ENTERTAINMENT WITHOUT BORDERS:
THE IMPACT OF DIGITAL TECHNOLOGIES
ON GOVERNMENT CULTURAL POLICIES, DOMESTIC FIRMS, AND CONSUMERS

By

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To my parents, Edwin and Marilou Marston, who supported me through my dreams no matter how far-fetched these goals seemed
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Many countries limit the influences of foreign entertainment products, such as music, film, and television programs, to protect their cultural identity. Commonly observed policy tools used by governments include quotas, tariffs, and subsidies. However, advances in digital technology have created new avenues, such as the Internet, for consumers to access foreign entertainment programs, bypassing government protection methods (Internet leakage). This calls for a re-examination of the effectiveness of these traditional tools. In Chapter 2, I build a unified analytical framework to study the impact of digital technology on cultural protection policies. The effectiveness of these tools is greatly impacted by the quality difference between domestic and foreign entertainment programs through traditional channels and the Internet.

Governments use a subsidy, a tariff, or a quota in an attempt to protect domestic industry or to benefit consumers. Internet leakage once again calls into question the effectiveness of these tools. In Chapter 3, I model the harmful effects of Internet
leakage and piracy to the efficiency of a subsidy, a tariff, and a quota when the government’s objective is to promote domestic industry or be benefit consumers.

Digital distribution, in addition to Internet technologies, allows Hollywood studios to deliver Video on Demand (VoD). Hollywood studios are currently reducing a movie’s DVD release window to offset losses from decreasing DVD sales. However, Hollywood studios believe that VoD has the potential to help offset studio losses. In Chapter 4, I create a model to examine the effects of adding VoD to the optimal DVD release window. Specifically I find that the addition of a VoD channel increases the optimal DVD release window, but the window is still smaller than those used by Hollywood studios today.
CHAPTER 1
INTRODUCTION

The advance of digital and communication technologies has led to the creation of digital products. Digital products have unique qualities that differentiate them from traditional products. First, digital products have a high fixed cost with a negligible marginal cost to reproduce them. Second, digital products can be perfectly copied with zero cost if no preventative measures are in place. Finally, digital products are able to be digitally transferred over networks. In addition to digital products, the advances of communication technologies have led to the Internet and Internet technologies. Internet technologies consist of the hardware and software required to maintain and run the infrastructure of the Internet. The progression of Internet technologies has created digital distribution, which allows consumers to access digital products anywhere, anytime. The properties of digital products and digital distribution make the methods used to study traditional products and distribution inadequate. Thus, research methods created to examine the digital medium are necessary. In this dissertation, I have developed methods to research the effects of digital distribution of digital products from a social, governmental, and economic perspective.

Digital and communication technologies have made considerable advancements during the last two decades. These advances have been both beneficial and problematic for governments, industries, and society. Governments have had to craft policies to deal with the different issues that have arisen from digital technologies. For example, China has created the “Great Fire Wall of China,” which limits the type of digital traffic that flows into the country. The European Union has created laws to protect database content and the privacy of an individual’s information. Industries have
had to adjust to the new ways of doing business, as well as the change in consumer behavior due to digital technologies. The ability to access up-to-date information instantly via the Internet has led consumers to move away from reading newspapers and magazines. This transformation has caused the publishing industry to reduce the number of newspapers and magazines while increasing the amount of content placed online. The television industry has taken this change as an opportunity to expand how it delivers its content to the consumers. Television programs, which would have been shown exclusively on TV, are now being streamed over the Internet for free for a period of time after the program has first aired on TV. These TV programs are also available to be purchased for digital download a day to a week after the original TV debut. With the tremendous growth in the number of users accessing the Internet, 248 million people in December 1999 to 1.8 billion people as of December 2009\(^1\), more people have to learn and understand the different aspects of digital technology. Consumers are also dealing with the advances of digital technology, learning and adjusting to new problems. For example, one issue consumers have had to learn and understand is how to use virus scanners and keep the software up to date. If consumers are not keeping the virus scanner up to date, their computers may be maliciously attacked. Since digital technology is constantly advancing, society will continuously need to consider and adapt to the changes.

Digital and Internet technology has, in essence, reduced the size of world, allowing consumers quicker and easier access to information, products, and other persons. In the early 1990s, to speak with someone across the world, an individual

\(^1\) [http://www.allaboutmarketresearch.com/Internet.htm](http://www.allaboutmarketresearch.com/Internet.htm)
needed to call that person on the telephone or write letters. Talking on the telephone would lead to large phone bills, and writing via snail mail would take days to reach the addressee. Using communication software, such as Skype, users can see and talk to another person for free. Now, thanks to digital technologies, people can send emails anywhere in the world with no delay. Less than two decades ago, consumers searching for news had to wait for a television news program to get a newscaster down to the scene or wait for newspapers that contained 10-hour-old news. Currently, consumers can get instant news via the Internet, courtesy of digital technologies and the Internet. Software companies, when completing a software program, used to have the program traditionally manufactured on CD, then shipped to the retail stores, increasing the time the software took to reach consumers. Today, software producers can complete their programs and immediately distribute the program online to consumers. The benefits that society has received from digital and Internet technology definitely offset the problems these technologies have produced. In addition to these issues, digital and Internet technologies have created new directions for researchers.

The traditional findings in different areas have not been found applicable to digital products and digital distribution based on their non-traditional qualities. Those in the field of operations management traditionally assumes that there is an inventory, holding costs, reproduction cost, and salvage value [13], which cannot be applied to digital products. Surveys done on operations management research have shown that applying traditional methods to digital products is ineffective and that new methods need to be researched [28,30].
Marketing research has also begun to study digital products. The marketing of
digital content is different than the marketing of traditional products because of the
digital contents’ accessibility, information recombination, navigation interaction, minimal
marginal cost, and speed of access to the product [39]. Maltz and Chiappetta [45]
examine how to efficiently segment the market based on the qualities of a digital
product and maximize the product’s profitability. Marketing researchers have also had
to examine selling of products over the Internet. Kiang et al. [37] examined what
product factors affect the ability of the product to be marketed online. Framback, et al.
[25] shows that online consumers prefer to interact with an employee when dealing with
complex services. Other researchers have examined different aspects of consumer
behavior which influence a consumer to purchase online [43].

Economists have also been examining new areas of research presented by the
advance in digital and communication technologies. Economists have shown that
traditional pricing schemes are not applicable to digital products due to their inherent
qualities [35]. Shapiro and Varian [50] examine how versioning of digital products can
be used to effectively price digital products and increase profits. Bakos and
Brynjolfsson [3] investigate how bundling digital products can be used to increase profit
and sales while decreasing dead weight loss. Economists have also been researching
E-Commerce. Brynjolfsson and Smith [12] study the causes in the differences of online
and traditional retailers pricing. Feng et al. [24] show under what condition single and
dual channel distribution are optimal to distribute digital products.

In spite of the work done by operations management, marketing, and economics
in the area of digital technology, little research has been conducted in the area of
information leakage and government policy. In this dissertation, I provide a unified analytical framework to study the impact of information leakage on the effectiveness of the three most common cultural protection policy tools: quota, tariff, and subsidy. I also examine the effect of information leakage when the government’s goal is to protect domestic industry using a quota, tariff, or a subsidy. Additionally, limited research has been conducted in the area of the sequential distribution of movies. No analytical studies have examined the addition of Video on Demand (VoD) channel between the theatrical release channel and DVD release channel. I provide a model to study the addition of a VoD channel to the sequential distribution of a movie on a movie’s optimal release window.

Governments that feel foreign cultural products threaten their domestic culture have traditionally defended themselves using a subsidy, a tariff, or a quota to limit these products. However, many of these cultural products are able to be digitized and distributed through the Internet. The multinational and amorphous nature of the Internet makes it difficult for governments to prevent its citizens from purchasing foreign digitized products (Internet leakage). Chapter 2 presents a model which describes how Internet leakage undermines the effectiveness of each tool and provides recommendations to governments in selecting the appropriate protection tool, based on Internet leakage and piracy.

Foreign cultural products not only threaten domestic culture but also threaten domestic industry. Governments seeking to protect or promote domestic industries will use a subsidy, a tariff, or a quota in an attempt to limit foreign products. Once again, Internet leakage limits the effectiveness of these tools since consumers can circumvent
these policies to purchase foreign digital products. In Chapter 3, I model the harmful effects of Internet leakage and piracy to the efficiency of a subsidy, a tariff, and a quota when the government’s objective is to promote domestic industry or be benefit consumers. In addition, I describe situations under which each selected tool should be optimal, based on the objective of a government.

Hollywood studios make a large profit on the sale of DVDs. However, in recent years the overall profit from the sale of DVDs has been steadily decreasing. To offset this decline in profits, Hollywood studios have been reducing the time period between a movie’s theatrical release and DVD release. With the public’s increased interest in streaming online entertainment, Hollywood executives have been examining streaming movies directly to consumers TV. Hollywood executives believe that a movie released in this Video on Demand (VoD) style during the theatrical release -- but prior to the DVD release -- is one way to help offset the decline in DVD sales. Models are presented in Chapter 4 to measure the effect of the addition of VoD to a movie’s release time.

Chapter 5 reviews the major findings of this dissertation and potential future work to be done.
CHAPTER 2
THE IMPACT OF DIGITAL TECHNOLOGIES ON GOVERNMENT CULTURAL POLICY

Preliminaries

One of America’s most important exports is popular culture, selling more than $80 billion worth of such entertainment products as books, video games, and movies annually\(^2\). For example, in 2008 approximately 78.5% of ticket sales worldwide in the film industry belonged to Hollywood productions. Hollywood movies grossed $9.942 billion internationally in 2008, an increase of 4.7% from $9.5 billion 2007\(^3\). Hollywood’s 2007 total European market share was 63.2%, while the median market share for western European Union (E.U.) countries was 64.43%. The European Union accounted for 61% of the exported audio visual services by the United States in the same year [44].

Many countries perceive the consumption of Hollywood movies and American pop music not only as eroding their national cultures and self identity but also crowding out domestically produced goods. In 1995, the European Union implemented the “Television Without Frontiers” directive to limit the influence of U.S. culture. This directive limits the amount of non-European TV programming broadcasted over E.U. member countries’ television stations. France has further implemented quotas on TV stations, radio stations, and cinemas. For television, at least 40% of broadcast time must be dedicated to French programming and an additional 20% dedicated to European programming to adhere to the European Union’s “Television Without

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\(^3\) [http://www.hollywoodreporter.com/hr/content_display/news/e3i6ad645d17ccf55b7ce7ef12cdd8057f7]
Frontiers” directive. Radio stations are required to play a mandated percentage of French language songs in addition to a percentage of French bands. Finally, a screen quota dictates the relative screen times of foreign and domestic films. The European Union is not alone in its implementation of cultural protections. Countries such as Brazil, South Korea, China, and Australia adopted similar policies to protect their own culture and domestic cultural goods.

The recent development of digital technologies, however, has created new avenues to deliver entertainment products, which makes a government’s attempt to maintain national identity and domestic cultural goods much more challenging. For example, such products as Apple TV, Microsoft’s Xbox 360, and Sony’s Playstation3 allow consumers to download music, movies, television programs, and software using broadband Internet connections. Advances in compression and streaming technologies have allowed Netflix, an Internet DVD rental company, to give consumers the ability to watch movies and television programs directly from their computer via the Internet. Major networks, such as Fox, NBC, ABC, and CBS, all post a significant portion of their newly broadcasted shows online on their websites. For example, as of April 2009, NBC broadcasted 18 scripted, reality, or news primetime shows, among which 13 shows are available to be viewed in full length on its website, including the full season of the show “Heroes” and the latest 10 episodes of “ER.” In addition to the networks, websites such as Hulu.com and Fancast.com also allow full-length episodes to be viewed. These websites have contracts with a number of television networks to broadcast both current and older television shows.
Governments have attempted to regulate the access of digital content through the aforementioned new channels by limiting access to the Internet or by limiting the type of content allowed within the country. However, governments have been very ineffective in accomplishing this task because the limitations put in place by these governments can be circumvented via software or hardware means. For instance, either virtual private networks or two-way satellite services can be used to bypass government monitoring and access content located outside of the domestic country. Since these governments have been unable to effectively regulate the Internet, the issue of Internet leakage will be a long-lasting problem.

In addition to the newly created Internet avenue for consumers to access entertainment programs, digital technology has also made it easier to pirate entertainment goods. The piracy of entertainment products has become a major concern for both content producers and governments. A U.S.-India Business Council study⁴ ("The Effects of Counterfeiting and Piracy on India’s Entertainment Industry," prepared for United States Indian Business Council by Ernst &Young India) estimates that piracy causes a loss of $4 billion each year to the Indian entertainment industry. The Motion Picture Association estimated in 2004 that $512 billion was lost in revenue from intellectual property theft (Motion Picture Association, Optical Disc Piracy v. Illegal Drug Trafficking, October 2005, p. 2). The availability of pirated goods, as well as the leakage through the new Internet channel, calls into question the effectiveness of traditional cultural protection policies in this digital era.

⁴ http://www.usibc.com/NR/rdonlyres/eqrkf3vsbfcc27vz32my4tzxlzy4jzfxeidphnnulyc63gqvui3ii3paonhsnyatnew5kb73an3mxoprx42qvszb/2008.03.27.
In essence, “Electronic commerce on the technological foundation of the Web-Internet compound has entered extensive areas of organizational and social activity” [63, p. 7], especially with the rapid development of digital technologies and the Internet. Despite abundant literature studying the impact of digital technologies and the Internet on various issues at the individual, organizational, and societal levels [10, 44, 54], little information systems (IS) research focuses on the challenges facing the government stemming from new developments of digital technologies. One notable exception is Zhu et al. [31], in which they analyze the European Union’s Database Directive introduced in 1996 to provide legal protection for database contents and to safeguard the investment of database makers. They identify socially beneficial policy choices under various conditions. This dissertation has a similar objective: to examine the effectiveness of traditional cultural policy protection tools prescribed in the European Union’s “Television Without Frontiers” directive in the new Internet environment.

Many economists have investigated the performance of various trade protection policies, most notably, subsidies (financial assistances from governments to encourage the production or purchase of a good), tariffs (taxes upon importation goods), and quotas (physical limits on the quantity of a good that can be imported). Among these policies, the most visible measure is the import quota. Quotas limit the quantity of foreign films, music, and television programs on the domestic channels, which include television, radio, and theatres. Bhagwati and Srinivasan [7] discover that the optimal tools to achieve the objective of import restriction, industry protection, and consumption restriction are tariff, subsidy, and a tax, respectively. The comparison of the effectiveness of a subsidy with that of a tariff began approximately five decades ago [3,
Various papers compare tariffs with quotas [18, 15] and find that uncertainty and market structure are the two critical factors that affect the equivalence of these two tools [4, 6, 46, 47]. Most of the research on the performance of trade protection policies deals with general industries but some research, such as Corden [17], examines it in specific industries.

Another stream of relevant literature relates to the digital distribution of products such as the effect of broadband penetration on DVD sales [51], and the effect of digital distribution in the market structure of the digital music industry [8]. In addition, attention has been paid to the impact of piracy of digital goods [29, 36, 53, 60]. Chellappa and Shivendu [14] examine the effects of trial or “lite” versions of a digital good on piracy and the conditions under which version are optimal. Chen and Png [16] investigate how government policies (subsidy, tax, and fines) can be used to enforce copyright and to induce the optimal domestic social welfare.

None of the extant research, however, considers the impact of leakage created by the advancement of digital technologies. In this dissertation, I provide a unified analytical framework to study the impact of digital technology on the effectiveness of the three most common culture protection policy tools: quota, tariff, and subsidy. I show that the relative performance of these protection tools is largely determined by the quality difference between the domestic digital entertainment and the foreign digital entertainment programs (distributed in both the traditional channels and the Internet channel). In general, I determine that the presence of leakage through the Internet reduces the effectiveness of quota, while making subsidy a more useful tool. I also find
that the social welfare under piracy is affected by the proportion of unethical users among consumers.

The remainder of Chapter 2 is structured as follows. I introduce the analytical model in the Section “The Model”. The “Baseline Model Without Leakage” section, studies the effectiveness of using a quota, tariff, or subsidy for the baseline case in which no digital entertainment from the Internet is available. The “Impact of Leakage via the Internet” section examines the impact of the leakage via the Internet on the effectiveness of traditional government cultural policies. The “Impact of Leakage via Internet In The Presence Of Piracy” section extends the model to consider the joint effect of piracy and Internet leakage. “The Summary” section recapitulates the previous sections.

