\delta$  does not increase, which contradicts Forslid's unambiguously increase in profit with respect to an increase in  $\delta$ .

### **C: Homogenous Product Oligopoly**

#### *Ex-Ante Period:*

If the entrant decides to enter the market with an injectable vaccine instead of a nasal mist vaccine the Stackelberg leader duopoly problem from the segmented model in the ex-ante period is extended to include three firms with three separate reaction functions. The incumbents have an advantage from their experience in the market; hence, the incumbent's marginal costs will be lower than the entrant's marginal costs:  $c_1 = c_2 < c_3$ . The fixed costs can also be assumed to be greater for the entrant for the large facility start-up costs they will incur. I assume first that the all

participants make above normal profit, and second that the incumbents can earn above normal profit while the entrant earns normal profit in both periods.

*Free Entry:*

The ex-ante demand from the segmented model now includes one more firm such that  $Q_0 = \sum_{i=1}^3 q_i = \theta N - P_0$  where  $P_0^{IN} = \theta N - q_1 - q_2 - q_3$ :  $c_1 = c_2 < c_3$ . Assume each firm maximizes their profit,  $\Pi_0^{IN} = (\theta N - q_i - q_j - q_k)q_i - c_i q_i - F_i$ , with respect to their quantity given the associated first-order conditions for each firm:

$$\begin{aligned}\frac{d\Pi_1}{dq_1} &= N\theta - 2q_1 - \bar{q}_2 - \bar{q}_3 - c_1 = 0 \\ \frac{d\Pi_2}{dq_2} &= N\theta - 2q_2 - \bar{q}_1 - \bar{q}_3 - c_2 = 0 \\ \frac{d\Pi_3}{dq_3} &= N\theta - 2q_3 - \bar{q}_1 - \bar{q}_2 - c_3 = 0\end{aligned}\tag{3.C.1}$$

The equilibrium quantities solved from (3.C.1) are<sup>25</sup>:

$$\begin{aligned}q_1 &= \frac{N\theta - 3c_1 + c_2 + c_3}{4} \\ q_2 &= \frac{N\theta + c_1 - 3c_2 + c_3}{4} \\ q_3 &= \frac{N\theta + c_1 + c_2 - 3c_3}{4}\end{aligned}\tag{3.C.2}$$

where  $q_3 < q_1 = q_2$  since the costs for the entrant are assumed to be greater than the costs of the incumbents. Consistent with the segmented and partially segmented

---

<sup>25</sup> See Appendix C.1 for derivation

models, only one price will exist in the ex-ante period, that of the injectable vaccine<sup>26</sup>:

$$P_0^{IN} = \frac{\theta N + c_1 + c_2 + c_3}{4} \quad (3.C.3)$$

Assuming  $c_1 = c_2$  the injectable firms earn profit equal to<sup>27</sup>:

$$\begin{aligned} \Pi_1 &= \left( \frac{(\theta N)^2 - c_1(2c_1 + \theta N + c_3) + c_3(2\theta N + c_3) - 4F_1}{4} \right) \\ \Pi_3 &= \left( \frac{(\theta N)^2 - c_1(-4c_1 - 4\theta N + 6c_3) - 3c_3\theta N - 4F_3}{4} \right) \end{aligned} \quad (3.C.4)$$

As expected from the difference in marginal and fixed costs, profit earned by the incumbents is greater than profit earned by the entrant as derived in Proposition 1.

**Proposition 1:**  $\Pi_1 > \Pi_3$

*Proof:*

Assume the contrary  $\Pi_3 > \Pi_1$

$$\begin{aligned} &\left( \frac{(\theta N)^2 - c_1(2c_1 + \theta N + c_3) + c_3(2\theta N + c_3) - 4F_1}{4} \right) \\ &< \left( \frac{(\theta N)^2 - c_1(-4c_1 - 4\theta N + 6c_3) - 3c_3\theta N - 4F_3}{4} \right) \end{aligned}$$

$$(\theta N)^2 - c_1(2c_1 + \theta N + c_3) + c_3(2\theta N + c_3) - 4F_1 < (\theta N)^2 - c_1(-4c_1 - 4\theta N + 6c_3) - 3c_3\theta N - 4F_3$$

$$-2c_1^2 - c_1\theta N - c_3c_1 + 2c_3\theta N + c_3^2 - 4F_1 < 4c_1^2 + 4c_1\theta N - 6c_3c_1 - 3c_3\theta N - 4F_3$$

$$c_3^2 + 5c_3c_1 + 5c_3\theta N - 4F_1 < 6c_1^2 + 5c_1\theta N - 4F_3$$

Since  $c_3 > c_1$ ,  $\Rightarrow c_3c_1 > c_1^2, c_3^2 > c_1^2 \therefore c_3^2 + 5c_3c_1 > 6c_1^2$ , and  $5c_3\theta N > 5c_1\theta N$

$F_1 < F_3$ ,  $\Rightarrow -4F_1 > -4F_3$ . There exists a contradiction such that

$$(c_3^2 + 5c_3c_1 + 5c_3\theta N - 4F_1) > (6c_1^2 + 5c_1\theta N - 4F_3)$$

$\therefore \Pi_1 > \Pi_3$ . Q.E.D

<sup>26</sup> See Appendix C.2

<sup>27</sup> See Appendix C.3 for derivation

As  $\theta$  increases in the ex-ante period, both price and profit increase

unambiguously,  $\frac{dP_0^{IN}}{d\theta} > 0$  and  $\frac{d\Pi_1}{d\theta} > 0$ . The comparative statics with respect to  $\theta$  in the injectable ex-ante segmented and partially segmented models are also positive. In all three models as  $\theta$  increases the demand and price in the ex-ante period increases for the injectable vaccine as shown in (3.C.5):

$$\begin{aligned}\frac{dP_0^{IN}}{d\theta} &= N > 0 \\ \frac{d\Pi_1}{d\theta} &= \frac{N(2\theta N + 2c_3 - c_1)}{4} > 0 \\ \frac{d\Pi_3}{d\theta} &= \frac{N(2\theta N + 4c_1 - 3c_3)}{4}\end{aligned}\tag{3.C.5}$$

From (3.C.5), as  $\theta$  increases, profit increases for the incumbents unambiguously. If I assume that the magnitude of  $N$  is much greater than marginal cost, the change in profit for the entrant is also positive with respect to an increase in  $\theta$ . Since I assume that the costs for the entrant are greater than the incumbents,  $c_3 > c_1$ , a change in  $\theta$  has a larger affect on the incumbents profit as shown in Proposition 2:

**Proposition 2:**  $\frac{d\Pi_1}{d\theta} > \frac{d\Pi_3}{d\theta}$

*Proof:*

Assume  $\frac{d\Pi_1}{d\theta} < \frac{d\Pi_3}{d\theta}$

$$\frac{N(2\theta N + 2c_3 - c_1)}{4} < \frac{N(2\theta N + 4c_1 - 3c_3)}{4} : N > 0$$

$$2\theta N + 2c_3 - c_1 < 2\theta N + 4c_1 - 3c_3$$

$$2c_3 - c_1 < 4c_1 - 3c_3$$

$5c_3 < 5c_1$  which contradicts the assumption  $c_3 > c_1$

$$\therefore \frac{d\Pi_1}{d\theta} > \frac{d\Pi_3}{d\theta} \text{ Q.E.D.}$$

The incumbents earn a larger profit if  $\theta$  increases compared to the entrant, because I assumed the incumbents have a lower cost structure compared to the entrant's cost structure.

*Limited Entry:*

If the incumbent firms try to deter entry, the incumbents would want to know the entrant's zero profit price to set a price slightly lower than the zero profit price that would deter entry. Given the assumed profit function, the incumbents determine that the zero profit quantity for the entrant is equal to<sup>28</sup>:

$$q_3 = \frac{-(\theta N - q_1 - q_2 - c_3) \pm \sqrt{(\theta N - q_1 - q_2 - c_3)^2 - 4F_3}}{-2} \quad (3.C.6)$$

Since the incumbents know their own quantities and assuming that they can estimate the entrant's costs, the incumbents choose a price or quantity at which the entrant's quantity would be below that of (3.C.6). At this point the entrant would decide not to enter the market since they would make below normal profit. Solving the set of first-order equations with the zero profit condition imposed on the nasal mist firm the new quantities supplied with their corresponding equilibrium solutions are<sup>29</sup>:

$$\begin{aligned} q_1 &= \frac{\theta N - \bar{q}_2 - \bar{q}_3 - c_1}{2} \\ &= \frac{1}{6} \left( \theta N - 5c_1 + c_2 + 3c_3 \pm \sqrt{(\theta N + c_1 + c_2 - 3c_3)^2 - 12F_3} \right) \\ q_2 &= \frac{\theta N - \bar{q}_1 - \bar{q}_3 - c_2}{2} \\ &= \frac{1}{6} \left( \theta N + c_1 - 5c_2 + 3c_3 \pm \sqrt{(\theta N + c_1 + c_2 - 3c_3)^2 - 12F_3} \right) \\ q_3 &= \frac{1}{2} \left( \theta N + c_1 + c_2 + 3c_3 \pm \sqrt{(\theta N + c_1 + c_2 - 3c_3)^2 - 12F_3} \right) \end{aligned} \quad (3.C.7)$$

<sup>28</sup> See Appendix C.4 for derivation

<sup>29</sup> Ibid C.5



I expect a change in  $\theta$  to have a positive affect on the quantities supplied in the ex-ante period, but the comparative static with respect to  $\theta$  is ambiguous as shown in

(3.C.8):

$$\begin{aligned}\frac{\partial q_1}{\partial \theta} = \frac{\partial q_2}{\partial \theta} &= \frac{N}{6} \left( 1 \pm \frac{(\theta N + c_1 + c_2 - 3c_3)}{\sqrt{(\theta N + c_1 + c_2 - 3c_3)^2 - 12F_3}} \right) \\ \frac{\partial q_3}{\partial \theta} &= \frac{N}{2} \left( 1 \pm \frac{(\theta N + c_1 + c_2 - 3c_3)}{\sqrt{(\theta N + c_1 + c_2 - 3c_3)^2 - 12F_3}} \right)\end{aligned}\tag{3.C.8}$$

The fraction is greater than one inside the parenthesis; therefore, the sign of the comparative static depends on whether the expression inside the parentheses is an addition or subtraction. If it is an addition, then the change in quantity with respect to  $\theta$  is positive, and vice versa for subtraction. However, a change in  $\theta$  unambiguously has a greater impact on quantity for the entrant. An increase in  $\theta$  should unambiguously increase market demand, but since I am solving for the entrant's zero profit quantity the comparative statics imply that the change in the firms' quantities are ambiguous. Therefore, the model is not a good abstraction of this situation.