**The Model**

I follow the spatial competition framework introduced in [21,40] that is widely adopted in Information Systems research [e.g., 1, 62] to study two firms -- the foreign and domestic entertainment program producers -- competing against each other through traditional channels under government regulation. I later extend the analyses to the case where consumers have access to the foreign program through the Internet, the new distribution channel not controlled by the government. Consumers are uniformly distributed by their preferences for product quality, $\theta \in [0,1]$, with a utility function $u_o(s, p) = \theta \cdot s - p$, where $s$ is the quality of the entertainment program and $p$ is its price. A rational consumer is concerned with maximizing his own utility function. The government’s objective is to select a policy tool to maximize the domestic social welfare that includes the domestic producer’s profit and all consumers’ surplus.
In this model I assume that foreign (subscript $f$) entertainment programs distributed through traditional channels have a higher quality than domestic (subscript $d$) entertainment programs, that is, $s_d < s_f$, because otherwise governmental protection is not required for domestic products. In addition, I focus on the case where foreign entertainment programs distributed on the Internet (subscript $i$) have a lower quality than those distributed through traditional channels but higher than that of domestic entertainment, that is, $s_d < s_i < s_f$. The quality of entertainment and cultural goods is a complex construct that has at least three dimensions: 1) production quality determined by the level of budget that affects the access to star actors and production technology; 2) product quality in terms of the post-production finishing of the goods consumers obtain; and 3) artistic quality represented by the originality and creativity of the goods. A domestic firm may create an entertainment program with original artistic quality. However, the same program is later turned into a product with higher production and product quality by the Hollywood studio with a much larger budget. For example, the Hollywood reshot movie, “True Lies,” outperforms its original French movie “La Totale”, making $146,563,703 at the U.S. box office and $219,000,000 in foreign box offices. Both totals dwarfed those made by “La Totale.” In this paper, the term “quality” refers to the first two dimensions of the quality construct, and I focus on the economic aspect of cultural production and international trade.

I consider a two-stage game: In stage one, the government announces which cultural protection tool to be implemented. In stage two, the two producers decide on optimal prices for their products based on the government’s implemented policy. Then consumers make their purchase decision based on the prices and quality of the
products to maximize their utility. The government’s objective is to maximize the overall
domestic social welfare given the optimal prices selected by the producers. As
consumers subscribe to broadband services mainly for Internet-related activities, the
marginal cost to consumers of using the Internet for entertainment is thus assumed to
be negligible. Table 2-1 summarizes the notation used in this dissertation.

Baseline Model Without Leakage

I first study the baseline cases without Internet leakage. The baseline case
occurs when foreign programs compete with domestic programs in traditional channels
with government regulation fully in effect.

Baseline: Quota $\bar{q}$ with No Leakage

In this case, a quota $\bar{q}$ is strictly enforced on the traditional channels through
which foreign entertainment is distributed. Let $\theta_d$ represent the marginal consumer who
is indifferent between consuming the domestic entertainment and not consuming at all,
and $\theta_f$ represent the marginal consumer who is indifferent between consuming the
domestic and foreign entertainment. Then, one has $\theta_d s_d - p_d = 0$, and $\bar{q}s_d - p_d = \bar{q}s_f - p_f$.
I consider only the case where $\bar{q} > \theta_f$, otherwise, the quota has no effect. As illustrated
in Figure 2-1. Demand of domestic and foreign entertainment under quota $\bar{q}$ and no
leakage.

, the demand for foreign entertainment is $Q_f = 1 - \bar{q}$, and the demand of domestic
entertainment is $Q_d = \bar{q} - \theta_d = \bar{q} - \frac{p_d}{s_d}$.
Given the quota $\overline{q}$ imposed by the government, the domestic firm solves the following problem:

$$\max_{p_d} \pi_d = p_d Q_d$$

$$\text{s.t. } p_d = \theta_d s_d,$$

(2-1)

while the problem facing the foreign firm is

$$\max_{p_f} \pi_f = p_f Q_f$$

$$\text{s.t. } p_f = \overline{q} (s_f - s_d) + p_d.$$  

(2-2)

The following lemma describes the optimal prices for the domestic and foreign firms.

**Lemma 2-1:** When there is no leakage and quota $\overline{q}$ is imposed on foreign entertainment, optimal pricing strategies for the domestic firm and the foreign firm are

$$p_d^* = \frac{s_d (s_f - s_d)}{4s_f - s_d},$$

$$p_f^* = \frac{2s_f (s_f - s_d)}{4s_f - s_d},$$

if $\overline{q} < \frac{2s_f - s_d}{4s_f - s_d}$, and

$$p_d^* = \frac{\overline{q} s_d}{2},$$

$$p_f^* = \frac{\overline{q} (2s_f - s_d)}{2},$$

if $\overline{q} \geq \frac{2s_f - s_d}{4s_f - s_d}$.

**Proof:** I delegate the proof of all lemmas and theorems to the Appendix.

The government determines the optimal quota to maximize the domestic social welfare by solving

$$\max_{\overline{q}} \left[ \pi_d^* + \int_0^{\overline{q}} (\theta s_d - p_d^*) d\theta + \int_{\theta d}^{\overline{q}} (\theta s_f - p_f^*) d\theta \right],$$

(2-3)

which leads to the following theorem.

**Theorem 2-1:** When there is no leakage and quota $\overline{q}$ is imposed on foreign entertainment, the government’s socially optimal quota should be set at the free trade equilibrium value $\overline{q}^* = \frac{2s_f - s_d}{4s_f - s_d}$. 

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Note that even though the optimal quota on foreign entertainment is set at the free trade level, the prices for both domestic and foreign entertainment are higher than those in the free trade case, which reduces consumer welfare. This is consistent with traditional international trade theory. Intuitively, when a quota is in effect, the domestic firm has less pressure to compete with a foreign firm because the foreign firm cannot serve the market exceeding the prescribed quota, resulting in a higher price of the domestic goods. This gives the foreign firm an incentive to also increase its price because a lower price will not increase demand due to the quota.

Based on the optimal quota set by the government, the corresponding optimal domestic social welfare is

$$SW^*(q^*) = \frac{4s_f^2 + 8s_ds_f - 3s_d^2}{8(4s_f - s_d)}.$$ (2-4)

**Baseline: Subsidies $\sigma$ with No Leakage**

In this case, a subsidy $\sigma$ is granted by the government to the consumers of domestic entertainment. Let $\theta_{d-\sigma}$ represent the consumer who is indifferent between consuming the domestic entertainment and not consuming at all, and $\theta_f$ represent the consumer who is indifferent between consuming the domestic and foreign entertainments. Then I have $\theta_{d-\sigma} \cdot s_d - (p_d - \sigma) = 0$, and $\theta_f \cdot s_f - p_f = \theta_f \cdot s_d - (p_d - \sigma)$. As illustrated in Figure 2, the demand for foreign entertainment is

$$Q_f = 1 - \theta_f = 1 - \frac{p_f - p_d + \sigma}{s_f - s_d},$$ (2-5)

and the demand for the domestic entertainment is
Given a subsidy $\sigma$, the profit functions for domestic and foreign firms are determined as follows:

\[
\max_{p_d} \pi_{d, \sigma} = p_d Q_{d, \sigma}
\]
\[
\text{s.t. } p_d = \theta_{d, \sigma} \cdot s_d + \sigma
\]  
\[
\max_{p_f} \pi_f = p_f \left(1 - \theta_f\right)
\]
\[
\text{s.t. } p_f = p_d - \sigma + \theta_f \left(s_f - s_d\right).
\]  

The following lemma describes the optimal prices for domestic and foreign firms.

**Lemma 2-2:** When there is no leakage and a subsidy $\sigma$ is given to the consumers of domestic entertainment, optimal pricing strategies for the domestic firm and the foreign firm are

\[
p_d^* = \frac{s_d \left(s_f - s_d\right)}{4s_f - s_d} + \frac{\sigma}{2} \left(1 - \frac{s_d}{4s_f - s_d}\right) \quad \text{and} \quad p_f^* = \frac{2s_f \left(s_f - s_d\right) - \sigma s_f}{4s_f - s_d}.
\]  

The government determines the optimal subsidy to maximize the domestic social welfare by solving

\[
\max_{\sigma} \left[ \pi_d^* + \int_{\theta_{d, \sigma}}^{\theta_f} \left(\theta s_d - p_d^* + \sigma\right) d\theta + \int_{\theta_{d, \sigma}}^{\theta_f} \left(\theta s_f - p_f^*\right) d\theta - \sigma \left(\theta_f - \theta_{d, \sigma}\right)\right].
\]  

**Theorem 2-2:** When there is no leakage and a subsidy $\sigma$ is given to domestic entertainment, the government’s socially optimal subsidy should be set at

\[
\sigma^* = \frac{s_d \left(s_f - s_d\right)}{s_f}.
\]

Given the optimal subsidy, the optimal domestic social welfare is given by

\[
Q_{d, \sigma} = \theta_f - \theta_{d, \sigma} = \frac{p_f - p_d + \sigma}{s_f - s_d} - \frac{p_d - \sigma}{s_d}.
\]  

\[\text{(2-6)}\]
Baseline: Tariffs $\tau$ with No Leakage

In this case, a tariff $\tau$ is strictly enforced on the traditional channel of foreign entertainment. Following a similar solution procedure to the “Baseline: Subsidies $\sigma$ with No Leakage” subsection, I derive the following results.

**Lemma 2-3:** When there is no leakage and a tariff $\tau$ is imposed on the foreign entertainment, optimal pricing strategies for the domestic firm and the foreign firm are

\[ p^*_d = \frac{s_d(s_f - s_d)}{4s_f - s_d} + \frac{\tau s_d}{2s_f} \left( \frac{s_d}{4s_f - s_d} + 1 \right) \text{ and } p^*_f = \frac{2s_f(s_f - s_d)}{4s_f - s_d} - \frac{\tau (2s_f - s_d)}{4s_f - s_d}. \]

The government determines an optimal tariff to maximize the domestic social welfare by solving

\[
\max_{\tau} \left[ \pi^*_d + \int_{\theta} (\theta s_d - p^*_d)d\theta + \int_{\theta} (\theta s_f - p^*_f - \tau)d\theta + \tau \left( 1 - \theta_{f+\tau} \right) \right].
\]

**Theorem 2-3:** When there is no leakage and a tariff $\tau$ is imposed on the foreign entertainment, the government’s socially optimal tariff equals

\[ \tau^* = \frac{s_f(2s_f - s_d)}{2(3s_f - s_d)}. \]

Given the optimal tariff, the optimal domestic social welfare is given by

\[
\text{SW}^*(\tau^*) = \frac{s_f \left( 2s_f^3 - 12s_d^2s_f + 13s_d s_f^2 + 16s_d^3 \right)}{2 \left( 4s_f - s_d \right)^2 \left( 3s_f - s_d \right)}.
\]

\(2-10\)

\(2-11\)

\(2-12\)
Comparison of Baseline Cases

In this subsection, I compare the performance of the three cultural protection tools to find which tool generates the highest optimal domestic social welfare. Comparing the optimal domestic social welfare leads to the following theorem.

**Theorem 2-4:** When there is no leakage, the use of a tariff produces a higher optimal domestic social welfare than a subsidy, and the use of a subsidy will always produce a greater optimal domestic social welfare than a quota, that is,

\[ SW^* (\tau^*) > SW^* (\sigma^*) > SW^* (\bar{q}^*) . \]

Theorem 2-4 shows a clear ranking among different cultural protection tools in the case of no leakage. A tariff produces the best domestic social welfare because of the increase in the government revenue. A subsidy is also effective because it not only increases the profit of the domestic firm, but also expands the consumption of the domestic entertainment. However, a quota does not perform as well as the other two tools because it not only limits the consumption of foreign goods, but also increases the prices of both foreign and domestic entertainment, which reduces the social welfare.

Figure 2-3 depicts the optimal domestic social welfare produced by these different policies according to the difference of quality levels produced by the domestic and the foreign firms. The figure shows that the performances of the three different cultural protection tools are mainly driven by the quality difference between the foreign and domestic entertainments. Optimal tariff always produces the highest social welfare among the cultural protection tools. The performance of optimal subsidy can be very close to that of optimal tariff when the quality difference between the domestic and
A foreign firm is neither too small nor too big (in the 40% - 60% range.) Imposing a quota, on the other hand, is always inferior to the other two policies.

**Impact of Leakage via the Internet**

I next consider the case where digital technologies enable the foreign firm to distribute its content over the Internet bypassing the domestic government’s control. For example, news networks, such as NBC, place their contents on the Internet after they are aired, which can be accessed from anywhere on the Internet. Leakage also occurs when Internet stores, such as iTunes, allow consumers to directly download entertainment content to a computer or media device. In this section, I examine the impact of leakage over the Internet on the three cultural protection policies under consideration: quota, tariff, and subsidy.

**Impact of Leakage through the Internet on Quota $q_t$**

This subsection examines the effect of quota when quota can control only the consumption quantity of foreign entertainment over traditional channels.

Let $\theta_i$ represent the marginal consumer who is indifferent between consuming the domestic entertainment and the foreign entertainment via the Internet. I then have three indifferent conditions: $\theta_d s_d - p_d = 0$, $\theta_i s_i - p_i = \theta_i s_i - p_i$, and $\overline{q_i} s_i - p_i = \overline{q_i} s_f - p_f$. As illustrated in Figure 2-4, the demand for the foreign entertainment via the traditional broadcast channel is $Q_f = 1 - \overline{q_i} = 1 - \frac{p_f - p_i}{s_f - s_i}$, the demand for the foreign entertainment via the Internet is $Q_i = \frac{p_f - p_i}{s_f - s_i} - \frac{p_i - p_d}{s_i - s_d}$, and the demand for the domestic entertainment is $Q_d = \theta_i - \theta_d = \frac{p_i - p_d}{s_i - s_d} - \frac{p_d}{s_d}$.
Given a quota \( \bar{q}_i \), the domestic firm solves the following problem

\[
\max_{p_d} \quad \pi_d = p_d Q_d \\
\text{s.t.} \quad p_d = \theta_d s_d
\]

(2-11)

while the foreign firm solves

\[
\max_{p_f, p_i} \quad \pi_f = p_f Q_f + p_i Q_i \\
\text{s.t.} \quad p_f = p_i + \bar{q}_i \left( s_f - s_i \right) \\
\quad p_i = p_d + \theta_i \left( s_i - s_d \right)
\]

(2-12)

The following lemma shows the optimal prices for the entertainment program in the domestic, Internet, and foreign traditional channels.

**Lemma 2-4:** When there is leakage through the Internet channel and quota \( \bar{q}_i \) is imposed on the foreign traditional channel, optimal pricing strategies for the domestic firm and the foreign firm are

\[
\begin{align*}
    p_d^* &= s_d \left( s_i - s_d \right) \\
    p_i^* &= \frac{2s_i \left( s_i - s_d \right)}{4s_i - s_d}, \quad \text{if } \bar{q}_i \leq \frac{1}{2}, \\
    p_{b}^* &= \frac{4s_f, s_i - s_d \left( s_f + 3s_i \right)}{2 \left( 4s_i - s_d \right)}, \\
    p_d^* &= \bar{q}_i s_d \left( s_i - s_d \right) \\
    p_i^* &= \frac{2\bar{q}_i s_i \left( s_i - s_d \right)}{4s_i - s_d}, \quad \text{if } \bar{q}_i > \frac{1}{2}, \\
    p_f^* &= \bar{q}_i \left( \frac{s_f \left( 4s_i - s_d \right) + s_i \left( 2s_i + s_d \right)}{4s_i - s_d} \right).
\end{align*}
\]
The goal of the government is to determine the optimal quota to maximize domestic social welfare by solving
\[
\max_{\bar{q}_i} \left[ \pi_d^* + \int_{q_d^*}^{\bar{q}_i} (\theta s_d - p_d^*) d\theta + \int_{q_i^*}^{\bar{q}_i} (\theta s_i - p_i^*) d\theta + \int_{q_f^*}^{\bar{q}_i} (\theta s_f - p_f^*) d\theta \right]. \tag{2-13}
\]

**Theorem 2-5:** When there is leakage through the Internet channel and a quota \(\bar{q}_i\) is imposed on the foreign traditional channel, the government’s socially optimal quota should be set at
\[
\bar{q}_i = \frac{2s_i (2s_f - s_i) - s_d (s_f + s_i)}{s_i (4s_f - 3s_i) - s_d s_f}.
\]

Given the optimal quota \(\bar{q}_i^*\), the optimal domestic social welfare is given by
\[
SW_d^* (\bar{q}_i^*) = \frac{s_i \left[ 4s_i^2 (s_f - s_i) - s_d^2 (s_f + s_i) + s_d s_i (7s_f - 4s_i) \right]}{2 (4s_i - s_d) \left( s_i (4s_f - 3s_i) - s_d s_f \right)}.
\tag{2-14}

**Impact of Leakage through the Internet on Tariff \(\tau_i\)**

In this subsection, the use of tariff is examined in the presence of leakage where a tariff can be effectively imposed only on foreign entertainment in the traditional channel. The three indifferent conditions include: 1) a consumer who is indifferent between consuming the domestic entertainment and not consuming at all satisfies \(\theta_d s_d - p_d = 0\); 2) a consumer who is indifferent between consuming the foreign entertainment via the Internet and the domestic entertainment satisfies \(\theta s_d - p_d = \theta s_i - p_i\); and 3) a consumer that is indifferent between consuming the foreign entertainment via the Internet and via traditional channel satisfies \(\theta_{f+\tau_i} s_i - p_i = \theta_{f+\tau_i} s_f - (p_f + \tau_i)\). As illustrated in Figure 2-5, the demand for the
foreign entertainment over the traditional channel is \( Q_{f+\tau} = 1 - \theta_{f+\tau} = 1 - \frac{p_f + \tau_i - p_i}{s_f - s_i} \), the demand for the foreign entertainment over the Internet is

\[ Q_i = \theta_{f+\tau} - \theta_i = \frac{p_f + \tau_i - p_i}{s_f - s_i} - \frac{p_i - p_d}{s_i - s_d}, \]

and the demand of domestic entertainment is

\[ Q_d = \theta_i - \theta_d = \frac{p_i - p_d}{s_i - s_d} - \frac{p_d}{s_d}. \]

Given the tariff \( \tau_i \), the profit functions for domestic and foreign firms are determined as follows

\[
\begin{align*}
\max_{p_d} \quad & \pi_d = p_d Q_d \\
\text{s.t.} \quad & p_d = \theta_d s_d \\
\end{align*}
\]

(2-15)

\[
\begin{align*}
\max_{p_f, p_i} \quad & \pi_f = p_f Q_{f+\tau} + p_i Q_i \\
\text{s.t.} \quad & p_i = p_d + \theta_i (s_i - s_d) \\
& p_f = p_i - \tau_i + \theta_{f+\tau} (s_f - s_i) \\
\end{align*}
\]

(2-16)

The following lemma describes the optimal pricings for the domestic and foreign firms in the presence of leakage over the Internet and a tariff \( \tau_i \) levied on foreign entertainment consumed over the traditional channel.

**Lemma 2-5:** When there is leakage through the Internet channel and a tariff \( \tau_i \) is imposed on the foreign entertainment in the traditional channel, optimal pricing strategies for the domestic firm and the foreign firm are
The government determines the optimal tariff to maximize the domestic social welfare by solving

$$
\begin{align*}
\pi_d^* &= \frac{s_d (s_i - s_d)}{4s_i - s_d}, \\
p_i^* &= \frac{2s_i (s_i - s_d)}{4s_i - s_d}, \\
p_f^* &= \frac{(s_f - \tau_f)(4s_i - s_d) - 3s_ds_i}{2(4s_i - s_d)}.
\end{align*}
$$

Theorem 2-6: When there is leakage through the Internet channel and a tariff $\tau_i$ is imposed on the foreign entertainment in traditional channel, the government’s socially optimal tariff should be set at $\tau_i^* = \frac{(s_f - s_i)}{3}$.

Given the optimal tariff, the optimal domestic social welfare is given by

$$
SW(\tau_i^*) = \frac{s_i (4s_i - s_d) - s_d (s_f - 7s_i)}{6(4s_i - s_d)}. 
$$

Impact of Leakage through the Internet on Subsidies $\sigma_i$

In this subsection, I examine the impact of leakage on the subsidy policy.

Following steps similar to those used in the “Impact of Leakage through the Internet on Tariff $\tau_i$“ subsection, I obtained the following results.

Lemma 2-6: When there is leakage through the Internet channel and a subsidy $\sigma_i$ is provided to domestic entertainment, optimal pricing strategies for the domestic firm and the foreign firm are
The government decides the optimal subsidy to maximize the domestic social welfare by solving

\[
\max_{\sigma}\left[\pi^* + \int_{\theta_d}^{\theta} (\theta s_d - p_d^* + \sigma_j) d\theta + \int_{\theta_i}^{\theta_j} (\theta s_j - p_i^*) d\theta + \int_{\theta_j}^{1} (\theta s_j - p_j^*) d\theta - \sigma(\theta_{j-\theta_d-\sigma_j})\right].
\] (2-19)

**Theorem 2-7:** When there is leakage through the Internet channel and a subsidy \(\sigma_i\) is given to domestic entertainment, the government’s socially optimal subsidy should be set at \(\sigma_i^* = \frac{s_d (s_i - s_d)}{s_i}\).

Given the optimal subsidy, the optimal domestic social welfare is specified by

\[
SW^*(\sigma_i^*) = \frac{\left(4s_j s_i - 4s_d^2 - s_d (s_f - 13s_i)\right)}{8(4s_i - s_d)}.
\] (2-20)

**Comparison of Cultural Policies in the Presence of Leakage via Internet**

In this subsection, I compare the optimal domestic social welfare under different cultural protection policies when there is leakage through Internet. Theorem 8 describes whether the optimal domestic social welfare will increase or decrease under each cultural protection policy with the increase of the quality of foreign entertainment program delivered through the Internet. Theorem 2-9 compares the optimal social welfare resulting from these policies in the presence of leakage via the Internet.
**Theorem 2-8:** When there is leakage through the Internet, the optimal domestic social welfare is decreasing in the quality of foreign entertainment program delivered through the Internet when a tariff is imposed, while it is increasing under the subsidy policy. The optimal social welfare under the quota policy may increase or decrease in the quality of foreign entertainment distributed via the Internet.

Theorem 2-8 shows that the higher the quality of the foreign entertainment program through the Internet, the less the optimal social welfare under tariff and quota policies. As the quality of the foreign entertainment program through the Internet increases, more consumers obtain foreign programs through the Internet, taking demand from both foreign entertainment through traditional channels and domestic entertainment. Thus, the overall demand for foreign entertainment increases while demand for domestic entertainment decreases, causing the decrease in domestic social welfare. Optimal domestic social welfare under the subsidy policy improves as the quality of foreign entertainment through the Internet increases, which benefits consumers. Hence the increased competition of foreign content between the traditional and Internet channels increases the domestic social welfare under subsidy.

**Theorem 2-9:** In the presence of leakage, the optimal domestic social welfare resulting from the use of a quota is dominated by the use of a tariff or subsidy. In addition, the tariff policy produces the highest optimal domestic social welfare when the quality of the foreign entertainment programs through the Internet $s_i$ is lower than the threshold value of

$$s_i = \frac{4s_i - 11s_d + \sqrt{313s_i^2 - 104s_i s_d + 16s_d^2}}{8},$$

while the subsidy policy is optimal when $s_i$ is higher than the threshold value.
Theorem 2-9 shows that both the tariff and subsidy policies could be optimal in generating the highest domestic social welfare in the presence of leakage. It is not difficult to understand the superiority of the tariff policy as it increases the government’s revenue. However, the effectiveness of the tariff decreases with an increase in the quality of foreign programs over the Internet because the increase of consumption of entertainment over the Internet is drawn from the other channels without expanding the total market. Also, a subsidy can be superior when \( s_i \) increases because it increases the amount of domestic entertainment consumption by enrolling consumers who would not consume any entertainment otherwise. Finally, the quota policy is the least effective in terms of creating the optimal domestic social welfare in the presence of leakage because the effect of the quota is blunted as more consumers have access to foreign entertainment through the Internet. Figure 2-6 illustrates these results.

**Impact of Leakage via Internet in the Presence of Piracy**

In this subsection, I explore the joint effect of piracy and leakage over the Internet on the effectiveness of the three cultural protection policies. I extend the model to examine the effect of piracy by adding two new parameters \( \alpha \) and \( c_g \). The parameter \( \alpha \in [0,1] \) indicates the percentage of ethical users who will purchase only foreign entertainment through legal channels, while \( (1 - \alpha) \) proportion of the consumers are unethical users, who may opt for pirating foreign entertainment or purchasing it through legal channels, depending on the cost of piracy \( c_g \). Piracy includes CD/DVD/VCD bootlegging, unauthorized resellers, and digital consumer sharing. The parameter \( c_g \) captures all the costs for an unethical user to pirate foreign entertainment, including the
search cost and the potential penalty of being caught. This parameter $c_g$ corresponds to the prevalence level of piracy as a strict enforcement of intellectual property rights, which leads to less piracy and results in a higher $c_g$. I focus on the case where $c_g$ is less than the quality of the pirated entertainment product through the Internet, that is, $0 \leq c_g < s_i$.

**Quota $\bar{q}_p$**

Because ethical consumers can purchase foreign entertainment products through the traditional channel or the Internet, or domestic entertainment, or not at all, I then have three indifferent conditions for the ethical users: $\theta_d s_d - p_d = 0$, $\theta_d s_d - p_d = \theta_i s_i - p_i$, and $\bar{q}_p s_i - p_i = \bar{q}_p s_f - p_f$. Similarly, two indifferent points for the unethical users include: $\theta_g s_g - c_g = 0$ and $\theta_{fg} s_g - c_g = \theta_{fg} s_f - p_f$. As illustrated in Figure 2-7, the demand of ethical users for foreign entertainment via the traditional channel is $Q_f = 1 - \bar{q}_p$, for foreign entertainment via the Internet is $Q_i = \frac{p_f - p_i}{s_f - s_i} - \frac{p_i - p_d}{s_i - s_d}$, and for domestic entertainment demand is $Q_d = \theta_d - \theta_i = \frac{p_i - p_d}{s_i - s_d} - \frac{P_d}{s_d}$. Demand of unethical users for foreign entertainment is $1 - \bar{q}_p$ and for pirated foreign entertainment is $Q_g = \theta_{fg} - \theta_g = \bar{q}_p - \frac{c_g}{s_g}$.

Given a quota $\bar{q}_p$, the domestic firm solves the following problem

\[
\begin{align*}
\max_{p_d} \quad & \pi_d = \alpha p_d Q_d \\
\text{s.t.} \quad & p_d = \theta_d s_d
\end{align*}
\]  (2-21)
while the foreign firm solves

\[
\begin{align*}
\max_{p_f, p_i} \quad & \pi_f = \alpha \left( p_f Q_f + p_i Q_i \right) + (1 - \alpha) \left( p_f Q_{fs} \right) \\
\text{s.t.} \quad & p_f = p_i + \bar{q}_{p} \left( s_f - s_i \right) \\
& \quad p_i = p_d + \theta_i \left( s_i - s_d \right) 
\end{align*}
\]

\( (2-22) \)

The following lemma shows the optimal prices for the entertainment program distributed through different channels.

**Lemma 2-7:** When there is leakage through the Internet channel and piracy is present, given the quota \( \bar{q}_{p} \) imposed by the government, optimal pricing strategies for the domestic firm and the foreign firm are:

\[
\begin{align*}
p_d^* &= \frac{s_d \bar{q}_{p} \left( s_i - s_d \right)}{4s_i - s_d}, \\
p_i^* &= \frac{2s \bar{q}_{p} \left( s_i - s_d \right)}{4s_i - s_d}, \\
p_f^* &= \bar{q}_{p} \frac{s_f \left( 4s_i - s_d \right) + s_i \left( 2s_i + s_d \right)}{4s_i - s_d}.
\end{align*}
\]

The goal of the government is to determine the optimal quota to maximize domestic social welfare by solving

\[
\max_{q_p} \left[ \alpha \left( \pi_d^* + \int_{0}^{\theta} \left( \theta s_d - p_d^* \right) d\theta \right) + \int_{0}^{\theta} \left( \theta s_i - p_i^* \right) d\theta + \int_{\tilde{q}_p}^{\theta} \left( \theta s_f - p_f^* \right) d\theta \right] + (1 - \alpha) \left( \int_{0}^{\theta} \left( \theta s_g - c_g \right) d\theta + \int_{\tilde{q}_p}^{\theta} \left( \theta s_f - p_f^* \right) d\theta \right)
\]

\( (2-23) \)

**Theorem 2-10:** When there exists leakage through the Internet channel and piracy, the government’s socially optimal quota should be set at

\[
\hat{q}_p = \frac{\left( c_g (1 - \alpha) (4s_i - s_d) + 2s_i \left( 2s_f - s_i \right) - s_d \left( s_f + s_i \right) \right)}{s_i \left( 4s_f + 4s_g \left( 1 - \alpha \right) - s_i \left( 4 - \alpha \right) \right) - s_d \left( s_f + (1 - \alpha) \left( 2s_i - s_g \right) \right)}.
\]
The optimal domestic social welfare is derived by plugging $\overline{q}_p$ back into the expression of domestic social welfare.\(^5\)

**Tariff $\tau_p$**

The three indifferent conditions for ethical users include: 1) a consumer who is indifferent between consuming the domestic entertainment and not consuming at all satisfies $\theta_d s_d - p_d = 0$; 2) a consumer who is indifferent between consuming the foreign entertainment over the Internet and the domestic entertainment satisfies $\theta_d s_d - p_d = \theta_i s_i - p_i$; and 3) a consumer who is indifferent between consuming the foreign entertainment over the Internet and foreign entertainment through traditional channel satisfies $\theta_f + \tau_p s_i - p_i = \theta_f s_f - (p_f + \tau_p)$. As illustrated in Figure 2-8, the demand of ethical users for foreign entertainment via the traditional channel is

$$Q_{1+\tau_p} = \frac{p_f - p_i + \tau_p}{s_f - s_i}, \text{ for foreign entertainment over the Internet is}$$

$$Q_i = \frac{p_f - p_i + \tau_p}{s_f - s_i} - \frac{p_i - p_d}{s_i - s_d}, \text{ and for domestic entertainment is } Q_d = \theta_i - \theta_d = \frac{p_i - p_d}{s_i - s_d} - \frac{p_d}{s_d}.$$  

Demand of unethical users for the foreign entertainment over the traditional channel is

$$Q_{fs} = \frac{p_f - c_g + \tau_p}{s_f - s_g} \text{ and for pirated foreign entertainment is } Q_g = \frac{p_f - c_g + \tau_p}{s_f - s_g} - \frac{c_g}{s_g}.$$  

Given a tariff $\tau_p$, the profit functions for domestic and foreign firms are determined as follows

---

\(^5\) I omit the optimal domestic social welfare expressions under the quota, tariff, and subsidy policies in the case of piracy and leakage as they are too complex and will take up several pages to describe.

\(^6\) [http://www.media-awareness.ca/english/issues/cultural_policies/canadian_content](http://www.media-awareness.ca/english/issues/cultural_policies/canadian_content)
The following lemma gives the optimal pricing strategies for the domestic and foreign firms.

**Lemma 2-8:** When there is leakage through the Internet channel and piracy is present, given a tariff $\tau_p$, the optimal pricing strategies for the domestic firm and the foreign firm are

\[
\begin{align*}
    p_d^* &= \frac{s_d \left(s_f + c_s (1-\alpha) - s_g \right) (s_i - s_d)}{4s_f \left(s_f - \alpha s_g \right) - s_d \left( s_f (5 - 4\alpha) - s_i (1-\alpha) - \alpha s_g \right)} \\
    p_i^* &= \frac{2s_f \left( s_f - s_k + c_s (1-\alpha) \right) (s_i - s_d)}{4s_f \left( s_f - \alpha s_g \right) - s_d \left(s_f (5 - 4\alpha) - s_i (1-\alpha) - \alpha s_g \right)} \\
    p_f^* &= \frac{4s_f \left(s_f^2 + \alpha \tau_p s_g - s_f (\tau_p - c_s (1-\alpha) + s_g) \right) - s_d \left(s_f (\alpha \tau_p + s_i) \right)}{4s_f \left(s_f - \alpha s_g \right) - s_d \left(s_f (5 - 4\alpha) - s_i (1-\alpha) - \alpha s_g \right)} \\
\end{align*}
\]

The government determines the optimal tariff to maximize the domestic social welfare by solving
\[
\max_{\tau_p} \left[ \alpha \left( \pi_d^* + \int_{0}^{\theta} (\theta s_d - p_d^*) d\theta + \int_{0}^{\theta} (\theta s_i - p_i^*) d\theta + \int_{0}^{\theta} (\theta s_f - p_f^* - \tau_p) d\theta + \tau_p (1 - \theta f + \pi_p) \right) \right] \\
+ (1 - \alpha) \left[ \int_{0}^{\theta} (\theta s_g - c_g) d\theta + \int_{0}^{\theta} (\theta s_f - p_f^* - \tau_p) d\theta + \tau_p (1 - \theta f + \pi_p) \right] \right].
\]

(2-26)

**Theorem 2-11:** When there is leakage through the Internet channel and piracy is present, the government’s socially optimal tariff should be set at

\[
\tau_p^* = \frac{(s_f - s_i)(s_f + c_g(1 - \alpha) - s_g)}{3(s_f - s_i)(1 - \alpha) - \alpha s_g}).
\]

**Subsidies \( \sigma_p \)**

Following a similar solution procedure used in the “Tariff \( \tau_p \)” subsection, I obtain

the following results.