*Ex-Post Period:*

*Free Entry:*

The ex-post period is also a capacity constrained problem due to the time constraints associated with the production process. Each firm is constrained by their maximal output from the ex-ante period minus the number of vaccinations distributed

in the ex-ante period such that demand and profit can be written as:

$$Q_1 = N(1-\delta) - \eta[\delta] - P_1 \quad (3.C.9)$$

$$\text{Min}(Q_1, \bar{Q}_1)$$

$$\Pi_1 = (P_1 - c_1)(N(1-\delta) - \eta[\delta] - P_1) - F_1 \quad (3.C.10)$$

If the firms compete in prices, the third firm will have to charge a higher price due to its higher marginal costs compared to firms one and two as implied by the first-order conditions, (3.C.11).

$$\begin{aligned} \frac{d\Pi_1}{dP_1} &= N(1-\delta) - \eta[\delta] + c_1 - 2P_1 = 0 \\ \frac{d\Pi_2}{dP_2} &= N(1-\delta) - \eta[\delta] + c_2 - 2P_2 = 0 \\ \frac{d\Pi_3}{dP_3} &= N(1-\delta) - \eta[\delta] + c_3 - 2P_3 = 0 \end{aligned} \quad (3.C.11)$$

Since the vaccines produced by all three companies are homogenous, the third firm would not earn profit, if it charged its optimal price,  $P_3$ , because consumers can buy the same product at a lower price,  $P_1$ . Therefore, the third firm must lower its price and charge the price of the other two firms. Hence, the market price is equal

to  $P_1 = P_2 = \frac{N(1-\delta) - \eta[\delta] + c_1}{2}$  and the total quantity supplied is<sup>30</sup>:

$$Q_1 = \frac{N(1-\delta) - \eta[\delta] - c_1}{2} \quad (3.C.12)$$

Profits made by the incumbent firms are greater than profits earned by the entrant.

This can be attributed to the lower cost structure for the incumbents. Following from the difference in cost structures, profits earned by the entrant are lower than profits

---

<sup>30</sup> See Appendix C.6 for derivation

earned by the incumbents, (3.C.13)<sup>31</sup>, since  $c_3 > c_1$ , and therefore

$$(N(1-\delta)-\eta[\delta]+c_1-2c_3)(N(1-\delta)-\eta[\delta]-c_1) < (N(1-\delta)-\eta[\delta]-c_1)^2:$$

$$\Pi_1 = \frac{1}{12}(N(1-\delta)-\eta[\delta]-c_1)^2 - F_1 \quad (3.C.13)$$

$$\Pi_3 = \frac{1}{12}(N(1-\delta)-\eta[\delta]+c_1-2c_3)(N(1-\delta)-\eta[\delta]-c_1) - F_3$$

$$\frac{\partial \Pi_1}{\partial \delta} = -\frac{1}{6}(N(1-\delta)-c_1-\eta[\delta])\left(N + \frac{\partial \eta[\delta]}{\partial \delta}\right) < 0 \quad (3.C.14)$$

$$\frac{\partial \Pi_3}{\partial \delta} = -\frac{1}{6}(N(1-\delta)+c_3-\eta[\delta])\left(N + \frac{\partial \eta[\delta]}{\partial \delta}\right) < 0$$

As  $\delta$  increases, demand decreases and I expect profits to decrease for both the entrant and the incumbent, as supported by (3.C.14).

#### *Limited Entry:*

If the incumbents induce the entrant to zero profit in the ex-post period to limit entry, the entrant's zero profit quantity equals<sup>32</sup>:

$$q_3 = \frac{1}{2}(N(1-\delta)-\eta[\delta]-\bar{q}_1-\bar{q}_2-c_3) \pm \frac{1}{2}\sqrt{(N(1-\delta)-\eta[\delta]-\bar{q}_1-\bar{q}_2-c_3)^2 - 4F_3} \quad (3.C.15)$$

Solving for the equilibrium, the incumbent's and the entrant's quantities equal:

$$q_1 = q_2 = \frac{1}{4}\left(N(1-\delta)-c_1-\eta[\delta] + \frac{4F_3}{N(\delta-1)-c_1+2c_3+\eta[\delta]}\right) \quad (3.C.16)$$

$$q_3 = \frac{2F_3}{N(1-\delta)+c_1-2c_3-\eta[\delta]}$$

<sup>31</sup> Ibid C.7

<sup>32</sup> See Appendix C.8 for derivation

Again the comparative static effects of the change in quantities with respect to a change in  $\delta$  are different from incumbents and the entrant. As  $\delta$  increases, the incumbent's quantity decreases and the entrant's quantity increases.

$$\frac{\partial q_1}{\partial \delta} = -\frac{1}{4} \left( \left( N + \frac{\partial \eta[\delta]}{\partial \delta} \right) + \frac{4F_3 \left( N + \frac{\partial \eta[\delta]}{\partial \delta} \right)}{\left( N(1-\delta) - c_1 + 2c_3 + \eta[\delta] \right)^2} \right) < 0 \quad (3.C.17)$$

$$\frac{\partial q_3}{\partial \delta} = \frac{2F_3 \left( N + \frac{\partial \eta[\delta]}{\partial \delta} \right)}{\left( N(1-\delta) + c_1 - 2c_3 - \eta[\delta] \right)^2} > 0$$

Since the entrant is at the zero profit quantity, if  $\delta$  increases then price decreases and in order to make zero profit the nasal mist firm must increase their quantity, as shown from the positive comparative static for the entrant in (3.C.17). The incumbent's quantity decreases as the severity increases in the limited entry because price decreases and the incumbents are maximizing their profit with respect to price. If price decreases, the incumbents quantity supplied will also decrease as seen in the comparative static in (3.C.17). Therefore, in the limit entry strategy there are countervailing tendencies between the incumbent's quantity and the entrant's quantity resulting from the zero profit condition.

## Chapter 4 Welfare Analysis and Implications in the Current Market

The flu vaccine has positive social externalities such that the U.S. government has an interest in the market dynamics. An examination of the consumer surplus derived from the three models discussed, and a case study of the shortage in 2004 elucidates why the government is interested in increasing and expanding the market. Given the recent subsidies distributed in the market, I analyze the effect of subsidies on the three models discussed in this paper as a method for expanding the market. The unique production process failures associated with biologics as illustrated by the shortage in 2004 and the jump in the Herfindahl index explains the recent keen interest from the government in expanding the market.

### A. Consumer Surplus:

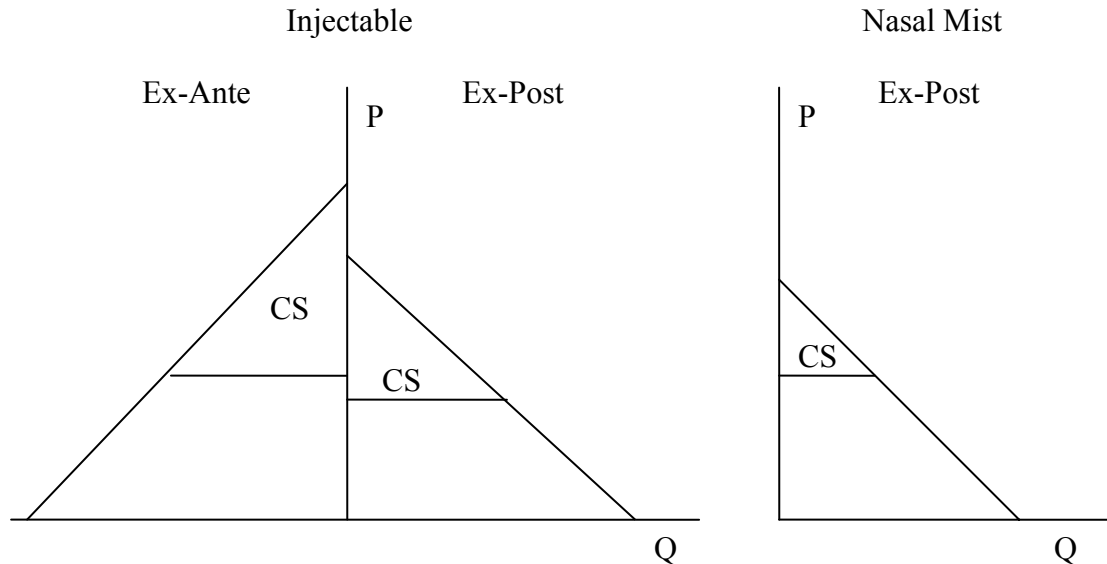
Consumer surplus is spread across the two different periods, the ex-ante and ex-post, which include the consumer surplus gained from both products in the ex-post period. Figure 1 explains the various components of consumer surplus including all three separate calculations for consumer surplus in the segmented market. In the segmented market model, the ex-ante consumer surplus is equal to<sup>33</sup>:

$$CS_0 = \frac{(2\theta N - c_2 - c_1)^2}{18} \quad (4.A.1)$$

In the ex-post period of the segmented model, consumer surplus includes consumer surplus from both the injectable market and the nasal mist market as outlined in Figure 1.

---

<sup>33</sup> See Appendix D.1 for derivation

**Figure 1: Consumer Surplus Overview: Segmented Market**

The ex-post consumer surplus is equal to<sup>34</sup>:

$$\begin{aligned}
 CS_1^{IN} &= -\frac{1}{50} \left( \frac{(c_1 + c_2 - 2\theta(N(\delta - 1) + \eta[\delta]))^*}{(c_1 + c_2 + 3\theta(N(\delta - 1) + \eta[\delta]))} \right) \\
 CS_1^S &= \frac{1}{8} \left( (N(1 - \delta - \theta + \delta\theta))^2 - c_3^2 \right) \\
 \text{Total } CS_1 &= CS_1^{IN} + CS_1^S = \tag{4.A.2} \\
 CS_1 &= \frac{1}{8} \left( (N(1 - \delta - \theta + \delta\theta))^2 - c_3^2 \right) - \\
 &\quad \frac{1}{50} \left( \frac{(c_1 + c_2 - 2\theta(N(\delta - 1) + \eta[\delta]))}{*(c_1 + c_2 + 3\theta(N(\delta - 1) + \eta[\delta]))} \right)
 \end{aligned}$$

In (4.A.2) consumer surplus in the injectable market is positive because

$$(c_1 + c_2 - 2\theta(N(\delta - 1) + \eta[\delta])) > 0 \text{ and } c_1 + c_2 + 3\theta(N(\delta - 1) + \eta[\delta]) < 0 \text{ all}$$

because  $\delta - 1 < 0$ . Consumer surplus should increase moving from the segmented

<sup>34</sup> Ibid D.2

model to the partially segmented model because there is more competition with the cross-over in demand from the nasal mist population into the injectable population.

The ex-ante consumer surplus in the partially segmented model is the same as in segmented model since the market ex-ante period includes only the injectable firms, and the quantities and prices remain the same. Consumer surplus for the ex-post period in the partially segmented model changes from the segmented model and is equal to:

$$\begin{aligned}
 CS_1^{IN} &= \frac{1}{8}(N(1-\delta) - \eta[\delta] - c_1)^2 \\
 CS_1^S &= \frac{1}{4} \left( \begin{aligned} &N^2(\delta-1)^2(\theta-1)^2 + c_3^2 - 4N(\delta-1)(\theta-1)\bar{P}_1^{IN} + 3(\bar{P}_1^{IN})^2 \\ &+ 2c_3(N(-1+\delta+\theta-\delta\theta) + 2\bar{P}_1^{IN}) \end{aligned} \right) \quad (4.A.3) \\
 CS_1^{IN} + CS_1^S &= \frac{1}{8}(N(1-\delta) - \eta[\delta] - c_1)^2 \\
 &+ \frac{1}{4} \left( \begin{aligned} &N^2(\delta-1)^2(\theta-1)^2 + c_3^2 - 4N(\delta-1)(\theta-1)\bar{P}_1^{IN} \\ &+ 3(\bar{P}_1^{IN})^2 + 2c_3(N(-1+\delta+\theta-\delta\theta) + 2\bar{P}_1^{IN}) \end{aligned} \right)
 \end{aligned}$$

The overall change in consumer surplus is ambiguous from the segmented to the partially segmented model in the ex-post period, which does not support my intuition.

The homogenous product oligopoly ex-ante consumer surplus is equal to<sup>35</sup>:

$$CS_0 = \frac{1}{32}(3\theta N - c_1 - c_2 - c_3)^2 \quad (4.A.4)$$

In the homogenous product oligopoly model, the ex-ante consumer surplus, (4.A.4), is greater than the ex-ante consumer surplus in the segmented and partially segmented models, (4.A.1), because an additional firm enters the ex-ante period, as shown in Proposition 3.

---

<sup>35</sup> Ibid D.4

**Proposition 3:**  $\frac{1}{32}(3\theta N - c_1 - c_2 - c_3)^2 > \frac{1}{18}(2\theta N - c_2 - c_1)^2 : (4.A.4) > (4.A.1)$

*Proof:*

$$\text{Assume the contrary: } \frac{(3\theta N - c_1 - c_2 - c_3)^2}{16} < \frac{(2\theta N - c_2 - c_1)^2}{9}$$

$$\frac{(3\theta N - c_1 - c_2 - c_3)}{4} < \frac{(2\theta N - c_2 - c_1)}{3}$$

$$\frac{(9\theta N)}{12} - \frac{3(c_1 + c_2 + c_3)}{12} < \frac{8\theta N}{12} - \frac{4(c_2 + c_1)}{12}$$

$\theta N < 3c_3 - c_2 - c_1$  which contradicts the assumptions  $N \gg c_i$  for all  $i$

$$\therefore \frac{(3\theta N - c_1 - c_2 - c_3)^2}{32} > \frac{(2\theta N - c_2 - c_1)^2}{18} \text{ Q.E.D}$$

This is consistent with theory that as the market grows, more competition leads to larger consumer surplus. However, the ex-post period is smaller in the homogenous product oligopoly, (4.A.5), than in the partially segmented model<sup>36</sup>.

$$CS_1 = \frac{1}{8}(N(1-\delta) - \eta[\delta] - c_1)^2 \quad (4.A.5)$$

An explanation for the difference would be that the consumer surplus from the nasal mists captures a portion of the population that would otherwise not receive a vaccine since it is in an injectable form. The nasal mist offers another delivery method for the vaccine that enlarges the consumer's options with product differentiation capturing a portion of the market untapped by the injectable vaccine. Therefore, I conclude that it is better from the consumer surplus standpoint to have more manufacturers in the market, as we see the ex-ante consumer surplus increase with increased homogenous product competition. It is also welfare increasing to have manufacturers producing differentiated products, as the ex-post period consumer surplus increases with the introduction of differentiated products.

---

<sup>36</sup> Ibid D.5



## **B. Subsidies:**

Due to the increased threat of a pandemic influenza, the U.S. government is subsidizing through direct cash subsidies the fixed costs for the influenza manufacturer's refurbishing, upgrading, and building of new facilities for the influenza vaccine. The cash subsidies for new facilities are aimed at increasing capacity of the current egg-based technology facilities and constructing new facilities for the future cell-culture production process.

The Department of Health and Human services has committed over "\$1.1 billion to six companies to advance cell-culture production" (Werble, 2006). Part of the \$1.1 billion is going to GSK and Novartis in the form of grants, of which GSK is using part of its subsidy to update its newly acquired facility in Pennsylvania for its new U.S. egg-based production hub (Werble, 2006). MedImmune also won a \$170 million contract from the government based on their experience producing a live virus vaccine, the nasal mist. In the case were the nasal mist might be viewed as a flop in the market, the experience gained from producing a differentiated product might have enhanced their potential to earn future profits with the changing technology. However, the new technology is not going to be available to the market until at least 2011, when GSK expects to have a facility ready to produce the vaccine using new technology (Werble, 2006). The egg-based production process is still the only process licensed to manufacture the flu vaccine in the U.S.

If the U.S. government subsidizes fixed costs, profit for all firms is insured to be above normal in all three of the models. Let the government subsidy be represented as a fraction,  $\alpha_i : i = 1, 2, 3$ , of the total fixed costs, F. Therefore, the new cost structure

can be written as  $C_i = c_i q_i + F_i(1 - \alpha_i) : i = 1, 2, 3$ . Hence, the impact of an increase in  $\alpha$  on profit is positive because as alpha increases, total costs decrease:  $\frac{\partial C_i}{\partial \alpha} = -F_i < 0$ .

Therefore, as alpha increases profit will also increase unambiguously for all the models, except in the case of the zero profit condition. Alpha does not have an effect on price or quantity in the ex-ante period or the ex-post duopoly competition until the zero profit condition is examined, because alpha drops out of the equation when the reaction functions are derived.

In the segmented market the quantities and prices calculated will be the same since fixed costs drop out of the equations when the first-order maximization equations are derived. Therefore, the fixed cost subsidy will have a direct positive effect on profit, because as alpha increases, costs decrease, and profit increases: in the ex-ante and ex-post periods  $\frac{d \Pi_i}{d \alpha} = F_i > 0, i = 1, 2, 3$ .

In the partially segmented model,  $\frac{d \Pi_i}{d \alpha}$  is equal to that of the segmented model in all the cases except for the limited entry case. Due to the zero profit condition an increase in  $\alpha$  should have a positive effect on the price of the injectable vaccine and an ambiguous effect on the price of the nasal mist. Hence, I consider the following comparative statics:

$$\begin{aligned} \frac{\partial P_1^{IN}}{\partial \alpha} &= \frac{-F_3}{(-N((1-\delta)(1-\theta)) + c_3 + P_1^S)} > 0 \\ \frac{\partial P_1^S}{\partial \alpha} &= \pm \frac{1}{4} \frac{-F_3}{\sqrt{\left( ((1-\theta)(N(1-\delta)) - P_1^{IN} + c_3)^2 \right.}} \quad (4.B.1) \\ &\quad \left. \sqrt{-4(c_3((1-\theta)(N(1-\delta)) - P_1^{IN}) + F_3(1-\alpha))} \right)} \end{aligned}$$

Without the zero profit condition, profits unambiguously increase with an increase in the subsidy. Hence, if profits increase with an increase in the subsidy then the price satisfying a zero profit condition on the third firm should also increase. This implies that the price of the injectable vaccine will increase in the zero profit condition, because the injectable firms can charge a higher price and still force the entrant to earn normal profit. I would expect the price of the nasal mist to increase, but the comparative static implies that it is ambiguous as derived from solving the quadratic equation.

In the homogenous product model, a change in alpha in the ex-ante period has a positive effect on profit for all three firms:  $\frac{d\Pi_i}{d\alpha} = F_i > 0, i = 1, 2, 3$ . In the zero profit condition a change in alpha has an ambiguous affect on the quantity for the entrant, and the partial with respect to profit is trivial since profit is zero for the entrant. The comparative statics with respect to  $\alpha$  equal:

$$\begin{aligned} \frac{\partial q_1}{\partial \alpha} = \frac{\partial q_2}{\partial \alpha} &= \left( \pm \frac{F_3}{\sqrt{(N\theta + c_1 + c_2 - 3c_3)^2 - 12F_3(1-\alpha)}} \right) \\ \frac{\partial q_3}{\partial \alpha} &= - \frac{\pm F_3}{\sqrt{(\theta N - q_1 - q_2 - c_3)^2 - 4F_3(1-\alpha)}} \end{aligned} \quad (4.B.2)$$

From (4.B.2), an increase in  $\alpha$  has an ambiguous effect on all the injectable firms in the limited entry case. If subsidies increase, profits should unambiguously increase providing an entry signal to firms considering entering the market. If profits unambiguously increase as  $\alpha$  increases, I expect the entrant's zero profit price would also increase as overall profit has increased. However, the comparative statics in (4.B.2) suggest that the model might not be a good abstraction of the situation. A

profit signal is helpful in attracting possible entrants into the market. The current market structure as shown by the Herfindahl index supports the reasoning behind government subsidies to provide the profit signal needed for expanding the market.