**Lemma 2-9:** When there is leakage through the Internet channel, and piracy is present, given the subsidy \( \sigma_p \), the optimal pricing strategies for the domestic firm and the foreign firm are:

\[
\begin{align*}
\pi_d^* &= \frac{2\sigma_p s_i (s_f - \alpha s_g) + s_d (s_f (s_i - \alpha) - s_i (\sigma_p - \alpha s_g) + \alpha \sigma_p s_g) + s_d (s_f - \alpha s_g) - s_i (\sigma_p - \alpha s_g) + \alpha \sigma_p s_g)}{4s_i (s_f - \alpha s_g) - s_d (s_f - \alpha s_g + 3s_i (1 - \alpha))}, \\
\pi_i^* &= \frac{s_i (\sigma_p s_f - \alpha \sigma_p s_g - 2c_g (1 - \alpha)(s_i - s_d))}{2(s_f - s_g)(s_i - s_d) - \sigma_p s_i (1 - \alpha)} \\
\pi_f^* &= \frac{-4s_i (s_f - \alpha s_g) + s_d (s_f - \alpha s_g + 3s_i (1 - \alpha))}{-8s_i (s_f - \alpha s_g) + 2s_i (s_f - \alpha s_g + 3s_i (1 - \alpha))}.
\end{align*}
\]
The government determines the optimal subsidy to maximize the domestic social welfare by solving:

\[
\max_{\alpha} \left[ \alpha \left( \pi_d^* + \int_{\theta_d}^{\theta_p} (\theta s_d - p_d^* + \sigma_p) d\theta + \int_{\theta_f}^{\theta_p} (\theta s_f - p_f^*) d\theta - \sigma_p (\theta_f - \theta_d) \right) \right]
\]

\[
+ (1 - \alpha) \left( \int_{\theta_e}^{\theta_p} (\theta s_e - c_s) d\theta + \int_{\theta_f}^{\theta_e} (\theta s_f - p_f^*) d\theta \right).
\]

(2-27)

**Theorem 2-12:** When there is leakage through the Internet channel and piracy is present, the government's socially optimal subsidy should be set at

\[
\sigma_p^* = \frac{s_d \left( s_f + c_e (1 - \alpha) - s_s \right) \left( s_f - s_d \right)}{s_s \left( s_f + \alpha s_s - s_d \left( 1 - \alpha \right) \right)}.
\]

**Comparison of Cultural Policies in the Presence of Leakage via Internet and Piracy**

In this subsection, I first examine the comparative statics of each cultural protection policy with respect to the proportion of ethical users and the cost of piracy. I next analyze the effect of these two piracy parameters on the optimal domestic social welfare under each policy. Finally, I compare the performance of the cultural protection policies in an environment where there exist both piracy and leakage through the Internet.

**Theorem 2-13:** When there is leakage through the Internet and piracy is present, the socially optimal quota, subsidy, and tariff are increasing in the cost of piracy \( c_e \).

Both the optimal quota and tariff are decreasing in the percentage of ethical users \( \alpha \).

However, the optimal subsidy is increasing with respect to \( \alpha \) if the cost of piracy, \( c_s \), is greater than the difference in the quality of pirated and domestic entertainment \( (s_s - s_d) \), and decreasing otherwise.
Table 2 summarizes the comparative statics.

Theorem 2-13 shows that as the cost of piracy increases, the intensity of government cultural protection policies increases as well. Since the number of consumers who pirate goods is reduced, as a result, more users are impacted by the government policies. Theorem 2-13 also states that both the optimal quota and tariff decrease as the number of unethical users increases. As the number of unethical users increases, the impact of quota and tariff is reduced since the number of users who can avoid the quota or tariff increases. The optimal subsidy, surprisingly, can either be increasing or decreasing in the proportion of ethical users $\alpha$, depending on the quality difference between the pirated goods and domestic goods relative to the cost of piracy. When the quality difference between pirated and domestic goods is less than the cost of piracy, the optimal subsidy will increases as the number of unethical users increases. This occurs because increasing the subsidy will help domestic entertainment to become more competitive with pirated foreign entertainment.

**Theorem 2-14:** When there is leakage through the Internet and piracy is present, the optimal domestic social welfare produced by quota, subsidy, or tariff policy is decreasing in $\alpha$. In addition, both the optimal domestic social welfare under subsidy and tariff are decreasing in $c_g$, while optimal domestic social welfare under subsidy can be either increasing or decreasing in $c_g$.

Table 2-3 summarizes the comparative statics of optimal domestic social welfare under each cultural policy with respect to $\alpha$ and $c_g$.

It is not surprising to find that the domestic social welfare is decreasing as the number of ethical users increases, because fewer consumers enjoy the pirated
entertainment. Domestic social welfare is increasing as the cost of piracy increases for both the subsidy and tariff cases because fewer consumers pirate foreign entertainment, and they either elect to purchase entertainment with higher prices or choose not to purchase at all.

Table 2-4 shows that when all consumers are ethical \((\alpha = 1)\), the model reduces to the case when no piracy is present. In the presence of piracy, both the optimal quota and tariff are greater than when only leakage is present. However, the optimal subsidy can be either greater than or less than that in case of the Internet leakage, depending on the quality of the domestic entertainment.

In the presence of both piracy and leakage through the Internet, the tariff policy generates the highest optimal domestic social welfare when a significant population of unethical users is present. However, as the number of unethical users decreases, granting subsidy becomes the preferred policy. Figure 2-9 depicts a numerical example of behavior of the optimal domestic social welfare under different cultural protection policies. The optimal domestic social welfare is determined by both the quality difference between the foreign entertainment distributed through the Internet and domestic entertainment, the cost of piracy, and the amount of unethical users. When quality difference between the foreign entertainment distributed through the Internet and domestic entertainment decreases, it causes the optimal domestic social welfare magnitude to decrease for all policy tools. As the quality of entertainment through the Internet increases and begins to compete with the foreign entertainment through the traditional channel, the magnitude of the optimal domestic social welfare slowly increases. As stated in Theorem , under all policies the optimal domestic social welfare
is decreasing as the number of unethical users decreases. The proportion of ethical users also determines the point at which subsidy surpasses tariff in generating a higher optimal domestic social welfare. When the number of ethical users is small, the tariff creates the optimal domestic social welfare. As the number of ethical users increases, the optimal domestic social welfare is eventually produced by the subsidy policy. This occurs because the subsidy is able to influence only ethical users, while the tariff influences both the ethical and unethical users. Consistent with the non-leakage and leakage cases, optimal domestic social welfare level under the quota policy is always dominated by that attained by either the tariff or subsidy policy tool.

**Summary**

As information and communication technologies improve and advance at a rapid rate, more entertainment goods, such as music, movies, and television programs, become available in domestic markets, which may potentially influence a country’s culture. Governments perceive these products as a threat to their national culture and combat this threat with traditional cultural protection tools, including quota, tariff, and subsidy. However, the ability for the foreign firm to deliver digital entertainment over new avenues, especially the Internet, has created leakage that challenges the effectiveness of these traditional cultural protection policy tools.

This dissertation analyzes the impact of Internet leakage on the effectiveness of quota, tariff, and subsidy policies in both the absence and presence of piracy of the foreign products from the perspective of a domestic government attempting to maximize the domestic social welfare. My research provides useful findings and recommendations for those countries at a competitive disadvantage in competing with foreign cultural goods.
I find that the effectiveness of cultural protection tools is largely determined by the quality difference between the domestic and foreign entertainment (through the traditional channels and the Internet channel). When there is no leakage, tariff produces the greatest optimal domestic social welfare due to its ability in taxing the consumption of foreign entertainment and generating government revenue. In the presence of leakage over the Internet, social welfare is higher when the quality difference between foreign entertainment via the Internet and domestic entertainment decreases. Either the tariff or subsidy policy produces the optimal domestic social welfare, depending on the quality of the foreign entertainment products. Similar to the leakage case, quality competition from piracy and Internet leakage produces a higher domestic social welfare, and either tariff or subsidy produces the highest optimal domestic social welfare. The domestic social welfare under piracy is also affected by the proportion of unethical users among consumers. The higher the number of unethical users, the higher the domestic social welfare will be, this is due to the increased access to foreign entertainment. Despite the popularity of the quota adopted as a cultural protection policy tool in reality, perhaps due to its low cost and ease of implementation, my research suggests that the quota policy is the least effective in attaining higher domestic social welfare in all the cases I consider, especially in the presence of Internet leakage and piracy.
Figure 2-1. Demand of domestic and foreign entertainment under quota $\bar{q}$ and no leakage.

$$\theta_d = \frac{p_d}{s_d} \quad \theta_f = \frac{p_f - p_d}{s_f - s_d}$$

Figure 2-2. Demand of domestic and foreign entertainment under subsidy $\sigma$ and leakage.

$$\theta_{d-\sigma} = \frac{p_d - \sigma}{s_d} \quad \theta_d = \frac{p_d}{s_d} \quad \theta_f = \frac{p_f - p_d + \sigma}{s_f - s_d}$$

Figure 2-3. Social welfare comparison of tariff, quota, and subsidy in the baseline case.
Figure 2-4. Demand of domestic and foreign entertainment under quota $\bar{q}_i$ and leakage 
\((s_d < s_i < s_f)\) and \((\theta_f < \bar{q}_i < 1)\).

\[
\begin{align*}
\theta_d &= \frac{p_d}{s_d} \\
\theta_i &= \frac{p_f - p_i}{s_f - s_i} \\
\theta_f &= \frac{p_f}{s_f} \\
\bar{q}_i &= 1
\end{align*}
\]

Figure 2-5. Demand of domestic and foreign entertainment under tariff $\tau_i$ and leakage.

\[
\begin{align*}
\theta_d &= \frac{p_d}{s_d} \\
\theta_i &= \frac{p_i - p_d}{s_i - s_d} \\
\theta_f &= \frac{p_f + \tau_f - p_i}{s_f - s_i} \\
\theta_{f+\tau} &= \frac{p_f + \tau_f}{s_f}
\end{align*}
\]

Figure 2-6. Social welfare comparison in leakage case for $s_d = 25\%$ of $s_f$. 

Social Welfare with Leakage

- Quota Social Welfare
- Subsidy Social Welfare
- Tariff Social Welfare

Social Welfare

Quality of Internet Entertainment

0.28 0.3 0.34 0.38 0.42 0.46 0.5 0.54 0.58 0.62 0.66 0.7 0.74 0.78 0.82 0.86 0.9 0.94 0.98
Figure 2-7. Demand of domestic, foreign piracy, and foreign entertainment under quota \( \tilde{q}_p \) and piracy with \((s_d < s_i < s_f)\), \((s_d < s_g < s_f)\), \((\theta_f < \tilde{q}_p < 1)\), and \((\theta_{fg} < \tilde{q}_p < 1)\).

Figure 2-8. Demand of domestic, foreign piracy, and foreign entertainment under quota \( \tau_p \) and piracy with \((s_d < s_i < s_f)\) and \((s_d < s_g < s_f)\).
Figure 2-9. Optimal domestic social welfare comparison in the piracy case ($s_i = 0.75$, $c_g = 0.02$, $s_g = s_i$, $s_f = 1$).
Table 2-1. Notation of the variables for the models in Chapter 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_d$</td>
<td>Quality of domestic entertainment through traditional channels (broadcast and cable)</td>
</tr>
<tr>
<td>$s_f$</td>
<td>Quality of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$s_i$</td>
<td>Quality of foreign entertainment through the Internet</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Consumer’s preferences (type) for quality, uniformly distributed over $[0,1]$</td>
</tr>
<tr>
<td>$\overline{q}$</td>
<td>Government imposed quota of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Government-imposed tariff of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Government-imposed subsidy for domestic entertainment</td>
</tr>
<tr>
<td>$\overline{q_i}$</td>
<td>Government-imposed quota of foreign entertainment through traditional channels in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\tau_i$</td>
<td>Government-imposed tariff of foreign entertainment through traditional channels in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\sigma_i$</td>
<td>Government-imposed subsidy for domestic entertainment in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$p_d$</td>
<td>Price of domestic entertainment through traditional channels</td>
</tr>
<tr>
<td>$p_f$</td>
<td>Price of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$p_i$</td>
<td>Price of foreign entertainment through the Internet</td>
</tr>
<tr>
<td>$u_\theta$</td>
<td>Consumer’s utility with preference for quality $\theta$</td>
</tr>
<tr>
<td>$Q_d$</td>
<td>Demand for domestic entertainment</td>
</tr>
<tr>
<td>$Q_i$</td>
<td>Demand for Internet channel foreign entertainment</td>
</tr>
<tr>
<td>$Q_f$</td>
<td>Demand for traditional channel foreign entertainment</td>
</tr>
<tr>
<td>$c_s$</td>
<td>Cost of an unethical user to pirate foreign entertainment</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Percentage of ethical users, that is, users who will not consume pirated goods</td>
</tr>
</tbody>
</table>
Table 2-2. Comparative statics of cultural protection policies with respect to the number of ethical users and cost of piracy

<table>
<thead>
<tr>
<th></th>
<th>$\tilde{q}_p$</th>
<th>$\sigma_p^*$</th>
<th>$\tau_p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>-</td>
<td>+ if $c_g &gt; s_g - s_d$</td>
<td>- if $c_g &lt; s_g - s_d$</td>
</tr>
<tr>
<td>$c_g$</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 2-3. Comparative statics of each cultural protection policy’s optimal domestic social welfare with respect to the number of ethical users and the cost of piracy under piracy and Internet leakage

<table>
<thead>
<tr>
<th></th>
<th>$SW^<em>(\tilde{q}_p^</em>)$</th>
<th>$SW^<em>(\sigma_p^</em>)$</th>
<th>$SW^<em>(\tau_p^</em>)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$c_g$</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 2-4. Effect of all unethical users ($\alpha = 0$, Total Piracy) and no unethical users ($\alpha = 1$, No Piracy) on the three cultural protection policies

<table>
<thead>
<tr>
<th></th>
<th>$\tilde{q}$</th>
<th>$\sigma$</th>
<th>$\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha = 0$</td>
<td>$\tilde{q}_p^* &lt; \tilde{q}_l^*$</td>
<td>$\sigma_p^* &gt; \sigma_l^*$ if $c_g &gt; s_g - s_d$</td>
<td>$\tau_p^* &gt; \tau_l^*$</td>
</tr>
<tr>
<td>$\alpha = 1$</td>
<td>$\tilde{q}_p^* = \tilde{q}_l^*$</td>
<td>$\sigma_p^* = \sigma_l^*$</td>
<td>$\tau_p^* = \tau_l^*$</td>
</tr>
</tbody>
</table>
CHAPTER 3
THE IMPACT OF DIGITAL TECHNOLOGIES ON DOMESTIC FIRM PROFITS AND CONSUMER SURPLUS

Introduction

The United States is a dominant player in the cultural goods market, exporting more than $80 billion worth annually. In 2007, the export of U.S. audio visual services grew 23% to $15 billion. More than 85% of film ticket sales worldwide belong to U.S. film productions. The top grossing film of 2008, (the US produced film “The Dark Knight”), receives more than $486 million from international sales while its total revenue was approximately $1 billion. As the number of American-produced books, music, software, films, and television programs increases, so do the number of countries that see this “invasion” as a threat to their national culture, and damaging to their domestic firms.

In the past, countries have had to implement different cultural policies to deal with cultural threats through traditional channels. A quota, subsidy, and tariff are among the most commonly observed policies. For example, the United Kingdom established the original screen quota to protect its domestic film industry in 1927. During 1927 more than 81% of the films shown in the United Kingdom were made in the United States. In Canada the Canadian Radio-Television and Telecommunications Commission (CRCT) currently requires the radio broadcasters to play a minimum of 35% Canadian content, and television broadcast stations are required to show 50% Canadian content between 6 p.m. and midnight in addition to 60% during the time between 6 a.m. and
midnight.⁶ Some countries provide a subsidy to local industries to protect cultural goods. As of 2008, different European Union countries have spent more than 1.6 Billion Euros to subsidize their national film industry.⁷ Many countries implement a tariff to protect national culture and local industries.

The digital production of entertainment goods and new distribution channels through the Internet make it easier to consume these entertainment goods. Four types of retail digital distributors are created: 1) Internet digital retailers who sell Digital content (such as the web store zml2.co); 2) Internet digital retailers which rent digital media to consumers for a limited period of time (for example, Netflix and Blockbuster); 3) Internet digital stores which both rent and sell digital media, for example, amazon.com and Itunes.com; and 4) advertising support streamers of digital media, which provide streaming access to movies and television programs and show periodic advertisements to viewers during the stream, such as hulu.com and ABC.com. Digital entertainment and its consumption through the Internet have grown at an increased rate. In 2007, 22% of global consumer Internet traffic was accounted for by Internet video (Digital Economy Fact book, 10⁸Edition). The Internet, in addition to hardware such as computers, Xbox’s, IPods, cell phones, and other devices, has put digital media at consumers’ finger tips almost anywhere at any time.

While the advent of digital production has created new distribution channels, it has also made the piracy of cultural goods easier. In 2005, the music industry lost more

⁶ http://www.media-awareness.ca/english/issues/cultural_policies/canadian_content_rules.cfm
than $4.5 billion from physical piracy and an estimated $20 billion in illegally downloaded songs (The Recording Industry 2006 Commercial Piracy Report). It has been estimated that worldwide motion picture associations lost more than $18.2 billion in 2005, with the U.S. motion picture industry suffering $6.1 billion in losses, approximately $3.72 billion due to physical piracy and $2.38 billion due to piracy over the Internet.\(^8\)

Digital leakage allows consumers to choose their favorite foreign program over the Internet. This practice has called into question the effectiveness of traditional cultural protection policies, leading to research at individual, organizational, and social levels [10, 44, and 54]. Little of this research has examined guidelines for governments to design economic protection policies with the advancement of digital technologies. Many economists have investigated government trade protection policies, including but not limited to subsidies, tariffs, and quotas. Two critical factors determining the equivalence of quotas and tariffs are the market structure and uncertainty [4, 5, 44, 47]. Chen and Hwang [11] discover that when there is low market-price uncertainty tariff is better than quota. Additionally a tariff creates a higher welfare and is better than a quota when the government’s purpose is generating revenue [18]. Yeh [59] shows that a tariff creates a higher welfare than subsidy when the protection required by the industry is less than that provided by the optimal tariff. Bandyopadhyay [3] finds that the relative difference in marginal cost between an exporting firm and its competitor determines when either a subsidy or tariff is the optimal tool. The welfare from a subsidy is higher than a tariff in the presence of domestic distortions [6] or if the terms of

\(^8\) [http://www.mpaa.org/press_releases/leksummarympa.pdf]
trade are consistent [17]. When the objective of the government is import restriction, industry protection, and consumption restriction, Bhagwati and Srinivasan [7] indicates that a tariff, subsidy, and tax are the optimal tools.

In addition to the research of traditional cultural protection policies, the research in digital product distribution and piracy is also a pertinent area of literature. The impact by digital distribution on piracy has been examined by Khouja and Sungjune[36], Gopal and Sanders [29], and Wu and Chen [60]. Sundarararian [53] examines the use of pricing and technology to control digital piracy while Chellappa and Shivendu [14] investigate under which conditions it is optimal to use versioning to manage digital piracy. The impact of digital distribution on the music industry’s market structure has been studied by Bockstedt et al. [8]. Smith and Telang [51] show that the digital distribution of media of the Internet does not affect the sales of DVDs. The use of government policies (fines, subsidy, and tax) to induce optimal domestic social welfare through managing digital piracy has been studied by Chen and Png [16].

In Chapter 3, I examine the impact of digital leakage and piracy on the effectiveness of a quota, tariff, and subsidy on domestic firms and consumers. The performance of the cultural protection policy tools depends on the difference in relative quality of the different cultural goods. Surprisingly, I find that consumers benefit most from a tariff except when prominent piracy occurs, during which time a subsidy is most beneficial. Domestic firms tend to benefit from a subsidy the most. However, when a small amount of piracy occurs, a quota benefits domestic firms more.

Chapter 3 is structured into the following sections. I introduce the analytical model in the “The Model” section. The “Domestic Firm Profits” section studies the
effectiveness of using a quota, tariff, or subsidy on domestic firm profits in the presence of leakage and piracy. The “Consumer Surplus” section examines the impact of Internet leakage and piracy on government cultural policy when the government objective is to benefit consumers. The “Summary” recapitulates these sections and concludes Chapter 3.

The Model

This model studies the decision of a government to select a cultural protection tool to maximize the domestic firm’s profit and domestic consumer surplus. Consider the domestic and foreign entertainment program producers, who compete in a regulated government channel. Additionally, consumers may access the foreign entertainment programs through a non-government-controlled channel -- the Internet. Consumers are differentiated by their quality preference \( \theta \in U[0,1] \), whose aim is to maximize their own utility without concerning government revenue. A consumer with a quality preference index of \( \theta \) receives a utility of \( u_\theta(s,p) = \theta \cdot s - p \) if consuming a product with quality \( s \) and price \( p \).

Assume that the domestic (subscript \( d \) ) entertainment programs have a lower quality than the foreign (subscript \( f \) ) entertainment programs, that is, \( s_d < s_f \), otherwise no need arises for the government to protect the domestic firms. This may be caused by the fact that a foreign movie producer with access to a large budget and top-of-the-line film, sound, editing, and special effects technologies. For example, Hollywood remade a Hong Kong film “Internal Affairs,” retitled as the movie “The Departed,” starring Jack Nicholson, Matt Damon, Mark Wahlberg, and Leonardo DiCaprio, and directed by Martin Scorsese. “The Departed” turned out to be a big success, making $132,384,315
at the U.S. box office and $289,847,354 in foreign box offices. Both totals dwarfed those made by “Internal Affairs.” In addition, I make the following two assumptions:

- The foreign entertainment programs delivered through the Internet (subscript $i$) have a higher quality than domestic entertainment programs, but has lower quality than traditional foreign entertainment products, $s_d < s_i < s_f$.

- In addition to the leakage, the foreign entertainment programs are pirated, distributed without the consent of the foreign firm, and the quality of the pirated (subscript $p$) programs is lower than the quality of the foreign entertainment programs through the government-regulated channel $s_d < s_i < s_f$.

I consider a two-stage game. In stage one, the government announces which cultural protection tool is to be implemented. In stage two, the two producers decide on optimal prices for their products based on the government’s implemented policy. Then consumers make their purchase decision based on the prices and quality of the products to maximize their utility. The government objective is to maximize the domestic social welfare given the optimal prices selected by the producers. In addition, I make the following assumptions and summarize notation in Table 3-1.

- Consumers subscribe to broadband services mainly for Internet-related activities. Hence, the marginal cost to consumers of using the Internet for entertainment is negligible.

- $0 \leq c_g < s_g$, that is, I focus on the case in which the cost of pirating foreign goods is less than the quality of the pirated entertainment product.

The two key measures which I will examine via the model are the domestic firm’s profit and consumer surplus. Examining the domestic firm profits will determine which cultural protection tool is most effective in protecting the domestic firms under each of the three cases. Examining the consumer surplus will show which tool is most beneficial to the consumer who is purchasing entertainment goods. For each tool, I solve for the optimal value of each case. Using the optimal value of quota, tariff, and
subsidy I am able to derive the value of the domestic firm’s profits and consumer surplus for the baseline, leakage, and piracy cases.

**Baseline Model Without Leakage**

I first study the baseline case where the domestic and foreign firms are able to distribute products through government-regulated channels.

I consider the quota first. The quota is the most visible cultural protection tool used throughout the world. Countries such as France, Brazil, and South Korea use quotas to protect their firms. The important aspect of a quota examined by this model is its ability to promote domestic goods through the reduction of access to foreign goods. It is assumed that the government can strictly enforce the quota, $q$, in government-regulated channels. The marginal consumer who is indifferent between consuming domestic entertainment and no entertainment is denoted as $\theta_d$, and the marginal consumer who is indifferent between consuming foreign entertainment and domestic entertainment is denoted as $\theta_f$. I then have $\theta_d = \frac{P_d}{s_d}$. I consider only the case where $\bar{q} \geq \theta_f$, otherwise, the quota has no effect. As illustrated in Figure 3-, the demand for foreign entertainment is $Q_f = 1 - \bar{q}$, and the demand for domestic entertainment is

$$Q_d = \bar{q} - \theta_d = \bar{q} - \frac{P_d}{s_d}.$$ 

Given the quota $\bar{q}$ imposed by the government, the domestic firm solves the following problem:

$$\max_{p_d} \pi_d = p_d Q_d$$

s.t. $p_d = \theta_d s_d$,

while the problem facing the foreign firm is
\[
\max_{p_f} \pi_f = p_f Q_f
\]
\[
s.t. \quad p_f = \bar{q} (s_f - s_d) + p_d,
\]
and the government solves the following problem when optimizing for domestic firm profits \( \max_{q} \pi_d^* \). The government derives the optimal quota, \( \bar{q}^* \), using Eq. \( \max_{q} \pi_d^* \).

Based on the optimal quota, the government then solves for domestic firm profits.

\[
\pi_d^* = p_d^* Q_d^* = \frac{s_d \left( 2s_f - s_d \right)^2}{4 \left( 4s_f - s_d \right)},
\]

When the government policy is to optimize consumer surplus, the government solves for

\[
\max_{q} \int_{\sigma_d}^{\bar{q}} (\theta s_d - p_d^*) d\theta + \int_{\bar{q}}^{1} (\theta s_f - p_f^*) d\theta.
\]

The government derives the optimal quota, \( \bar{q}^* \), using Eq. (2). Based on the optimal quota, the government then solves for domestic firm profits.

\[
CS_q (\bar{q}^*) = \int_{\sigma_d}^{\bar{q}} (\theta s_d - p_d^*) d\theta + \int_{\bar{q}}^{1} (\theta s_f - p_f^*) d\theta = \frac{s_d \left( 2s_f - s_d \right)}{2 \left( 4s_f - s_d \right)}.
\]

Similarly, I derive the profit of the domestic firm, as well as consumer surplus, under the two other protection tools. I present the results in Tables 3-6 and 3-7. It should be noted that when solving for the optimal tariff and optimal subsidy under the government’s policy to promote the domestic firm, the problem being solved is a minimization. The optimal tool used to solve for the optimal domestic firm profit is the same tool used when the government is solving for the optimal consumer surplus.
Impact of Leakage Via Internet

I now consider the case in which the foreign firm is not only able to distribute content through government-controlled channel, but also able to distribute content through the Internet, bypassing the control of the domestic government. For example, websites such as hulu.com take entertainment content, such as movies and TV shows, and place them on the Internet after they have been broadcasted. Leakage also occurs if consumers are able to directly download entertainment content through online stores such as amazon.com. In this subsection, I examine the effect of leakage on the government cultural protection tools.

I now examine the effect of quota when foreign firms are able to bypass the government-regulated channel through distributing content on the Internet. In addition to the indifferent marginal consumer $\theta_d$ and $\theta_f$ as discussed in the previous section, the marginal consumer who is indifferent between consuming the domestic entertainment and the foreign entertainment via the Internet is denoted as $\theta_i$. I then have three indifferent conditions: $\theta_d = \frac{p_d}{s_d}$, $\theta_i = \frac{p_i - p_d}{s_i - s_d}$, and $\bar{\theta}_i = \frac{p_f - p_i}{s_f - s_i}$. As illustrated in Figure 3, the demand for foreign entertainment via the traditional broadcast channel is

$$ Q_f = 1 - q_i = 1 - \frac{p_j - p_i}{s_j - s_i}, $$

for foreign entertainment via the Internet is

$$ Q_i = \frac{p_f - p_i}{s_f - s_i} - \frac{p_i - p_d}{s_i - s_d}, $$

and for domestic entertainment is

$$ Q_d = \theta_i - \theta_d = \frac{p_i - p_f}{s_i - s_d} - \frac{p_d}{s_d}. $$

Given a quota $\bar{q}_i$, the domestic firm solves the following problem

$$ \max_{p_d} \quad \pi_d = p_d Q_d $$

s.t. \quad p_d = \theta_d s_d, \quad (3-6) $$

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while the foreign firm solves

\[
\max_{p_f, p_i} \pi_f = p_f Q_f + p_i Q_i
\]

\[
s.t. \quad p_f = p_i + q_i (s_f - s_i),
\]

\[
p_i = p_d + \theta_i (s_i - s_d)
\]

and the government solves the following problem \(\max \pi_i^*\). The government derives the optimal quota, \(q^*\), using \(\max \pi_i^*\). Based on the optimal quota, the government then solves for domestic firm profits and consumer surplus.

\[
\pi_d^* = p_d^* Q_d^* = \frac{s_d s_i (s_i - s_d) \left(2s_i (s_f - s_i) - s_d (s_f + s_i)\right)^2}{\left(4s_i - s_d\right)^2 \left(s_f s_f - s_i \left(4s_f - 3s_i\right)\right)^2}
\]

When the government policy is to optimize consumer surplus, the government solves for

\[
\max \int_0^\theta \left(\theta s_d - p_d^*\right) d\theta + \int_0^{\bar{\theta}} \left(\theta s_i - p_i^*\right) d\theta + \int_{\bar{\theta}}^1 \left(\theta s_f - p_f^*\right) d\theta.
\]

The government derives the optimal quota, \(q^*\), using Eq. (3-9). Based on the optimal quota, the government then solves for domestic firm profits and consumer surplus.

\[
CS_q (q^*) = \int_0^\theta \left(\theta s_d - p_d^*\right) d\theta + \int_0^{\bar{\theta}} \left(\theta s_i - p_i^*\right) d\theta + \int_{\bar{\theta}}^1 \left(\theta s_f - p_f^*\right) d\theta
\]

\[
= \frac{s_d^2 s_f - s_d s_i (8s_f + s_d)}{8 (4s_i - s_d)^2} + \frac{4s_i^2 (4s_f + 7s_d)}{8 (4s_i - s_d)^2}
\]

Similarly, I derive the profit of the domestic firm, as well as consumer surplus under the two other protection tools. I present the results in Tables 3-8 and 3-9. It should be noted that when solving for the optimal tariff and optimal subsidy under the government’s policy to promote the domestic firm, the problem being solved is a
minimization. The optimal tool used to solve for the optimal domestic firm profit is the same tool used when the government is solving for the optimal consumer surplus.

**Impact of Leakage Via Internet in the Presence of Piracy**

In this subsection, I examine the case where, in addition to leakage, there is also piracy of the foreign entertainment product. Consumers are now able to access foreign entertainment through three separate channels: 1) government-controlled channel, 2) the Internet (the leakage channel), and 3) piracy. Assume that there is $\alpha \in [0,1]$ percent of ethical users in the society who will purchase only entertainment content through legal channels; and for unethical users, there is a cost of $c_g$ in order to consume pirated goods, which includes the cost of purchasing the pirated good and the cost of being prosecuted by the government for consuming a pirated good.

As ethical consumers can purchase foreign entertainment products through the traditional channel, the Internet, or domestic entertainment, or not purchase products at all, I then have three indifferent conditions for the ethical users: $\theta_d = \frac{p_d}{s_d}$, $\theta_i = \frac{p_i - p_d}{s_i - s_d}$, and $\tilde{q}_p = \frac{p_f - p_i}{s_f - s_i}$. Similarly, for the unethical users there are two indifferent points:

$\theta_g s_g - c_g = 0$ and $\theta_{fg} s_g - c_g = \theta_{fg} s_f - p_f$. As illustrated in Figure 3, the demand from the ethical users for the foreign entertainment via the traditional broadcast channel is $Q_f = 1 - \tilde{q}_p$, for foreign Internet entertainment demand is $Q_i = \frac{p_f - p_i}{s_f - s_i} - \frac{p_i - p_d}{s_i - s_d}$, and for domestic entertainment demand is $Q_d = \theta_i - \theta_d = \frac{p_i - p_d}{s_i - s_d} - \frac{P_d}{s_d}$. The demand of unethical
users for foreign entertainment is $Q_{fg} = 1 - \bar{q}_p$ and for pirated foreign entertainment, demand is the demand is

$$Q_g = \theta_{fg} - \theta_g = \bar{q}_p - \frac{c_g}{s_g}. \quad (3-11)$$

Given a quota $\bar{q}_p$, the domestic firm solves the following problem

$$\max_{p_d} \pi_d = \alpha p_d Q_d \quad s.t. \quad p_d = \theta_d s_d, \quad (3-12)$$

while the foreign firm solves

$$\max_{p_f} \pi_f = \alpha (p_f Q_f + p_i Q_i) + (1 - \alpha) p_f Q_{fg} \quad s.t. \quad p_f = p_i + \bar{q}_p (s_f - s_i), \quad p_i = p_d + \theta_i (s_i - s_d), \quad (3-13)$$

and the government solves the following problem $\max_q \alpha \pi_d^*$. The government derives the optimal quota, $\bar{q}^*$, using Eq. $\max_q \alpha \pi_d^*$. Based on the optimal quota, the government then solves for domestic firm profits and consumer surplus.

$$\pi_d^* = p_d^* Q_d = \frac{\alpha s_d s_i (s_i - s_d) (c_f (1 - \alpha) (4s_i - s_d) + 2s_i (2s_f - s_i) + s_g (s_f + s_i)) \theta s_d - p_d^* d\theta + \int_{\theta_i}^{\theta_f} (\theta s_f - p_f^*) d\theta + (1 - \alpha) \int_{\theta_g}^{\theta_f} (\theta s_f - c_g) d\theta + \int_{\theta_f}^{\theta_g} (\theta s_f - p_f^*) d\theta)}{(4s_i - s_d)^2} \quad (3-14)$$

When the government policy is to optimize consumer surplus the government solves for

$$\max_q \alpha \left(\int_{\theta_d}^{\theta_f} (\theta s_d - p_d^*) d\theta + \int_{\theta_i}^{\theta_f} (\theta s_i - p_i^*) d\theta + \int_{\theta_f}^{\theta_g} (\theta s_f - p_f^*) d\theta\right) +$$

$$\left(1 - \alpha\right) \left(\int_{\theta_g}^{\theta_f} (\theta s_f - c_g) d\theta + \int_{\theta_f}^{\theta_g} (\theta s_f - p_f^*) d\theta\right). \quad (3-15)$$

The government derives the optimal quota, $\bar{q}^*$, using Eq.(3-15). Based on the optimal quota, the government then solves for domestic firm, profits and consumer surplus.
Similarly, I derive the profit of the domestic firm as well as consumer surplus, under the two other protection tools. I present the results in 3-10 and Appendix B.