### C. Market Shares:

The Herfindahl index shows the industry concentration in the influenza market,  $\sum_{i=1}^n (100s_i)^2$  where  $s_i$  is the market share of firm  $i$ . The numbers below show the Herfindahl Index from the 2000-01 flu season to the 2004-05 season. In the 2000-01 flu season there were three firms in the market all producing an injectable product. In the 2003-04 flu season the nasal mist product enters the market and one of the injectable firms exits the market. In 2004-05 a shortage occurred due to a contamination in Chiron's supply resulting in a loss of its entire supply. Since Chiron was estimated to supply almost half of the market demand, the market concentration rose, as shown in Table 3, when Chiron pulled their vaccine supply for the 2004-05 season (GAO, 2005). The remaining injectable firm supplied most of the demand which explains the jump in the Herfindahl index.

**Table 3: Herfindahl Index 2000-2005**

Year	2000-01	2001-02	2002-03	2003-04	2004-05*
Herfindahl Index	3662	4186	3238	4462	9418

Source: Danzon et al.

\* Shortage Year

The jump in the Herfindahl index in the 2004-05 flu season is an interesting example of how the nasal mist firm did not capture a large portion of the market when there was high demand for the flu vaccine. An examination of the 2004 shortage reveals the

dangers as illustrated by the jump in the Herfindahl index as a result of production uncertainty with a few firms in the market.

#### **D. The 2004 Shortage**

In the 2004-2005 influenza season three manufacturers participated in the market: Aventis Pasteur (injectable), Chiron (injectable), and MedImmune (nasal mist). Chiron announced in October of 2004 that its license for the influenza vaccine had been temporarily suspended, and it would not be distributing vaccine for the current season, which was expected to be about half of the season's supply of the influenza vaccine. The influenza vaccine shot significantly dominates the market. In the 2003-2004 season Aventis and Chiron produced about 96 percent of the United States influenza vaccine (GAO, 2005).

The CDC and the Advisory Committee on Immunization Practices (ACIP) recommend target groups, including both the low and high risk populations, for vaccination every year. The CDC recommended that about 185 million people receive the influenza vaccine in May 2004 (*Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004). Most of the influenza vaccine is distributed and administered by the private sector. There are "relatively small amounts of the vaccine purchased and distributed by the CDC or by state and local health departments" (*Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004). The CDC estimated that there would be about 100 million doses of the influenza vaccine available in the 2004-2005 season (*Statement of Janet*

*Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004). In August of 2004, Chiron announced that a small portion of the vaccine did not meet sterility specifications and their distribution would be delayed. On October 5, 2004, Chiron announced that their license had been temporarily suspended by the regulatory agency in the United Kingdom. Chiron's manufacturing plant is in the U.K. and therefore their vaccine shipments are subject to both the U.S. and the U.K. regulatory agencies.

After the Chiron announcement on October 5, 2004, the ACIP revised and redistributed their recommendations for the target groups for a flu shot. Aventis had already distributed a portion of their supply, which led to a surplus of the vaccine to providers who had ordered from Aventis, while no vaccine was available to those providers who had ordered from Chiron. Aventis was asked by the CDC immediately after the October 5, 2004 announcement to halt the distribution of its remaining 25 million doses of the vaccine while the CDC analyzed the situation (GAO, 2005). The Department of Health and Human Services was also coordinating with MedImmune to increase their production from one to three million doses (GAO, 2005).<sup>37</sup> In mid-October public health officials began acting on distributing the remaining 25 million doses across the U.S. to those high risk groups of individuals (GAO, 2005).

Distribution is based on pre-booked orders placed well in advance of known demand such that the providers of the vaccine who had ordered from Chiron did not receive any vaccine where providers who ordered from Aventis received their vaccine on time in shipments beginning in August and September. Hence, certain providers

---

<sup>37</sup> MedImmune was able to "blend and fill" their "excess bulk vaccine" into more doses for distribution. (Coelingh, 2004)

could hold their vaccination clinics on time, while others had no vaccine to distribute. The shortage relative to the demand caused the distributors and others with supplies of the vaccine the ability to sell to the highest bidder and not fill the lower priced orders (*Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004). In a previous shortage year, 2000, a physician's office ordered the vaccine in April at a price of \$2.87 per dose and when no vaccine had arrived by November, the office was forced to place four smaller orders from three more distributors to obtain the vaccine at increasing prices of \$8.80, \$10.80, and \$12.80 per dose (*Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004). "The four more expensive orders were delivered immediately, before any vaccine had been received from the original April order" (*Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004). The CDC collected similar allegations of such price gouging for the 2004 shortage and provided information to state attorney generals. By November, 18, 2004 the CDC had forwarded "over 100 reports of alleged price gouging that they received from 33 states." (*Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, 2004).

The FDA has the authority to ensure that companies are complying with cGMP under the Food, Drug and Cosmetic Act. However, under the same act the FDA does not have the authority to regulate public or private hospitals or other medical entities to "purchase, or trade a drug or vaccine or offer to sell, purchase, or

trade a drug or vaccine for emergency medical reasons" (GAO, 2005). Neither the FDA nor the CDC had the authority to regulate the price or the distribution of the vaccine. However, the CDC distributed recommendations and working with Aventis established a multi-phase plan for distributing the remaining vaccine to reach those in the high risk target groups (GAO, 2005).

The CDC and The Department of Health and Human Services do not have the regulatory authority to set the price or resale price of the flu vaccine. However, they did try to prevent price gouging during the 2004 shortage. "HHS filed a brief in Broward County court in Florida to support the State of Florida's prosecution of price gouging by distributors of flu vaccine" (Department of Health and Human Services Press Office, 2004). The CDC also sent a memo to the states encouraging price monitoring and prosecution of price gouging. Price gouging differs from state to state; therefore, is not a federal issue (CDC, 2004). Each state must prosecute price gougers based on their state's definition of price gouging. Price gouging allegations exemplify the concerns of two few manufacturers in an industry that is susceptible to product contaminations leading to the withdrawal of large portions of supply from the market, and subsequently decreasing the social welfare with fewer vaccines offered at higher prices.



## **Chapter 5 Conclusion**

The shortage in 2004 illustrates the dangers of a market with production uncertainty and only a few manufacturers. Vaccines are one of the most cost effective health prevention methods available (Perez-Tirso & Gross, 1992); the social return for vaccine development is estimated to be about twice that of the private return (Forslid, 2005). Since influenza is transmitted from human-to-human, vaccinating one person benefits those living in the same community. Therefore, the U.S. government has an interest to increase the vaccine supply such that another supply shock will not lead to a highly concentrated industry allowing for price gouging to occur, which would lead to under consumption and decrease the social welfare. As the Second Theorem of Welfare Economics states, subsidies or lump-sum transfers can adjust the welfare distribution as disturbed in the flu vaccine market by the market failures associated with production uncertainty and high fixed costs.

The injectable vaccine captures over ninety-five percent of the influenza market (GAO, 2005), which when there was a shortage created a severe concentration of the industry, as supported by the jump in the Herfindahl index, and prices dramatically increased. Subsidies as supported by all but the limited entry models allow for the firms to earn above normal profits, which act as a profit signal encouraging more firms to enter the market, rendering the monopoly model previously applied irrelevant. My model implies that subsidies allow for a profit signal and with both an expanding injectable market and product differentiation the social welfare is increasing.

As a new entrant, MedImmune is attempting product differentiation as a method to steal a share of the market from the injectable vaccine, or it is an attempt to expand the market, or both. However, MedImmune's product was not as widely accepted as it had hoped. MedImmune has the capacity to produce up to 26 million doses a year, but they choose to only produce between two and five million doses a year. However, a study recently published in the *New England Journal of Medicine* suggests that MedImmune's nasal mist vaccine is more effective than the injectable vaccine in infants possibly segmenting the market further for the nasal mist ("Beyond the Egg: Vaccines", 2007). The decision by MedImmune to enter with product differentiation might increase their profits when new information is received by the consumer.

New entrants are expanding the market, which means we can expect the Herfindahl index to decrease, and consumer surplus to increase as suggested by all three models. As the Herfindahl index decreases, the implications of a less concentrated market suggest fewer future shortages as the number of manufacturers with smaller market shares increases. In the case study of 2004, one of the leading problems was that there were too few manufacturers in the market such that a contamination in one of the facilities cut supply in half. The supply shock would be alleviated by competition as each firm would be producing a smaller share of the market.

In the preparation for a pandemic the Department of Health and Human Services has awarded 240 million dollars in contracts to Sanofi-Pasteur (formally Aventis-Pasteur) and Chiron in order to attempt to stockpile a close substitute to the

possible pandemic strain (CBO, 2006). The general consensus about stockpiling pandemic strain vaccines is that it is a method of subsidizing the manufacturers in order to keep them interested in researching and producing flu vaccines. The lag time in production for the influenza vaccine is of concern in the context of a pandemic outbreak such that the current seasonal flu market is becoming increasingly important in terms of potential capacity and the number of licensed manufacturers. The government is using targeted subsidies as a way of alleviating the high fixed costs associated with vaccine manufacturing such that the higher average costs compared to marginal costs is not as much of a deterrent for possible entrants. As shown in my subsidy analysis, an increase in the subsidy,  $\alpha$ , decreases the total costs and allows for above normal profits for all but the limited entry models. As firms make above normal profit in the market, outside firms will consider entering the market decreasing the likelihood of another price gouging situation. The government has taken a keen interest in the topic since the Congressional Budget Office released their analysis of the macroeconomic effects of a pandemic stating that U.S. GDP will fall five percent if a pandemic influenza were to hit the U.S. (CBO, 2006).

The model presented in this paper is a simplification of the market demands, ex-ante and ex-post, in order to capture the firms' behavior in the case of entry and product differentiation. The demand does not reflect the individual's choices and explicitly derive the number of doses distributed in the ex-ante period. Consumer's base their decisions not only on the expectation of the severity of the flu, but also on various demographics and their perception of themselves as a healthy or an unhealthy individual (Mullahy, 1999). It is widely known that a person's decision to get a flu

shot may also depend on their decisions from the previous year and the previous year's severity. An extension to this paper would be to include a time varying component to  $\eta$  such that  $\eta$  depends not only on the expectation of  $\delta$ , but also on  $\delta_{-1}$ , signifying the previous year's  $\delta$ . This extension model might capture some of the time varying aspects of the change in demand from year to year and capture some of the uncertainty associated with the volatile demand not captured in this model.

## Bibliography

- Armstrong, M., & Sappington, D. E. M. (2006). Regulation, Competition, and Liberalization. *Journal of Economic Literature*, 44(2), 325-366.
- Baron, D. P. (1989). Design of Regulatory Mechanisms and Institutions. In *Handbook of Industrial Organization. Volume 2. Schmalensee, Richard Willig, Robert D., eds., Handbooks in Economics, no. 10 Amsterdam; Oxford and Tokyo: North-Holland; distributed in the U.S. and Canada by Elsevier Science, New York.* (pp. 1347-1447).
- Baron, D. P., & Besanko, D. (1984). Regulation, Asymmetric Information, and Auditing. *Rand Journal of Economics*, 15(4), 447-470.
- Baron, D. P., & Besanko, D. (2003). Regulation and Information in a Continuing Relationship. In *The Principal Agent Model: The Economic Theory of Incentives. Laffont, Jean-Jacques, ed., Elgar Reference Collection. International Library of Critical Writings in Economics, vol. 162. Cheltenham, U.K. and Northampton, Mass.: Elgar.* (pp. 397-432).
- Berndt, E. R., Glennerster, R., Kremer, M. R., Lee, J., Levine, R., Weizsacker, G., et al. (2005). *Advanced Purchase Commitments for a Malaria Vaccine: Estimating Costs and Effectiveness* (National Bureau of Economic Research, Inc, NBER Working Papers: 11288. 2005.).
- Besanko, D., & Sappington, D. E. M. (1987). *Designing Regulatory Policy with Limited Information*. Chur, Switzerland: New York.
- Beyond the Egg: Vaccines. (2007, March 10th, 2007). *The Economist*.
- Bockem, S. (1994). A Generalized Model of Horizontal Product Differentiation. *The Journal of Industrial Economics*, 42(3), 287-298.
- CBO. (2006). *A Potential Influenza Pandemic: An Update on Possible Macroeconomic Effects and Policy Issues*. U.S. Congressional Budget Office.
- CDC, AMA. (2006). *The National Vaccine Summit Newsletter*. Center for Disease Control and Prevention.
- CDC. (2004). Influenza Vaccine Supply Update. Center for Disease Control and Prevention. Retrieved 1/22/07 from <http://www.cdc.gov/od/oc/media/transcripts/t041012.htm>.
- CDC. (2005). Overview of Vaccine Safety. Center for Disease Control and Prevention. Retrieved 9/22/06, from [http://www.cdc.gov/od/science/iso/about\\_iso.htm](http://www.cdc.gov/od/science/iso/about_iso.htm)

- CDC. (2006). The Influenza (Flu) Viruses. Center for Disease Control and Prevention. Retrieved 10/26/06, from <http://www.cdc.gov/flu/about/fluviruses.htm>
- CDC. (2006, July 24, 2006). Key Facts About Influenza (Flu) Vaccine. Center for Disease Control and Prevention. Retrieved 9/23/06, from <http://www.cdc.gov/flu/protect/keyfacts.htm>
- CDC. (2006, September 26, 2006). Questions & Answers: Thimerosal-Containing Influenza Vaccine. Center for Disease Control and Prevention. from <http://www.cdc.gov/flu/about/qa/thimerosal.htm>
- Coelingh, K. (2004). Witness Testimony: Flu Vaccine: Protecting High-Risk Individuals and Strengthening the Market. (108 session). U.S. House of Representatives Washington, DC: MedImmune.
- Danzon, P. M., Pereira, N. S., & Tejawani, S. S. (2005). Vaccine Supply: A Cross-National Perspective. *Health Affairs*, 24(3), 706.
- Danzon, P., & Pereira, N. S. (2005). Why Sole-Supplier Vaccine Markets May Be Here To Stay. *Health Affairs*, 24(3), 694.
- DiMasi, J. A., & et al. (1991). Cost of Innovation in the Pharmaceutical Industry. *Journal of Health Economics*, 10(2), 107-142.
- FDA. (2006). *FDA Approves Influenza Vaccines To Be Manufactured for Upcoming Flu Season*. Retrieved 9/22/06. from <http://www.fda.gov/bbs/topics/NEWS/2006/NEW01423.html>.
- FDA. (2006). *Frequently Asked Questions*. Retrieved 9/24/06. from <http://www.fda.gov/cber/faq.htm#4>
- Finkelstein, A. (2004). Static and Dynamic Effects of Health Policy: Evidence from the Vaccine Industry. *The Quarterly Journal of Economics*, 119(2), 527-564.
- Flu Vaccine: Protecting High-Risk Individuals and Strengthening the Market*, U.S. House of Representatives, 108 Session. (2004).
- Forslid, R. (2005). *Can we Trust Private Firms as Suppliers of Vaccines for the Avian Influenza?* (C.E.P.R. Discussion Papers, CEPR Discussion Papers: 4980. 2005.): Centre for Economic Policy Research.
- Gabszewicz, J. J., Shaked, A., Sutton, J., & Thisse, J. F. *Price Competition Among Differentiated Products: A Detailed Study of a Nash Equilibrium* (Suntory and Toyota International Centres for Economics and Related Disciplines, LSE, STICERD - Theoretical Economics Paper Series. 1981.).

- Gabszwick, J. J., & Thisse, J. F. (1986). On the Nature of Competition with Differentiated Products. *The Economic Journal*, 96(381), 160-172.
- GAO. (2005). *Influenza Vaccine: Shortages in 2004-2005 Season Underscore Need for Better Preparation* (No. GAO-05-984). Washington, DC: Government Accountability Office.
- Health Industry Distributors Association. (2006). *Influenza Vaccine Production & Distribution: Market Brief*.
- Heavey, S. (2004). Flu Vaccine Makers Say Government Must Increase Demand [Electronic Version]. *Reuters*.
- HHS Makes Price Gouging Brief in Florida Available to All States. (2004). Department of Health and Human Services Press Office.
- HHS. (2007). *Preventive Services: Flu Information*: U.S. Department of Health and Human Services.
- Hotelling, H. (2003). Stability in Competition. In *The Economics of Business Strategy*. Kay, John, ed., *Elgar Reference Collection. International Library of Critical Writings in Economics*, vol. 163. Cheltenham, U.K. and Northampton, Mass.: Elgar. (pp. 692-708).
- How to Shore up Nation's Vaccine Supply [Electronic Version]. *Infectious Disease News*, 2002 from <http://www.infectiousdiseaseneews.com/200203/frameset.asp?article=vaccine.asp>.
- Kauf, T. L. (1999). Price Discrimination and Bargaining Power in the U.S. Vaccine Market: Implications for Childhood Immunization Policy. *Quarterly Review of Economics & Finance*, 39(2), 249-265.
- Kremer, M. (2000). *Creating Markets for New Vaccines Part I: Rationale* (National Bureau of Economic Research, Inc, NBER Working Papers: 7716. 2000.).
- Kremer, M. (2000). *Creating Markets for New Vaccines Part II: Design Issues* (National Bureau of Economic Research, Inc, NBER Working Papers: 7717. 2000.).
- Kremer, M., & Snyder, C. M. (2005). *Why Are Drugs More Profitable Than Vaccines?* (National Bureau of Economic Research, Inc, NBER Working Papers: 9833. 2003.).

- Laffont, J.-J. (2005). *Regulation and Development*. Cambridge, UK ; New York: Cambridge University Press.
- Lessons Learned: New Procurement Strategies for Vaccines*. (2002): Mercer Management Consulting.
- Lister, S. A. (2004). *Influenza Vaccine Shortages and Implications*: Congressional Research Service: Library of Congress.
- Lister, S. A. (2005). *Pandemic Influenza: Domestic Preparedness Efforts* (CRS Report for Congress): Congressional Research Service: The Library of Congress.
- Matthews, J. T. (2006). Egg-Based Production of Influenza Vaccine: 30 Years of Commercial Experience. *The Bridge*, 36(3), 17-24.
- Mullahy, J. (1999). It'll Only Hurt a Second? Microeconomic Determinants of Who Gets Flu Shots. *Health Economics*, 8(1), 9-24.
- NIAID. (May 28, 2005 ). Focus on the Flu. from [http://www3.niaid.nih.gov/news/focuson/flu/illustrations/antigenic/antigenics\\_hift.htm](http://www3.niaid.nih.gov/news/focuson/flu/illustrations/antigenic/antigenics_hift.htm)
- Nicholson, W. (2005). *Microeconomic Theory : Basic Principles and Extensions* (9th ed.). Mason, Ohio: Thomson/South-Western.
- Offit, P. A. (2005). Why Are Pharmaceutical Companies Gradually Abandoning Vaccines? *Health Affairs*, 24(3), 622.
- Osterholm, M. T. (2005). Preparing for the Next Pandemic. *Foreign Affairs*, 84(4), 24.
- Pauly, M. V. (1996). *Supplying vaccines : an economic analysis of critical issues*. Amsterdam: Washington, DC.
- Perez-Tirse, J., & Gross, P. A. (1992). Review of Cost-Benefit Analyses of Influenza Vaccine. *Pharmacoeconomics*, 2(3), 198-206.
- Phlips, L., & Thisse, J.-F. (1982). Spatial Competition and the Theory of Differentiated Markets: An Introduction. *The Journal of Industrial Economics*, 31(1/2), 1-9.
- Ropp, K. Just What is a Biologic, Anyway? , from <http://www.fda.gov/bbs/topics/CONSUMER/CON00202.html>