**Domestic Firm Profits**

In this section I examine the impact of the cultural protection tools on domestic firm profits in the baseline, leakage, and piracy cases.

**Domestic Firm Profits Baseline Case**

I first compare the domestic firm profits under the baseline case, given the optimal value of a quota, tariff, and subsidy. Proposition 3-1 compares the domestic firm profits produced under each of the cultural policy tools.

**Proposition 3-10:** Under the baseline case, a quota produces the greatest domestic firm profits followed by a tariff, and a subsidy produces the smallest domestic firm profit of all tools. That is, \( \pi_d^*(q^*) > \pi_d^*(\tau^*) > \pi_d^*(\sigma^*) \).

The optimal quota when the government wants to protect domestic firms is to set \( q = 1 \), not letting the foreign firm import any products. Thus, as the quality of the domestic firm increases, the profit of the domestic firm increases, and with no competition, under a quota, domestic firms produce the greatest profit. After a quota, a tariff offers the second best protection for the domestic firms. A tariff is more effective at increasing the price and decreasing the demand of the foreign firm’s entertainment than subsidy is at decreasing the price and increasing the demand of the domestic entertainment. Thus, the domestic firm benefits more when a tariff is imposed rather than a subsidy.
Domestic Firm Profits with Leakage

In this subsection, I compare domestic firm profits in the presence of Internet leakage, given the optimal value of a quota, tariff, and subsidy. Examining the effects of a tariff on the domestic firm profits gives the following proposition:

**Proposition 3-11:** The optimal tariff should be set such that domestic firm profits should not be affected, \( \pi_d^*(\tau) = \pi_d^*(\tau^*) = \frac{s_d s_l (s_i - s_d)}{(4s_i - s_d)^2} \).

In the baseline case, the tariff had a direct impact on the domestic firm profits, however, when leakage is present, a tariff has no effect on the optimal domestic firm’s profits. The leakage is able to buffer the direct effects of a tariff on the domestic firm, allowing only its indirect effects to be felt.

The analysis of the optimal domestic firm profits leads to the following proposition:

**Proposition 3-12:** In the presence of leakage, the domestic firm’s profits under the tools of a quota and a tariff are equal, \( \pi_d^*(\tilde{q}_i^*) = \pi_d^*(\tau_i^*) \).

In the presence of leakage, I find that both a tariff and quota are equivalent in their benefit to the domestic firms. Examining and comparing the domestic firm profits with leakage under each of the policy tools gives the following proposition:

**Proposition 3-13:** When there is leakage of foreign entertainment products through the Internet, a subsidy generates the most domestic firm profits than a quota, and a quota generates more than tariff, that is, \( \pi_d^*(\sigma_i^*) > \pi_d^*(\tilde{q}_i^*) = \pi_d^*(\tau_i^*) \).

In contrast to the baseline case, a subsidy is the most beneficial to the domestic firms. Providing a subsidy to consumers increases the demand for domestic entertainment
goods, creating greater profits under leakage than the other tools. The leakage makes the effect of both a quota and tariff equivalent, as stated in Proposition 3-12, and decreases the effectiveness of both a tariff and quota.

**Domestic Firm Profits with Piracy**

In this subsection, I compare the domestic firm profits in the presence of Internet leakage and piracy given the optimal value of a quota, tariff, and subsidy. Proposition 3-5 is derived by examining the effect of the cost of piracy and the amount of unethical users on each of the cultural protection policies.

**Proposition 3-14:** When there is leakage through the Internet and piracy is present, the domestic firm profits under the socially optimal quota, subsidy, and tariff is increasing in the cost of piracy $c_g$ and in the percentage of ethical users $\alpha$.

As expected the domestic firm profits increase as the percentage of ethical users increase. The domestic firms do not profit from unethical users. As the number of unethical users decreases, the potential consumer base becomes larger for the domestic firms to profit from. Similarly, as the cost of piracy increases, the domestic firm profits also increase for both a subsidy and tariff. The cost of piracy, however, has no effect on the domestic firm profits under a quota. Since the optimal quota is set to prohibit any foreign products, only leakage and pirated foreign goods are consumed. Increasing or decreasing the cost of piracy will now directly affect only the unethical users’ choice of whether to pirate goods or do without, and thus has no effect on the domestic firm profits.

Figure 3- and Figure 3- display a numerical example of the optimal domestic firm profits when $s_i = 0.75s_f$ and $s_g = s_i$. Unlike the baseline or leakage case, the domestic
firms prefer either subsidy or quota to create the largest domestic firm profits. The intensity of piracy and the relative difference in the quality of the Internet dictate the tool which benefits the domestic firms the most. Unsurprisingly, the intensity of the piracy also directly affects the magnitude of the domestic firm profits under each of the different tools. As the intensity of piracy increases, the magnitude of the domestic firm profits decreases, and as the intensity of piracy decreases the magnitude of the domestic firm profits increases. Decreasing the relative difference in quality between the domestic and foreign traditional products also slightly increases the magnitude of the domestic firm profits. While maintaining subsidy or quota as the most beneficial to the domestic firm profits.

When there is no leakage, a quota is most beneficial to domestic firms. When there is leakage, a subsidy benefits the domestic firms the most and turns a quota and tax into equivalent tools. When there is Internet leakage and piracy, either a quota or subsidy can be the most beneficial to the domestic firm, based on the amount of unethical users and the quality difference between Internet and domestic entertainment, 
\[ \left( s_i - s_d \right). \]

**Consumer Surplus**

In this section, I examine the impact of the cultural protection tools that is consumer surplus in the baseline, leakage, and piracy cases.

**Baseline Consumer Surplus**

I first compare the consumer surplus under the baseline case given the optimal value of quota, tariff, and subsidy. Comparing the optimal consumer surplus under each tool in the baseline case leads to Proposition 3-6.
Proposition 3-15: When there is no leakage, the consumer surplus produced by subsidy is dominated by consumer surplus produced by a tariff, \( CS'(\tau') > CS'(\sigma') \).

Additionally when \( s_d > 0.6375 \), the consumer surplus produced under a tariff is dominated by consumer surplus produced under quota, that is \( CS'(\tau') > CS'(\tau^q') \) when \( s_d > 0.6375 \) and \( CS'(\tau') \geq CS'(\tau^q') \) when \( s_d \leq 0.6375 \).

First, consumer surplus is increasing in the quality of domestic entertainment, \( s_d \), or equivalently, when the difference in quality between domestic and foreign entertainment, \( (s_f - s_d) \), decreases. Intuitively, the closer the quality levels between foreign and domestic entertainment, the more intense the competition between firms, which is beneficial to the consumer. Secondly, tariff produces the greatest consumer surplus when \( s_d \leq 0.6375 \).

Leakage Consumer Surplus

In this subsection, I compare the domestic firm profits in the presence of Internet leakage, given the optimal value of a quota, tariff, and subsidy.

Proposition 3-16: When there is leakage, the consumer surplus produced by a tariff dominates the consumer surplus produced by a subsidy, which in turn dominates the consumer surplus produced by quota, \( CS'(\tau') > CS'(\sigma') > CS'(\tau^q') \).

When Internet leakage is present, a tariff is the most beneficial tool to consumers. The tariff impacts the price foreign traditional and foreign Internet entertainment but does little to impact the overall consumer demand. A quota is the least effective of all tools in creating consumer surplus. A quota limits the number of foreign goods purchased, which increases the price of both foreign traditional products and foreign Internet...
products reducing, the overall amount of products consumed, and making quota the least effective tool. Additionally, as the quality of the domestic firm product increases, so does the consumer surplus produced by each of the tools.

**Piracy Consumer Surplus**

In this subsection, I compare the consumer surplus produced under the optimal value of a quota, tariff, and subsidy in the presence of Internet leakage and piracy. Examining the effect of the cost of piracy and the amount of unethical users on each of the cultural protection tool leads to Proposition 3-8.

**Proposition 3-17:** When there is leakage through the Internet and piracy is present, the consumer surplus under the socially optimal quota, subsidy, and tariff is decreasing in the percentage of ethical users, \( \alpha \). Consumer surplus under the optimal quota is decreasing in the cost of piracy \( c_g \), while under the optimal subsidy or tariff, consumer surplus can either be increasing or decreasing.

Unsurprisingly, consumer surplus always decreases as the percentage of ethical users increases. As the number of unethical users decreases, the number of consumers partaking in all the products decreases, thus causes the overall consumer surplus to decrease. When the cost of piracy increases, consumer surplus is always decreasing under a quota. The decrease in consumer surplus occurs due to the fact that the number of users consuming pirated entertainment is decreasing as the cost of piracy increases reducing the overall number of consumers partaking in all entertainment. Consumer surplus under both subsidy and tariff is both decreasing and increasing. The following conditions are examples of conditions under which consumer surplus under a subsidy or tariff is increasing or decreasing due to the cost of piracy.
When $s_d = 0.25 s_f$, $s_g = s_i$, $\alpha = 0.50$, and $s_i = 0.9 s_f$, $CS(\sigma_g)$ is decreasing when $c_g < 0.2594$ and increasing when $c_g > 0.2594$ and if $\alpha = 0.90$ $CS(\sigma_g)$ is decreasing when $c_g < 0.4611$ and increasing when $c_g > 0.4611$. When $s_d = 0.25 s_f$, $s_g = s_i$, $\alpha = 0.50$, and $s_i = 0.9 s_f$, $CS(\tau_g)$ is decreasing when $c_g < 0.0851$ and increasing when $c_g > 0.0851$, and if $\alpha = 0.90$ $CS(\tau_g)$ is decreasing when $c_g < 0.1923$ and increasing when $c_g > 0.1923$.

Figure 3- displays a numerical example of the optimal consumer surplus. Unlike the baseline or leakage case, consumers prefer either subsidy or tariff to be used by the government. Similar to domestic firm profits, intensity of piracy and the relative difference in the quality of the Internet dictate the tool which benefits the domestic firms the most. As expected, when the number of unethical users increases, and thus the greater the magnitude of consumer surplus and vice versa. Similarly, the quality difference between the Internet and domestic entertainment benefit the consumers. As the quality difference decreases, the magnitude of consumer surplus increases.

In the baseline case, the consumers benefit most from government use of a tariff when $s_d \leq 0.6375$, otherwise consumers find the government’s use of a quota as the most beneficial. In the presence of leakage, the use of a tariff creates the greatest consumer surplus. When there is Internet leakage and piracy, either a subsidy or tariff produces the greatest consumer surplus. The most beneficial tool to consumers is determined by intensity of unethical users, while the magnitude of the consumer surplus is also influenced by the quality difference between foreign Internet and domestic entertainment, $(s_i - s_d)$. 
**Summary**

As the world economy continues to expand, dominant firms are looking outside domestic markets to expand, and countries are permeated with foreign goods. When countries are invaded with cultural goods, the government sees this infiltration as a threat to both domestic firms and their own domestic culture. The advances of the Internet and digital distribution have brought about new avenues of delivery and created leakage that is readily available to domestic consumers. Internet leakage calls into question the effectiveness of government cultural policies, specifically their effectiveness in protecting domestic industry.

In Chapter 3, a model is designed to examine the effects of Internet leakage in the presence of piracy on the traditional cultural protection tools of quota, subsidy and tariff. I examine the performance of each of the tool’s benefit to consumers and its effectiveness to protect domestic firms. The most beneficial tool to protecting domestic firm profits is either a quota or subsidy. A quota is the dominate tool in the baseline case, while subsidy dominates in the leakage case. Introducing piracy makes either a quota or subsidy most beneficial to the domestic firms, based on the amount of unethical users. Consumers may benefit from any of the tools based on the case. A quota is most beneficial to consumers only in the baseline case with little difference in quality and the least beneficial in the other cases. A tariff dominates the consumer surplus in the baseline case when the domestic entertainment is of medium-to-low quality and in the presence of leakage. However, in the piracy case, either a subsidy or tariff dominates the consumer surplus. When the amount of unethical users is small, then a tariff is most beneficial to consumers. As the amount of unethical users begins to increase, either a tariff or subsidy produces the greatest consumer surplus, based on
the relative difference of the entertainment process. A subsidy dominates consumer surplus when the intensity unethical users is equal to or greater than half the population.
Figure 3-1: Demand of domestic and foreign entertainment under a quota $\bar{q}$ and no leakage.

Figure 3-2: Demand of domestic and foreign entertainment under a quota $\bar{q}_i$, leakage, $(s_d < s_i < s_f)$ and $(\theta_f < \bar{q}_i < 1)$.
Figure 3-3: Demand of domestic, foreign piracy, and foreign entertainment a under quota $\bar{q}_p$ and piracy with $(s_d < s_i < s_f)$, $(s_d < s_g < s_f)$, $(\theta_f < \bar{q}_p < 1)$, and $(\theta_{fg} < \bar{q}_p < 1)$. 
Figure 3-4: Domestic firm profits comparison in piracy case for \( s_i = 0.75s_f \), \( s_g = s_i \), \( c_g = 0.02s_f \), and \( \alpha = 0.50 \).
Figure 3-5: Domestic firm profits comparison in piracy case for $s_i = 0.75s_f$, $s_g = s_i$, $c_g = 0.02s_f$, and $\alpha = 0.90$.

Figure 3-6: Consumer surplus comparison in piracy case for $s_i = 0.75s_f$, $s_g = s_i$, $c_g = 0.02s_f$, and $\alpha = 0.50$. 