- Salanie, B. (2000). *The Microeconomics of Market Failures*. Translation. Cambridge and London: MIT Press.
- Salinsky, E. (2004). Tick-Tock: Preparing for the Next Influenza Pandemic. George Washington University: National Health Policy Forum.
- Salinsky, E., & Werble, C. (2006). The Vaccine Industry: Does It Need A Shot in the Arm: National Health Policy Forum.
- Sappington, D. E. M., & Stiglitz, J. E. (1987). Information and Regulation. In *Public Regulation: New Perspectives on Institutions and Policies*. Bailey, Elizabeth E., ed., MIT Press Series on the Regulation of Economic Activity, no 14 Cambridge, Mass. and London: MIT Press. (pp. 3-43).
- Schmalensee, R., & Willig, R. D. (1989). *Handbook of Industrial Organization*. Amsterdam: New York.
- Shaked, A., & Sutton, J. (1982). Relaxing Price Competition Through Product Differentiation. *The Review of Economic Studies*, 49(1), 3-13.
- Shubik, M., & Levitan, R. (1980). *Market Structure and Behavior*. Cambridge, Mass.: Harvard University Press.
- Statement of Janet Heinrich Director, Health Care: Flu Vaccine: Recent Supply Shortages Underscore Ongoing Challenges*, Statement for the Record U.S. House of Representatives (2004).
- Statement of Macia Crosse Director, Health Care: Applying Lessons Learned from the 2004-05 Influenza Vaccine Shortage*. Statement for the Record U.S. House of Representatives (2005).
- Stehlin, I. B. (1995). How FDA Works to Ensure Vaccine Safety. *FDA Consumer Magazine*.
- Testimony: Infectious Disease Preparedness: Federal Challenges in Responding to Influenza Outbreaks*, U.S Senate (2004).
- Tirole, J. (1988). *The Theory of Industrial Organization*. Cambridge, Mass.: MIT Press.
- Tracy, A. L., Thomas, G. M., & Alan, R. H. (2005). Overcoming Economic Barriers To The Optimal Use Of Vaccines. *Health Affairs*, 24(3), 666.
- Werble, C. (2006, October 2006). Flu Speed Ahead for Vaccines Market. *The RPM Report*, 1, 11-19.

Werble, C. (2006, September 2006). The Vaccine Boom. *The RPM Report*, 1, 13-24.

Wood, S. C., Nguyen, V. H., & Schmidt, C. (2000). Economic Evaluations of Influenza Vaccination in Healthy Working-Age Adults: Employer and Society Perspective. *Pharmacoeconomics*, 18(2), 173-183.

## Appendix

### A.1

Segmented Ex-Ante Stackelberg Leader Solution:

Solve for Quantities: (3.A.3)

$$q_1 = \frac{N\theta - \bar{q}_2 - c_1}{2}$$

$$q_2 = \frac{N\theta - \bar{q}_1 - c_2}{2}$$

$$q_1 = \frac{N\theta - \frac{N\theta - \bar{q}_1 - c_2}{2} - c_1}{2}$$

$$q_1 = \frac{N\theta + \bar{q}_1 + c_2 - 2c_1}{4}$$

$$\frac{3}{4}q_1 = \frac{N\theta + c_2 - 2c_1}{4}$$

$$q_1 = \frac{N\theta + c_2 - 2c_1}{3} \text{ by symmetry}$$

$$q_2 = \frac{N\theta + c_1 - 2c_2}{3}$$

### A.2

Segmented Ex-Ante Stackelberg Leader Profits: (3.A.4)

$$\Pi_1 = [N\theta - q_1 - q_2]q_1 - c_1q_1 - F_1$$

$$\Pi_1 = \left[ N\theta - \left( \frac{N\theta + c_2 - 2c_1}{3} \right) - \frac{N\theta + c_1 - 2c_2}{3} \right] \left( \frac{N\theta + c_2 - 2c_1}{3} \right) - c_1 \left( \frac{N\theta + c_2 - 2c_1}{3} \right) - F_1$$

$$\Pi_1 = \left[ \frac{N\theta - c_2 - c_1}{3} \right] \left( \frac{N\theta + c_2 - 2c_1}{3} \right) - \left( \frac{N\theta c_1 + c_2 c_1 - 2c_1^2}{3} \right) - F_1$$

$$\Pi_1 = \frac{(N\theta)^2 - N\theta c_2 - 4N\theta c_1 - 2c_2 c_1 + 8c_1^2}{9} - F_1$$

$$\Pi_2 = \frac{(N\theta)^2 - N\theta c_1 - 4N\theta c_2 - 2c_2 c_1 + 8c_2^2}{9} - F_2$$

**A.3**

Segmented Ex-Post:

Nasal Mist Monopoly Reaction Function: (3.A.6)

$$Q_1^S = (1-\theta)(N(1-\delta)) - P_1^S$$

$$\Pi_3 = P_1^S q_3 - c_3 q_3 - F_3$$

$$\Pi_3 = ((1-\theta)(N(1-\delta)) - q_3 - c_3) q_3 - F_3$$

$$\Pi_3 = -q_3^2 + ((1-\theta)(N(1-\delta)) - c_3) q_3 - F_3$$

$$\frac{\partial \Pi_3}{\partial q_3} = -2q_3 + ((1-\theta)(N(1-\delta)) - c_3) = 0$$

$$q_3 = \frac{1}{2}((1-\theta)(N(1-\delta)) - c_3)$$

$$q_3 = \frac{1}{2}[(N(1-\delta - \theta + \delta\theta)) - c_3]$$

$$P_1^S = \frac{1}{2}((1-\theta)(N(1-\delta)) + c_3)$$

**A.4**

Segmented Ex-Post Nasal Mist Profits: (3.A.8)

$$\Pi_3 = \left( \frac{1}{2}[(N(1-\delta - \theta + \delta\theta)) - c_3] \right)^2 - F_3$$

$$\Pi_3 = \frac{1}{4}([(N(1-\delta - \theta + \delta\theta)) - c_3]^2) - F_3$$

**A.5**

Segmented Ex-Post Injectable:

Bertrand Duopoly: (3.A.10), (3.A.11)

$$\Pi_1 = (P_1^{IN} - c_1)q_1 - F_1$$

$$P_1^{IN} = \theta(N(1-\delta) - \eta[\delta]) - q_1 - q_2$$

$$q_1 = \theta(N(1-\delta) - \eta[\delta]) - P_1^{IN} - q_2$$

$$\Pi_1 = (P_1^{IN} - c_1)(\theta(N(1-\delta) - \eta[\delta]) - P_1^{IN} - q_2) - F_1$$

$$(P_1^{IN} - c_1)(\theta(N(1-\delta) - \eta[\delta]) - P_1^{IN} - q_2) - F_1$$

$$-(P_1^{IN})^2 + P_1^{IN}(\theta(N(1-\delta) - \eta[\delta]) + c_1 - q_2) - F_1$$

$$\frac{\partial \Pi_1}{\partial P_1^{IN}} = (\theta(N(1-\delta) - \eta[\delta]) + c_1 - \bar{q}_2) - 2P_1^{IN} = 0$$

**A.6**

Segmented Injectable Ex-Post Quantities: (3.A.12)

$$q_1 + q_2 = \theta(N(1-\delta) - \eta[\delta]) - \frac{(\theta(N(1-\delta) - \eta[\delta]) + c_1 - \bar{q}_2)}{2}$$

$$q_1 = \frac{(\theta(N(1-\delta) - \eta[\delta]) + c_1 - \bar{q}_2)}{2} - q_2$$

Solve for Equilibrium: (3.A.13)

$$q_1 = -\frac{1}{5}((N(\delta-1) + \eta)\theta + 2c_1 - 3c_2)$$

$$q_2 = -\frac{1}{5}((N(\delta-1) + \eta)\theta - 3c_1 + 2c_2)$$

Segmented Injectable Profits: (3.A.14)

$$\Pi_1 = \left(\frac{1}{5}(-2(N(\delta-1) + \eta[\delta])\theta + c_1 + c_2) - c_1\right) \left(-\frac{1}{5}((N(\delta-1) + \eta)\theta + 2c_1 - 3c_2)\right) - F_1$$

$$\Pi_1 = \frac{1}{25}((N(\delta-1) + \eta[\delta])\theta + 2c_1 - 3c_2)(2(N(\delta-1) + \eta[\delta])\theta + 4c_1 - c_2) - F_1$$

**B.1**

Partially Segmentation Ex-Post Injectable

Bertrand Solution: (3.B.2), (3.B.3), (3.B.4)

$$\Pi^{IN} = P_1^{IN} q_1 - c_1 q_1 - F_1$$

$$\Pi^{IN} = P_1^{IN} (N(1-\delta) - \eta[\delta] - P_1^{IN}) - c_1 (N(1-\delta) - \eta[\delta] - P_1^{IN}) - F_1$$

$$\Pi^{IN} = -(P_1^{IN})^2 + P_1^{IN} (N(1-\delta) - \eta[\delta] + c_1) - c_1 (N(1-\delta) - \eta[\delta]) - F_1$$

$$\frac{\partial \Pi^{IN}}{\partial P_1^{IN}} = (N(1-\delta) - \eta[\delta] + c_1) - 2P_1^{IN} = 0$$

$$P_1^{IN} = \frac{1}{2}(N(1-\delta) - \eta[\delta] + c_1)$$

$$Q_1^{IN} = q_1 + q_2 = \frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1)$$

$$\Pi_1^{IN} = \left(\frac{1}{2}(N(1-\delta) - \eta[\delta] + c_1)\right) \left(\frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1)\right)$$

$$-c_1 \left(\frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1)\right) - F_1$$

$$\Pi_1^{IN} = \frac{1}{4}(N^2(1-\delta)^2 - 2\eta[\delta](N(1-\delta)) + \eta[\delta]^2 + c_1^2) - c_1 \left(\frac{1}{2}(N(1-\delta) - \eta[\delta])\right) - F_1$$

**B.2**

Partially Segmented Ex-post Bertrand Solution: Nasal Mist: (3.B.5), (3.B.7),

$$\Pi_3 = P_1^S \left( (1-\theta)(N(1-\delta)) - P_1^S - P_1^{IN} \right) - c_3 \left( (1-\theta)(N(1-\delta)) - P_1^S - P_1^{IN} \right) - F_3$$

$$\Pi_3 = -(P_1^S)^2 + P_1^S \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) - c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) - F_3$$

$$\frac{\partial \Pi_3}{\partial P_1^S} = (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 - 2P_1^S = 0$$

$$P_1^S = \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)$$

$$Q_1^S = \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - c_3 \right) - \frac{3}{2} P_1^{IN}$$

$$\Pi_3 = \frac{1}{4} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) - F_3$$

**B.3**

Comparative Statics: (3.B.8), (3.B.9), (3.B.11)

$$P_1^{IN} = \frac{1}{2} (N(1-\delta) - \eta[\delta] + c_1)$$

$$\frac{\delta P_1^{IN}}{\delta \delta} = -\frac{1}{2} \left( N - \frac{\delta \eta[\delta]}{\delta \delta} \right)$$

$$Q_1^{IN} = q_1 + q_2 = \frac{1}{2} (N(1-\delta) - \eta[\delta] - c_1)$$

$$\frac{\delta Q_1^{IN}}{\delta \delta} = -\frac{1}{2} \left( N - \frac{\delta \eta[\delta]}{\delta \delta} \right)$$

$$\Pi_1^{IN} = \frac{1}{4} (N^2(1-\delta)^2 - 2\eta[\delta](N(1-\delta)) + \eta[\delta]^2 + c_1^2) - c_1 \left( \frac{1}{2} (N(1-\delta) - \eta[\delta]) \right) - F_1$$

$$\frac{\delta \Pi_1^{IN}}{\delta \delta} = \frac{1}{2} \left( -N^2(1-\delta) - 2 \frac{\delta \eta[\delta]}{\delta \delta} (N(1-\delta)) + 2\eta[\delta]N + 2\eta[\delta] \frac{\delta \eta[\delta]}{\delta \delta} \right) - c_1 \left( \frac{1}{2} \left( -N - \frac{\delta \eta[\delta]}{\delta \delta} \right) \right)$$

**B.3 cont:**

$$\Pi_3 = \frac{1}{4} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) - F_3$$

$$\frac{\delta \Pi_3}{\delta \delta} = -\frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) \left( (1-\theta)N + c_3(1-\theta)N \right)$$

$$\frac{\delta \Pi_3}{\delta \delta} = -\frac{1}{2} \left( (1-\theta)^2 N^2 (1-\delta) - P_1^{IN} \left( (1-\theta)N \right) - c_3(1-\theta)N \right)$$

$$\frac{\delta \Pi_3}{\delta \theta} = -\frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) \left( N(1-\delta) \right) + c_3 \left( N(1-\delta) \right)$$

$$\frac{\delta \Pi_3}{\delta \theta} = -\frac{1}{2} \left( (1-\theta)(N(1-\delta))^2 - P_1^{IN} \left( N(1-\delta) \right) - c_3 \left( N(1-\delta) \right) \right)$$

**B.4**

Partially Segmented Zero profit Condition: (3.B.12)

$$\Pi_3 = -(P_1^S)^2 + P_1^S \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) - c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) - F_3 = 0$$

$$P_1^S = \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) \pm \frac{1}{2} \sqrt{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)}$$

**B.5**

Partially Segmented Limited Entry Price and Comparative Statics (3.B.13)

$$P_1^S = \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) \pm \frac{1}{2} \sqrt{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)}$$

$$P_1^S - \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) = \frac{1}{2} \sqrt{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)}$$

$$\left( 2P_1^S - (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 = \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)$$

$$4F_3 - 4 \left( P_1^{IN} - P_1^S \right) \left( N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S \right) = 0$$

$$4F_3 + 4P_1^S \left( N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S \right) = 4P_1^{IN} \left( N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S \right)$$

$$P_1^{IN} = \frac{F_3 + P_1^S \left( N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S \right)}{\left( N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S \right)}$$

$$\frac{\delta P_1^{IN}}{\delta \delta} = \frac{N(\theta-1)F_3}{\left( N(-1 + \delta + \theta - \delta\theta) + c_3 + P_1^S \right)^2} < 0$$

**B.6**

Comparative Statics: (3.B.14)

$$P_1^S = \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right) \pm \frac{1}{2} \sqrt{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)}$$

$$\frac{\delta P_1^S}{\delta \delta} = -\frac{N}{2} (1-\theta) \pm \frac{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} - c_3 \right) N(1-\theta)}{\sqrt{\left( (1-\theta)(N(1-\delta)) - P_1^{IN} + c_3 \right)^2 - 4 \left( c_3 \left( (1-\theta)(N(1-\delta)) - P_1^{IN} \right) + F_3 \right)}}$$

**C.1**

Homogenous Product Oligopoly Ex-Ante Solving Simultaneous Equations: (3.C.2)

$$q_1 = \frac{\theta N - \bar{q}_2 - \bar{q}_3 - c_1}{2} = \frac{\theta N - \frac{\theta N - \bar{q}_1 - \bar{q}_3 - c_1}{2} - \bar{q}_3 - c_1}{2}$$

$$q_1 = \frac{\theta N - \frac{\theta N - \bar{q}_1 - \bar{q}_3 - c_1}{2} - \bar{q}_3 - c_1}{2} = \frac{2\theta N - (\theta N - \bar{q}_1 - \bar{q}_3 - c_2) - 2\bar{q}_3 - 2c_1}{4}$$

$$3q_1 = \theta N + c_2 - \bar{q}_3 - 2c_1$$

$$q_2 = \frac{\theta N - \bar{q}_1 - \bar{q}_3 - c_2}{2} = \frac{\theta N - \frac{\theta N - \bar{q}_2 - \bar{q}_3 - c_1}{2} - \bar{q}_3 - c_2}{2}$$

$$3q_2 = \theta N + c_1 - \bar{q}_3 - 2c_2$$

$$q_3 = \frac{\theta N - \bar{q}_2 - \bar{q}_1 - c_3}{2} = \frac{\theta N - \frac{\theta N + c_1 - \bar{q}_3 - 2c_2}{3} - \frac{\theta N + c_2 - \bar{q}_3 - 2c_1}{3} - c_3}{2}$$

$$q_3 = \frac{\theta N + c_1 + c_2 - 3c_3}{4}$$

$$q_1 = \frac{\theta N - 3c_1 + c_2 + c_3}{4}$$

$$q_2 = \frac{\theta N + c_1 - 3c_2 + c_3}{4}$$



**C.2**

Price: (3.C.3)

$$P_0^{IN} = \theta N - \left( \frac{\theta N - 3c_1 + c_2 + c_3}{4} \right) - \left( \frac{\theta N + c_1 - 3c_2 + c_3}{4} \right) - \left( \frac{\theta N + c_1 + c_2 - 3c_3}{4} \right)$$

$$P_0^{IN} = \left( \frac{\theta N + 3c_1 - c_1 - c_1 + 3c_2 - c_2 - c_2 + 3c_3 - c_3 - c_3}{4} \right)$$

$$P_0^{IN} = \frac{\theta N + c_1 + c_2 + c_3}{4}$$

**C.3**

Homogenous Product Oligopoly Ex-Ante Profits: (3.C.4)

$$\Pi_1 = (\theta N - q_1 - q_2 - q_3) q_1 - c_1 q_1 - F_1$$

$$\Pi_1 = \left( \theta N - \left( \frac{\theta N - 3c_1 + c_2 + c_3}{4} \right) - \left( \frac{\theta N + c_1 - 3c_2 + c_3}{4} \right) \right) \left( \frac{N\theta - 3c_1 + c_2 + c_3}{4} \right) - \left( \frac{\theta N + c_1 + c_2 - 3c_3}{4} \right)$$

$$-c_1 \left( \frac{N\theta - 3c_1 + c_2 + c_3}{4} \right) - F_1$$

$$\Pi_1 = \left( \frac{\theta N + 3c_1 - c_1 - c_1 + 3c_2 - c_2 - c_2 + 3c_3 - c_3 - c_3}{4} \right) \left( \frac{\theta N - 3c_1 + c_2 + c_3}{4} \right) - c_1 \left( \frac{N\theta - 3c_1 + c_2 + c_3}{4} \right) - F_1$$

$$-c_1 \left( \frac{N\theta - 3c_1 + c_2 + c_3}{4} \right) - F_1$$

$$\Pi_1 = \left( \frac{\theta N + c_1 + c_2 + c_3}{4} \right) \left( \frac{\theta N - 3c_1 + c_2 + c_3}{4} \right) - c_1 \left( \frac{N\theta - 3c_1 + c_2 + c_3}{4} \right) - F_1$$

$$\Pi_1 = \left( \frac{(\theta N + c_1 + c_2 + c_3)(\theta N - 3c_1 + c_2 + c_3) - c_1(N\theta - 3c_1 + c_2 + c_3) - 4F_1}{4} \right)$$

$$c_1 = c_2$$

$$\Pi_1 = \left( \frac{(\theta N + 2c_1 + c_3)(\theta N - 2c_1 + c_3) - c_1(N\theta - 2c_1 + c_3) - 4F_1}{4} \right)$$

$$\Pi_1 = \left( \frac{(\theta N)^2 - 4c_1^2 + 2c_3\theta N + c_3^2 - c_1N\theta + 2c_1^2 - c_3c_1 - 4F_1}{4} \right)$$

$$\Pi_1 = \left( \frac{(\theta N)^2 - 2c_1^2 + 2c_3\theta N + c_3^2 - c_1N\theta - c_3c_1 - 4F_1}{4} \right)$$