Figure 3-7: Consumer surplus comparison in piracy case for $s_i = 0.75s_f$, $s_g = s_i$, $c_g = 0.02s_f$, and $\alpha = 0.90$. 
Table 3-1. Notation of the variables for the models in Chapter 3

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_d$</td>
<td>Quality of domestic entertainment through traditional channels (broadcast and cable)</td>
</tr>
<tr>
<td>$s_f$</td>
<td>Quality of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$s_i$</td>
<td>Quality of foreign entertainment through the Internet</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Consumer’s preferences (type) for quality, uniformly distributed over $[0,1]$</td>
</tr>
<tr>
<td>$\overline{q}$</td>
<td>Government imposed quota of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Government-imposed tariff of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Government-imposed subsidy for domestic entertainment</td>
</tr>
<tr>
<td>$\overline{q}_t$</td>
<td>Government-imposed quota of foreign entertainment through traditional channels in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\tau_t$</td>
<td>Government-imposed tariff of foreign entertainment through traditional channels in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\sigma_t$</td>
<td>Government-imposed subsidy for domestic entertainment in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\overline{q}_p$</td>
<td>Government-imposed quota of foreign entertainment through traditional channels in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\tau_p$</td>
<td>Government-imposed tariff of foreign entertainment through traditional channels in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$\sigma_p$</td>
<td>Government-imposed subsidy for domestic entertainment in the presence of leakage through the Internet</td>
</tr>
<tr>
<td>$p_d$</td>
<td>Price of domestic entertainment through traditional channels</td>
</tr>
<tr>
<td>$p_f$</td>
<td>Price of foreign entertainment through traditional channels</td>
</tr>
<tr>
<td>$p_i$</td>
<td>Price of foreign entertainment through the Internet</td>
</tr>
<tr>
<td>$u_\theta$</td>
<td>Consumer’s utility with preference for quality $\theta$</td>
</tr>
<tr>
<td>$Q_d$</td>
<td>Demand for domestic entertainment</td>
</tr>
<tr>
<td>$Q_f$</td>
<td>Demand for foreign Internet channel entertainment</td>
</tr>
<tr>
<td>$Q_t$</td>
<td>Demand for foreign traditional channel entertainment</td>
</tr>
<tr>
<td>$Q_p$</td>
<td>Demand for pirated foreign pirate channel entertainment</td>
</tr>
<tr>
<td>$Q_{fs}$</td>
<td>Demand for foreign pirate channel entertainment</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Percentage of ethical users</td>
</tr>
<tr>
<td>$c_s$</td>
<td>User’s cost of consuming a pirated good</td>
</tr>
</tbody>
</table>
Table 3-2. Optimal domestic firm’s profit for a quota, tariff, and subsidy in the baseline case

<table>
<thead>
<tr>
<th>Optimal Domestic Firm’s Profits, $\pi_d^*$, Baseline Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $\bar{q}^*$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
</tr>
<tr>
<td>Subsidy, $\sigma^*$</td>
</tr>
</tbody>
</table>

Table 3-3. Optimal consumer surplus for a quota, tariff, and subsidy in the baseline case

<table>
<thead>
<tr>
<th>Optimal Consumer Surplus, $CS_d^*$, Baseline Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $\bar{q}^*$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
</tr>
<tr>
<td>Subsidy, $\sigma^*$</td>
</tr>
</tbody>
</table>

Table 3-4. Optimal domestic firm’s profit for a quota, tariff, and subsidy in the leakage case

<table>
<thead>
<tr>
<th>Optimal Domestic Firm Profits, $\pi_i^*$, Leakage Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $\bar{q}^*$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
</tr>
<tr>
<td>Subsidy, $\sigma^*$</td>
</tr>
</tbody>
</table>
Table 3-5. Optimal consumer surplus for a quota, tariff, and subsidy in the leakage case

<table>
<thead>
<tr>
<th>Optimal Consumer Surplus, $CS^*_i$, Leakage Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $q^*$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
</tr>
<tr>
<td>Subsidy, $\sigma^*$</td>
</tr>
</tbody>
</table>

Table 3-6. Optimal domestic firm’s profit for a quota, tariff, and subsidy in the piracy case

<table>
<thead>
<tr>
<th>Optimal Domestic Firm’s Profits, $\pi_d^*$, Piracy Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $q^*$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
</tr>
<tr>
<td>Subsidy, $\sigma^*$</td>
</tr>
</tbody>
</table>

Table 3-7. Each cultural protection policy’s optimal domestic firm profits relationship with the number of ethical users and the cost of piracy under piracy and Internet Leakage

| $\pi_d \left( q_p \right)$ | $\pi_d \left( \sigma_p \right)$ | $\pi_d \left( \tau_p \right)$ |
|-----------------------------------------------|
| $\alpha$ | $+$ | $+$ | $+$ |
| $c_g$ | $0$ | $+$ | $+$ |
Table 3-8. Each cultural protections policy’s optimal consumer surplus relationship with the number of ethical users and the cost of piracy under piracy and Internet Leakage

<table>
<thead>
<tr>
<th></th>
<th>$CS(q_p)$</th>
<th>$CS(\sigma_p)$</th>
<th>$CS(\tau_p)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>$c_g$</td>
<td>−</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>
The distributions of many entertainment products follow a marketing strategy called “sequential distribution.” Sequential distribution is designed to optimize a producer’s profit of a product that is released to consumers sequentially in different markets [31, 57]. While other products, such as books and video games, follow the sequential distribution strategy, it seems that sequential distribution was designed specifically for Hollywood movies. Hollywood movies are now currently released in the United States through four distribution channels: 1) the theater, 2) DVD sales and rental, 3) on demand through satellite and cable companies, and 4) rights sold to television. Currently, the release order of distribution channels for DVD sales and rental and on demand, is to release in both channels simultaneously. However the FCC in May 2010, with guidelines, gave Hollywood studios the ability to shut down home theater equipment analog signals.\(^9\) This ability was given to Hollywood to allow studios to potentially release first run movies over Video on Demand (VoD) simultaneously or within weeks of a theatrical release while limiting the ability of consumers to pirate the movie. This ability has enabled Hollywood studios the ability to switch the order of the release of movie on DVD and the release of VoD. In lieu of this new development, the objective of Chapter 4 is to study the optimal timing of the release of a movie in the

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theater, DVD sales and rental, and on demand through satellite and cable companies distribution channels.

In 2009, Hollywood movies made $9.87 billion in U.S. box office receipts, which was a box office record. This was an increase by 9.7% from the U.S. 2008 box office receipts, also a record at the time. Unfortunately, this increase in the box office is not due to an increase in the number of people attending movies. The actual number of people attending movies during this time has been relatively flat. To compensate for this flat attendance, Hollywood studios and theaters have instigated two strategies: 1) increase ticket prices and 2) introduce 3D movies. Hollywood also makes a significant amount of money from movie sales and rentals after the initial theatrical run. In 2009, Hollywood studios made more than $8.73 billion from DVDs sales and $8.15 billion in DVD rentals. Theses DVD rentals have been steady during the last few years, with an increase of half a percent from 2008. However, DVD sales have been steadily decreasing since a record high of $12.1 billion in 2004. Between 2008 and 2009, DVD sales decreased 13.2%, from $10.06 billion to $8.73 billion. For years, Hollywood has been looking for a way to deal with profit losses from DVD sales.

To deal with the recent decrease in the profits of its DVD sales, Hollywood studios has begun to shrink the time-release window. According to Waterman et al [58], the window was steady from 1997 until 2002 at which point the window decreased from 25.4 weeks to 24.4 weeks. By 2009 the window has shrunk to an average of 19.3 weeks. However, some studios shrink their average movie release times even more. The theatrical to DVD release window has been reduced to just an average of 17.4

weeks. The shrinking of the window has led to the discussion of a simultaneous release of a movie on all channels. A JP Morgan report claims that while a simultaneous release will reduce box office revenues, it will increase the movie studio’s revenues by 36%.\textsuperscript{11} The decrease of the window may have helped studios slow the loss of revenue, but they still have not found the optimal release window. The examination of this window has been very limited. Lehmann and Weinberg [11] and Frank [5] examine the time-release window using empirical models examining market data, both of which conclude that the window should be shortened. Prasad, et al. [12] theoretically examines aspects of the time release-window, and concluded that actions, which cause consumers to wait for the video rather than the theater, decrease studio profits. Optimizing the time-release window is one of these actions. Hennig-Thureau, et al. [7] also empirically investigates the effect of a movie’s sequential distribution and timing on a studio’s revenue.

Another area that movie studios have been researching at as a potential to offset losses from DVD sales is VoD. Video on Demand was introduced in the mid-1990’s using Internet protocol television, and VoD is currently available to most homes in the United States. Video on Demand has been largely studied from a technical standpoint, examining quality of service, compression algorithms for online delivery, peer-assisted content delivery, and queuing performances [2, 3, 9, 8, 14]. Researchers have also analyzed examining the pricing of services over the Internet [1], and even more specific to the pricing of VoD [10]. Zhu [18] states that VoD will eventually lead to the disintermediation of movie industry value chain, leading to the removal of DVD rental stores. Researchers have looked into the area of financing, production, distribution, and

\textsuperscript{11} \url{http://www.businessweek.com/bwdaily/dnflash/jan2006/nf20060124_4959_db011.htm}
advertising of movies [13, 15]. In Chapter 4, I specifically examine the area of sequential distribution.

I develop an analytical model, which expands on Lehmann and Weinberg’s [11] model, to examine the effects of adding VoD into the sequential distribution of a movie. Specifically I insert VoD in between a movie’s theatrical release and a movie’s DVD release. I find that the DVD release window is always larger than that of Lehmann and Weinberg’s [42] theatrical release window. I also find that comparing the overlapping distribution VoD model to the non-overlapping model, the addition of overlap always decreases the VoD release window and tends to decrease the DVD release window.

The rest of Chapter 4 is divided into the following sections. I introduce our non-overlapping VoD model in the “Model 1” section. In the “Model 1 Analysis” section, I discuss Lehmann and Weinberg [42] model and compare its findings with Model 1. I introduce an overlapping VoD model in the “Model 2” section and then compare outcomes of Model 1 and Model 2 in the “Model 2 Analysis” section. The “Summary” recapitulates these sections.

**Model 1**

In this section, I consider a Hollywood movie studio whose goal is to maximize its profits from three distribution channels-Theater, DVD, Video on Demand, and DVD sales. The Hollywood studio needs to decide an optimal release time of VoD, an optimal price per showing of VoD charged to the VoD distributor, and an optimal release time of the DVD. Given the pricing from the studio, the VoD distributor in turn sets an optimal price of VoD for the end consumers, while the DVD retailer determines the optimal order quantity of DVDs that he purchase.
In this model, the movie will be sequentially released over the three distribution channels. The movie is first released in the theater. After completing its run in the theater, the movie is then released on VoD, and when the movie has finished its run over VoD, it will then be released for DVD rental. Let $\Pi_i^C(t)$ be the Hollywood studio’s profit at time $t$ when the movie is released in the movie theater, let $\Pi_i^B(x,t,t_s)$ be the Hollywood studio’s profit from the VoD channel when $t_s \leq t \leq t_s$, and let $\Pi_i(t,t_s)$ be the Hollywood studio’s profit from the DVD rental channel when $t \geq t_s$. Figure 4- shows the release times of the movie in each channel in Model 1.

The Hollywood Studio’s goal is to optimize its profit with a discount rate of $\rho$ given by:

$$P(\mathbf{x}, t_2, t_3) = \int_0^{t_2} \Pi_i^C(t) e^{-\rho t} dt + \int_{t_2}^{t_3} \Pi_i^B(x,t,t_s) e^{-\rho t} dt + \int_{t_3}^{\infty} \Pi_i(t,t_s) e^{-\rho t} dt \quad (4-1)$$

Based on empirical work done by Lehmann and Weinberg [11], a movie’s revenue in the first channel, the theater, can be modeled as an exponential function. Thus, the movie’s revenue from theaters in Model 1 can be formulated as:

$$M_i^C(t) = m_i^C e^{-\rho t} \quad 0 \leq t \leq t_2 \quad (4-2)$$

Where $m_i^C$ and $d_i > 0$.

**VoD Distributer’s Profit**

A VoD distributor’s profits are based on the amount it pays to the Hollywood movie studio for the right to show the movie. The two fees that a VoD distributor will have to pay include: 1) a fixed fee for the right to show the movie and 2) the fee per...

---

12 Subscript indicates the release channel (theatrical, VoD, or DVD), and a superscript indicated the release period (theatrical release, VoD release, or DVD/Rental Release). If the superscript is followed by a number, it is an indication of the model.
showing of the movie over VoD. The VoD distributor is going to optimize his profit with respect to \( w \), based on the price given by the Hollywood studio. The VoD distributor’s profit function is:

\[
P_{\text{VoD}} = (w - x) \left( \int_{0}^{t_2-t_3} M^B_2(w) e^{-pt} \, dt \right) - F
\]  

Similar to the theater channel, I assume that VoD demand can also be modeled as an exponential function and is formulated as:

\[
M^B_2(w) = m^B_2(w) e^{-d_2 t} \quad t_2 \leq t \leq t_3
\]  

\[
m^B_2(w) = (I^B_2 - wS)
\]

Where \( m^B_1 > 0 \) and \( d_2 > 0 \). Then Eq(5) is substitute into Eq(3) and I then simplify \( P_{\text{VoD}} \) to get:

\[
P_{\text{VoD}} = \frac{(w - x) \left( -1 + e^{(d_2 + \rho)(t_2 - t_3)} \right) \left( wS - I^B_2 \right)}{(d_2 + \rho)} - F
\]  

I then solve for the optimal \( w \) and get (proof can be found in the Appendix C):

\[
w^* = \frac{Sx + I^B_2}{2S}
\]

**DVD Retailer’s Optimal Order Quantity**

The DVD retailer’s objective is to optimize the amount of DVDs purchased, based on the time that the DVD will be released. The DVD retailer has to trade off lost revenue from understocking the DVDs with the cost of purchasing and holding additional DVDs. While the DVD retailer has the option to order DVDs at any time, ordering a DVD more than once or after the DVD has been released is not optimal.
Since the demand for DVDs is exponentially decreasing and initially there is under capacity, a period of time \( \tau \) will occur in which the DVD retailer will lose sales.

The DVD rental channel demand also has been shown to follow an empirical decline, thus:

\[
V(t, t_3) = v_1(t_3) e^{-v_3(t-t_3)} \quad t \geq t_3
\]  

(4-8)

with \( V(t, t_3) \) being the initial DVD rental rate at time \( t \) when a DVD is released at time \( t_3 \) and \( v_1 e^{-v_3 t_3} \) being the implicit DVD rental potential. Since for the time \( \tau \), it is known that there will be an under capacity since the demand will equal rental capacity, thus:

\[
nq = V(\tau) = v_1 e^{-v_3 \tau} = k_i e^{-v_3 \tau}
\]  

(4-9)

With

\[
k_i = v_1 e^{-v_3 t_3}
\]  

(4-10)

Thus

\[
\tau = \frac{1}{v_3} \ln \frac{k_i}{nq}
\]  

(4-11)

The DVD retailer’s profit when it orders \( q \) DVDs is

\[
P_r = r \left[ \int_0^\tau n q du + \int_\tau^T k_i e^{-v_3 u} du \right] - pq - hqT - \ell \int_0^\tau \left( k_i e^{-v_3 u} - nq \right) du
\]  

(4-12)

The DVD retailer’s profit function, in addition to the cost of DVDs, includes the cost of holding each DVD and the cost of lost sales due to the initial understocking of the DVD. I then solve for the optimal \( q^* \)

\[
q^* = \frac{k_i}{n} e^{-\left(\frac{(p+hT)v_3}{r+\ell}\right)q}
\]  

(4-13)
While $q^*$ includes both the cost of lost sales and the cost of holding, these are not critical to the issues that are being reviewed. For the rest of the paper, it will therefore be assumed that there is no cost of lost sales ($l = 0$) or cost of holding ($h = 0$). After $l = 0$ setting and $h = 0$, the optimal order quantity is:

$$q^* = \frac{k_1}{n} e^{-\frac{p_v s}{m}} = \frac{v_1}{n} e^{-v \eta_1} e^{-\frac{p_v s}{m}}$$  \hspace{1cm} (4-14)

**Hollywood Studios’ Optimal Release Times and Optimal VoD Profit Share**

Now that the response by both the Video on Demand distributor and the DVD retailer are known, the Hollywood studio can attempt to find the optimal VoD time release, DVD time release, and the optimal profit-sharing price. As in Lehmann and Weinberg [42], a constant gross margin is assumed for the Hollywood studio of $M_r$ in the first channel and $M_v$ in the third channel. The Hollywood studio’s profit is shown in Eq (1), when simplified:

$$P(t_2, t_3, x) = \int_0^{t_2} M_r m_t C e^{-d_t} e^{-\rho t} dt + \int_0^{t_3} x \left(I_2^{B_1} - w^* S \right) e^{-d_t} e^{-\rho t} dt + M_v q^*(t_3, p) e^{-\rho t}$$ \hspace{1cm} (4-15)

Eq (4-15) when $q^*$ and $w^*$ are substituted in is:

$$P(t_2, t_3, x) = M_T \left( \frac{m_r C}{(d_1 + \rho)} \left(1 - e^{-\eta_2 (d_1 + \rho)}\right) + \frac{x \left(I_2^{B_1} - w^* S\right) \left(1 - e^{(d_2 + \rho)(t_2 - t_1)}\right)}{(d_2 + \rho)} \right)$$ \hspace{1cm} (4-16)

Based on Eq(4-16) I can solve for $t_2, t_3,$ and $x$, and solving for each gives:
\[ t_2^* = \frac{\ln \left( \frac{I_{21}^B}{M_t m_{i1}^C 8S} \right)}{\ln \left( \frac{I_{21}^B}{M_t m_{i1}^C 8S} \right) - \frac{d_2}{v_{3}^B} \ln \left( \frac{v_{3}^B M_v v_1}{n} e^{-\frac{v_{3}^B}{m}} \right)} - \frac{d_2}{v_{3}^B} \ln \left( \frac{v_{3}^B M_v v_1}{n} e^{-\frac{v_{3}^B}{m}} \right) \]  

(4-17)

\[ t_3^* = \frac{1}{v_{3}^B} \left\{ \frac{\ln \left( \frac{I_{21}^B}{M_t m_{i1}^C 8S} \right)}{\ln \left( \frac{I_{21}^B}{M_t m_{i1}^C 8S} \right) - \frac{d_2}{v_{3}^B} \ln \left( \frac{v_{3}^B M_v v_1}{n} e^{-\frac{v_{3}^B}{m}} \right)} - \frac{d_2}{v_{3}^B} \ln \left( \frac{v_{3}^B M_v v_1}{n} e^{-\frac{v_{3}^B}{m}} \right) \right\} \]  

(4-18)

\[ x^* = \frac{I_{21}^B}{2S} \]  

(4-19)

Using Eq(4-17), Eq(4-18), and Eq(4-19), I can solve for the optimal \( w^* \) and \( P^* \left( t_2^*, t_3^*, x^* \right) \), giving Eq(4-20) and EQ(4-21).

\[ w^* = \frac{3I_{21}^B}{4S} \]  

(4-20)

\[ P^* \left( t_2^*, t_3^*, x^* \right) = \frac{M_t m_{i1}^C \left( 1 - e^{-d_2 t_2^*} \right)}{d_1} + \frac{\left( I_{21}^B \right)^2 \left( 1 - e^{-d_2 (t_2^* - t_3^*)} \right)}{d_2} + M_v v_1 e^{-v_1 t_3^*} e^{-\frac{v_{3}^B}{m}} \]  

(4-21)

**Analysis of Model 1**

To analyze the results of Model 1, I will compare Model 1 results with the results of the Lehmann and Weinberg [42] model, that is, the Baseline model. The Baseline model characterizes the optimal release time between theater and DVD with only a theater and DVD as distribution channels, as seen in Figure 4. Lehmann and Weinberg’s [42] optimal order quantity and release time are:
\[ t^*_2 = \frac{1}{(m_2 - v_2^b)} \left\{ \ln \left[ \frac{m_1^n n M_L}{v_2^b v_1 M_V} \right] + \left( \frac{p v_2^A}{r n} \right) \right\} \quad (4-22) \]

\[ q^* = \frac{v_1}{n} e^{-v_2^b \frac{p v_2^A}{r n}}. \quad (4-23) \]

To analyze Model 1 and the Baseline model, appropriate numbers are selected for each of the variables. The variables \( M_T, M_V, m_1^b, m_2, d_2, v_1, v_2^A, v_3^A, \) and \( v_2 \) are selected based on the dataset which Lehmann and Weinberg [42] used, while the variables \( p, r, n, t^*_2, S, \) and \( d_2 \) are selected based on the current environment for movies and movie rentals. Table 4-3 shows each of the variables and their values used during the numerical evaluation of Model 1 and the Baseline model.