**C.4**

Homogenous Product Oligopoly Ex-Ante Limited Entry Quantity: (3.C.6)

$$\Pi_3 = (\theta N - q_1 - q_2 - q_3)q_3 - c_3q_3 - F_3 = 0$$

$$(\theta N - q_1 - q_2 - c_3)q_3 - q_3^2 - F_3 = 0$$

$$q_3 = \frac{-(\theta N - q_1 - q_2 - c_3) \pm \sqrt{(\theta N - q_1 - q_2 - c_3)^2 - 4F_3}}{-2}$$

**C.5**

Homogenous Product Ex-Ante Quantities:

Solving for Simultaneous Equations: (3.C.1)(3.C.7)

$$\frac{d\Pi_1}{dq_1} = N\theta - 2q_1 - \bar{q}_2 - \bar{q}_3 - c_1 = 0$$

$$\frac{d\Pi_2}{dq_2} = N\theta - 2q_2 - \bar{q}_1 - \bar{q}_3 - c_2 = 0$$

$$q_1 = \frac{N\theta - \bar{q}_2 - \bar{q}_3 - c_1}{2}$$

$$q_1 = \frac{1}{6} \left( N\theta - 5c_1 + c_2 + 3c_3 \pm \sqrt{(N\theta + c_1 + c_2 - 3c_3)^2 - 12F_3} \right)$$

$$q_2 = \frac{N\theta - \bar{q}_1 - \bar{q}_3 - c_2}{2}$$

$$q_2 = \frac{1}{6} \left( N\theta + c_1 - 5c_2 + 3c_3 \pm \sqrt{(N\theta + c_1 + c_2 - 3c_3)^2 - 12F_3} \right)$$

$$q_3 = \frac{-(\theta N - \bar{q}_1 - \bar{q}_2 - c_3) \pm \sqrt{(\theta N - \bar{q}_1 - \bar{q}_2 - c_3)^2 - 4F_3}}{-2}$$

$$q_3 = \frac{1}{2} \left( N\theta + c_1 + c_2 + 3c_3 \pm \sqrt{(N\theta + c_1 + c_2 - 3c_3)^2 - 12F_3} \right)$$

**C.6**

Homogenous Product Ex-Post Quantities: (3.C.12)

$$Q_1 = N(1 - \delta) - \eta[\delta] - P_1$$

$$Q_1 = N(1 - \delta) - \eta[\delta] - \frac{N(1 - \delta) - \eta[\delta] + c_1}{2}$$

$$Q_1 = \frac{N(1 - \delta) - \eta[\delta] - c_1}{2}$$

**C.7**

Homogenous Product Ex-Post Profits: (3.C.13)

$$\Pi_1 = \left( \frac{N(1-\delta) - \eta[\delta] - c_1}{2} \right) \left( \frac{1}{6} (N(1-\delta) - \eta[\delta] - c_1) \right) - F_1$$

$$\Pi_1 = \frac{1}{12} (N(1-\delta) - \eta[\delta] - c_1)^2 - F_1$$

$$\Pi_3 = \left( \frac{N(1-\delta) - \eta[\delta] + c_1 - c_3}{2} \right) \left( \frac{1}{6} (N(1-\delta) - \eta[\delta] - c_1) \right) - F_3$$

$$\Pi_3 = \frac{1}{12} (N(1-\delta) - \eta[\delta] + c_1 - 2c_3)(N(1-\delta) - \eta[\delta] - c_1) - F_3$$

**C.8**

Homogenous Product Ex-Post Limit Entry: Zero profit Condition: (3.C.15)

$$\Pi_1 = (N(1-\delta) - \eta[\delta] - \bar{q}_1 - \bar{q}_2 - c_3)\bar{q}_3 - \bar{q}_3^2 - F_3 = 0$$

$$q_3 = \frac{-(N(1-\delta) - \eta[\delta] - \bar{q}_1 - \bar{q}_2 - c_3) \pm \sqrt{(N(1-\delta) - \eta[\delta] - \bar{q}_1 - \bar{q}_2 - c_3)^2 - 4F_3}}{-2}$$

$$q_3 = \frac{1}{2} (N(1-\delta) - \eta[\delta] - \bar{q}_1 - \bar{q}_2 - c_3) \pm \frac{1}{2} \sqrt{(N(1-\delta) - \eta[\delta] - \bar{q}_1 - \bar{q}_2 - c_3)^2 - 4F_3}$$

**D.1**

Welfare Analysis:

Consumer Surplus Segmented: (4.A.1)

$$q_1 + q_2 = \frac{2N\theta - c_2 - c_1}{3}$$

$$P_0 = \theta N - Q_0$$

$$P_0 = \theta N : Q_0 = 0$$

$$\text{Price: } P_0 = \theta N - \frac{2\theta N - c_2 - c_1}{3}$$

$$P_0 = \frac{\theta N - c_2 - c_1}{3}$$

$$CS = \frac{1}{2} \left( \theta N - \left( \frac{\theta N - c_2 - c_1}{3} \right) \right) \left( \frac{2\theta N - c_2 - c_1}{3} \right)$$

$$CS = \frac{1}{2} \left( \frac{2\theta N - c_2 - c_1}{3} \right)^2$$

$$CS = \frac{(2\theta N - c_2 - c_1)^2}{18}$$

**D.2**

Segmented Ex-Post Consumer Surplus: (4.A.2)

$$CS_1^{IN} = \frac{(P_1^{IN} - P_1^{IN}[Q_1^{IN}])Q_1^{IN}}{2} =$$

$$CS_1^{IN} = \left( \frac{5\theta(N(1-\delta) - \eta[\delta]) - (-2(N(\delta-1) + \eta)\theta + c_1 + c_2)}{5} \right) *$$

$$\left( \frac{(2\theta(N(1-\delta) - \eta[\delta]) - c_1 - c_2)}{2} \right) \frac{1}{2}$$

$$CS_1^{IN} = -\frac{1}{50} \left( (c_1 + c_2 - 2\theta(N(\delta-1) + \eta))(c_1 + c_2 + 3\theta(N(\delta-1) + \eta)) \right)$$

$$CS_1^S = \frac{(P_1^S - P_1^S[Q_1^S])Q_1^S}{2} =$$

$$\frac{1}{2} \left( (1-\theta)(N(1-\delta)) - \frac{1}{2} [(N(1-\delta-\theta+\delta\theta)) - c_3] \right) \left( \frac{1}{2} [(N(1-\delta-\theta+\delta\theta)) - c_3] \right)$$

$$\frac{1}{8} \left( (N(1-\delta-\theta+\delta\theta))^2 - c_3^2 \right)$$

$$Total\ CS = CS_1^{IN} + CS_1^S$$

$$= \frac{1}{8} \left( (N(1-\delta-\theta+\delta\theta))^2 - c_3^2 \right)$$

$$- \frac{1}{50} \left( (c_1 + c_2 - 2\theta(N(\delta-1) + \eta[\delta]))(c_1 + c_2 + 3\theta(N(\delta-1) + \eta[\delta])) \right)$$

**D.3**

Consumer Surplus Partially Segmented: Ex-Post: (4.A.3)

$$CS_1^{IN} = \frac{1}{2} \left( N(1-\delta) - \eta[\delta] - \frac{1}{2}(N(1-\delta) - \eta[\delta] + c_1) \right) \left( \frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1) \right)$$

$$CS_1^{IN} = \frac{1}{2} \left( \frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1) \right) \left( \frac{1}{2}(N(1-\delta) - \eta[\delta] - c_1) \right)$$

$$CS_1^{IN} = \frac{1}{8} (N(1-\delta) - \eta[\delta] - c_1)^2$$

$$CS_1^S = (P_1^S - P_1^S[Q_1^S]) Q_1^S$$

$$CS_1^S = \left( (1-\theta)(N(1-\delta)) - \bar{P}_1^{IN} - \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - \bar{P}_1^{IN} + c_3 \right) \right) *$$

$$\left( \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - c_3 \right) - \frac{3}{2} \bar{P}_1^{IN} \right)$$

$$CS_1^S = \left( \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - \bar{P}_1^{IN} - c_3 \right) \right) \left( \frac{1}{2} \left( (1-\theta)(N(1-\delta)) - c_3 \right) - \frac{3}{2} \bar{P}_1^{IN} \right)$$

$$CS_1^S = \frac{1}{4} \left( \begin{aligned} &N^2(\delta-1)^2(\theta-1)^2 + c_3^2 - 4N(\delta-1)(\theta-1)\bar{P}_1^{IN} + 3(\bar{P}_1^{IN})^2 \\ &+ 2c_3(N(-1+\delta+\theta-\delta\theta) + 2\bar{P}_1^{IN}) \end{aligned} \right)$$

**D.4**

Homogenous Product Consumer Surplus Ex-Ante: (4.A.4)

$$CS = \frac{1}{2} \left( \theta N - \frac{\theta N + c_1 + c_2 + c_3}{4} \right) \left( \frac{3\theta N - c_1 - c_2 - c_3}{4} \right)$$

$$CS = \frac{1}{32} (3\theta N - c_1 - c_2 - c_3)^2$$

**D.5**

Homogenous Product Consumer Surplus Ex-Post: (4.A.5)

$$CS_1 = \frac{1}{2} (P_1 - P_1[Q_1]) Q_1$$

$$CS_1 = \frac{1}{2} \left( (N(1-\delta) - \eta[\delta]) - \frac{N(1-\delta) - \eta[\delta] + c_1}{2} \right) \left( \frac{N(1-\delta) - \eta[\delta] - c_1}{2} \right)$$

$$CS_1 = \frac{1}{2} \left( \frac{N(1-\delta) - \eta[\delta] - c_1}{2} \right)^2$$

$$CS_1 = \frac{1}{8} (N(1-\delta) - \eta[\delta] - c_1)^2$$