When numerically examining Model 1’s VoD release window with the Baseline DVD release window, Model 1’s VoD release window is shorter. Analyzing the DVD release window in Model 1 and comparing it with the Baseline model’s DVD release window, Model 1’s release window is always greater. Finally, the optimal DVD order quantity under Model 1 is always less than the Baseline model. The difference between Model 1’s and the Baseline model’s optimal DVD order quantity is driven by the optimal length of each models movie’s theatrical release period. The DVD release window dictates the optimal quantity purchased by the DVD stores. The shorter the release time, the larger the quantity of DVDs sold. Model 1’s optimal DVD release time for the average movie is longer than the Baseline model’s optimal DVD release time. Thus the optimal quantity with the addition of VoD will be smaller than that of the Baseline model.
Theatrical Release Decay Rate

The analysis of the theatrical release decay rate, $d_1$, gives an interesting look at its impact on Model 1. First, the profits of the Hollywood studio decline as the decay rate increases. This decline intuitively makes sense because the larger the decay rate, the smaller the number of consumers who will watch the movie in the theater, thereby reducing the Hollywood Studio’s overall profit. The VoD release window, $t_2$, and the DVD release window, $t_3$, are significantly affected by the theatrical decay rate. Decreasing the theatrical decay from the baseline significantly increases both VoD and DVD release window. Increasing the theatrical decay rate from the baseline case will decrease the size of the window and decrease the difference between Model 1’s release windows and the Baseline model release window. Figure 4- shows the comparison of Model 1 and the Baseline Model’s release case. The optimal order quantity is increasing with respect to the theatrical decay rate, as expected, since the optimal DVD release period is decreasing.

VoD Decay Rate

Examining the VoD decay rate, $d_2$, leads to several insights. Similarly to when $d_1$ increases, the profits of the Hollywood studio decline when $d_2$ increases. The decrease in the Hollywood Studio’s profits occurs once again because fewer consumers will watch the movie. The VoD release window, $t_2$, is seen to be decreasing as the VoD decay rate increases. Similarly, the time to DVD release window is also decreasing, but at a faster rate than the VoD release window, which can be seen in Figure 4-. The difference between the VoD and DVD release window is decreasing as the VoD decay rate increases, this decrease is occurring to offset the loss from the decrease in
consumer viewing the VoD. Finally, as expected, the optimal DVD order quantity is increasing as the VoD decay rate increases.

**VoD Zero Price Demand**

The VoD zero price demand for the VoD release period, $I_{0}^{*}$, is seen to impact a number of variables. The optimal order quantity is decreasing as the VoD zero price demand increases. The VoD release window is significantly increasing as the VoD zero price demand increases. The increase of the VoD zero price demand increases the VoD release window. However, as seen in Figure 4, the increase in time is rather small. The difference in the VoD and DVD release window is increasing because as the VoD zero price demand increases, the amount of money earned by the VoD will increase. Finally, the Hollywood studio’s profit is increasing when the increase of the VoD slope.

**Price Sensitivity**

The price sensitivity variable, $S$, affects the different variables in an opposite way to the decay rate variable. The profit of the Hollywood studio is decreasing with the increase of the price sensitivity variable. The optimal order quantity is also continuously increasing as the price sensitivity variable increases. The optimal VoD release window is seen to be very slightly increasing with the price sensitivity variable, while the optimal DVD release window is significantly decreasing as the price sensitivity variable increases, as seen in Figure 4-. The difference between the VoD release window and the DVD release window is decreasing because as the VoD becomes more price sensitive, less profits are made from the VoD channel.

**Model 2**

As in Model 1, the movie will be sequentially released over the three distribution channels. However, in this model, the release of one distribution channel can overlap a
second channel. The movie is first released in the theater. Let \( \Pi^C_1(t) \) be the Hollywood studio’s profit at time \( t \) when the movie is released in the movie theater. During the movie’s theatrical run, the movie can then be released on VoD. Let \( \Pi^B_1(t,t_2) \) be the Hollywood studio’s profit from the theatrical channel and \( \Pi^B_2(x,t,t_2) \) be the Hollywood studio’s profit from the VoD channel when \( t_2 \leq t \leq t_3 \). Finally, when the movie has finished its theatrical run, it will then be released on DVD. Let \( \Pi^A_2(x,t,t_3) \) be the movie studio’s profit from the VoD channel and \( \Pi_3(t,t_3) \) be the movie studio’s profit from the DVD channel when \( t \geq t_3 \). Figure 4- shows the release times of the movie in each channel in Model 1.

The Hollywood movie studio’s goal is to optimize its profit with a discount rate of \( \rho \) given by:

\[
P(t_2,t_3,x) = \int_0^{t_2} \Pi^C_1(t)e^{-\rho t} dt + \int_{t_2}^{t_3} \Pi^B_1(t)e^{-\rho t} dt + \int_{t_2}^{t_3} \Pi^B_2(t,t_2,t_3)e^{-\rho t} dt \\
+ \int_0^{t_3} \Pi^A_2(t,t_3)e^{-\rho t} dt + \int_{t_3}^{\infty} \Pi_3(t,t_3)e^{-\rho t} dt
\]

The revenue for the movie from theaters in Model 2 is modeled exponentially, thus movie revenue from theaters is formulated as:

\[
M^C_i(t) = m^C_i e^{-\rho dt} \quad 0 \leq t \leq t_2
\]

and

\[
M^B_i(t) = m^B_i e^{-\rho dt} \quad t_2 \leq t \leq t_3.
\]

Where \( m^C_i > m^B_i \) and \( d_i > 0 \).

VoD Distributer’s Profit

The fee structure for Model 2 is the same as in Model 1, however, in Model 2 additional VoD sales occur during the DVD rental release channel. The VoD distributor’s profit function is:
\[ P_{VoD} = (w-x)(\int_{0}^{t_1} m_{1}^{B}(w)e^{-d_{1}t} e^{-\rho t} dt + \int_{t_1}^{t_2} m_{2}^{B}(w)e^{-d_{2}t} e^{-\rho t} dt + \int_{t_2}^{t_3} m_{2}^{A}(w)e^{-d_{2}t} e^{-\rho t} dt) - F \quad (4-27) \]

Similar to the VoD demand in Model 1, I modeled VoD demand as an exponential function and formulate it as follows:

\[ M_{2}^{B}(w) = m_{2}^{B}(w)e^{-d_{2}t} \quad t_2 \leq t \leq t_3 \quad (4-28) \]
\[ m_{2}^{B}(w) = (I_{2}^{B2} - wS) \quad (4-29) \]
\[ M_{2}^{A}(w) = m_{2}^{A}(w)e^{-d_{2}t} \quad t \geq t_3 \quad (4-30) \]
\[ m_{2}^{A}(w) = (I_{2}^{A2} - wS). \quad (4-31) \]

Where \( m_{1}^{B} > m_{1}^{A} > 0 \) and \( d_{2} > 0 \). Then Eq(4-29) and Eq(4-31) are substituted into Eq(4-27) and then I simplify \( P_{VoD} \) to get:

\[ P_{VoD} = \frac{(w-x)(-Sw + (1+e^{d_{2}+\rho(t_2-t_3)})(wS - I_{2}^{B2}) + I_{2}^{A2})}{(d_{2} + \rho)} - F. \quad (4-32) \]

I then solve for the optimal \( w \) and get:

\[ w^{*} = \frac{Sw + I_{2}^{B2} + \frac{I_{2}^{B2} - I_{2}^{A2}}{2} + e^{d_{2}+\rho(t_2-t_3)}}{2S} \quad (4-33) \]

**DVD Retailer’s Optimal Order Quantity**

As in Model 1, the DVD retailer’s objective is to optimize the amount of DVDs it purchased based on the time that the DVD will be released. The optimal order quantity in Model 2 is the same as that of Model 1, but the only difference is \( v_{3} \) replaces \( v_{1} \), as the rentals per store.

\[ q^{*} = \frac{v_{3}}{n} e^{-\lambda} \quad \left( \frac{p_{1}^{A}}{n} \right) \quad (4-34) \]
Hollywood Studio’s Optimal Release Times and Optimal VoD Profit Share

Since the Video on Demand distributor and the DVD retailer responses are known, the Hollywood studio attempts to find the optimal VoD time release, DVD time release, and the optimal profit-sharing price. As in Model 1, I assume a constant gross margin for the Hollywood studio of $M_T$ in the first channel and $M_v$ in the third channel.

The Hollywood studio’s profit is shown in EQ (4-24), when simplified:

$$P(t_2, t_3, x) = M_T \frac{m_i^c}{(d_i + \rho)} \left(1 - e^{-t_2(d_i + \rho)}\right) + M_T \frac{m_i^b}{(d_i + \rho)} \left(1 - e^{(d_i + \rho)(t_2 - t_1)}\right)$$

$$+ \frac{x(1 + I_2^{b2} - w^*S)(1 - e^{(d_i + \rho)(t_2 - t_1)})}{(d_i + \rho)} + \frac{x(1 + I_2^{A2} - w^*S)}{(d_i + \rho)}$$

$$+ M_v \frac{v_3}{n} e^{-v_3 x} \left(\frac{p_v A}{m}\right) e^{-\rho t_3}.$$ (4-35)

Eq(4-36) is Eq(4-35) simplified when $q^*$ and $w^*$ are substituted into it:

$$P(t_2, t_3, x) = M_T \frac{m_i^c}{(d_i + \rho)} \left(1 - e^{-t_2(d_i + \rho)}\right) + M_T \frac{m_i^b}{(d_i + \rho)} \left(1 - e^{(d_i + \rho)(t_2 - t_1)}\right)$$

$$+ \frac{x \left(1 + I_2^{b2} - xS + \frac{I_2^{b2} - I_2^{A2}}{2 - e^{d_i(t_2 - t_1)}}\right)(1 - e^{(d_i + \rho)(t_2 - t_1)})}{2d_2}$$

$$+ \frac{x \left(1 + I_2^{A2} - \frac{1}{2} \left(I_2^{b2} + xS + \frac{I_2^{b2} - I_2^{A2}}{2 - e^{d_i(t_2 - t_1)}}\right)\right)}{d_2} + M_v \frac{v_3}{n} e^{-v_3 x} \left(\frac{p_v A}{m}\right) e^{-\rho t_3}.$$ (4-36)

However, using Eq(4-36), a closed form solution cannot be found. Attempting to solve for a closed form solution leads to the following equations:

$$t_2 = \frac{-\frac{p_v A}{nr} + \ln 2M_v v_3 v_3^b - (v_3^b - 1)^* \ln 2m_i^c M_T - \ln \left(2e^{d_i m_i^b M_T} - e^{d_i nSx^2 + e^{d_i nSf_{22}^b}}\right)}{(v_3^b - 1) \ln \left(1 + e^{d_i x (I_2^{b2} - Sx)}\right)} \left(1 + (d_i) (v_3^b - 1)\right)^{-1} \left(1 + (d_i) (v_3^b - 1)\right)} (4-37)$$
Using Eq(4-37), Eq(4-38), and Eq(4-39), I am able to numerically solve for \( t_2^* \), \( t_3^* \), and \( x^* \). The analysis of Model 2 will be based on the numerical solutions that were found.

**Analysis of Model 2**

To analyze Model 2, I create a numerical solution of both Model 1 and Model 2. The variables used are the same employed during the analysis of Model 1. One new variable is added to baseline variables, \( t_2^{A3} \), the VoD zero price demand when the DVD release occurs. This variable is based on the current environment of movie rentals and \( t_2^{A3} = .3 \) during Model 2’s numerical analysis.

When examining the VoD release window of Model 2 and the DVD release window of the Baseline model, the VoD release window is smaller than that of the DVD release window. However, when comparing the DVD release window of Model 2 with that of the Baseline model, the Baseline model’s window is smaller than that of Model 2. Finally when the optimal DVD order quantity is compared with the baseline case; the baseline case’s optimal order quantity is always greater.

**Theatrical Decay Rate**

Examining the effect of the theatrical decay rate on Model 1 and Model 2’s optimal DVD order quantity, both are increasing with the theatrical decay rate. The
comparison of Model 1’s with Model 2 optimal DVD order quantity can be seen in Figure 4-. Model 1 optimal DVD order quantity is more sensitive to the theatrical decay rate. With no channel overlap, the model is less sensitive to the theatrical decay rate. The comparison of the optimal release windows of Model 1 and Model 2 can be seen in Figure 4-. The optimal VoD window for both models are similar, however, Model 2’s VoD release window is always less than that of Model 1’s VoD release window. Model 1’s optimal DVD release window is more sensitive to the theatrical decay rate, indicating that adding the channel overlap reduces the DVD release window’s sensitivity to the theatrical decay rate. As expected, Model 2’s profit is decreasing as the theatrical decay rate increases.

**VoD Decay Rate**

The VoD decay rate has a similar effect on Model 2 as the theatrical decay rate. The optimal order quantity for each model is increasing, but both are less than the Baseline model. Adding channel overlap makes Model 2 less sensitive to the VoD decay rate. Model 1’s optimal order quantity is increasing at a faster rate than Model 2’s optimal order quantity. Comparing the optimal release windows of each model, in Figure 4- shows all release windows decrease as the VoD decay rate increases. However, both of Model 1’s optimal VoD and DVD release windows are more sensitive to Model 2’s release window. It should also be noted that Model 1’s VoD windows are always greater than that of Model 2. Model 2’s profit is decreasing as the VoD decay rate increase at a similar rate.

**VoD Zero Price Demand**

The VoD zero price demand for the VoD release period has an opposite effect on Model 2 and Model 1. Model 1’s and Model 2’s optimal DVD order quantity are both
decreasing as VoD zero price demand increases, with Model 1 being sensitive to the VoD zero price demand, as seen in Figure 4-. Figure 4- shows the comparison of the optimal release windows of Model 1 and Model 2. The optimal VoD release window for each model is decreasing while optimal DVD release windows are increasing, as the VoD zero price demand increases. The sensitivity of Model 1’s DVD release window is greater than that of Model 2’s DVD release window. However both Model 1 and Model 2’s initial VoD release period is increasing as the VoD zero price demand increases. Model 2’s profit is increasing as the VoD zero price demand increases at a similar rate.

**Price Sensitivity**

Examining the price sensitivity of VoD, the optimal DVD order quantity is increasing as the price sensitivity increases for both models. As with the other variables, Model 1 is more sensitive to the price sensitivity than Model 2. The increase in VoD price sensitivity decreases the VoD release window and DVD release window for both Model 1 and Model 2, as seen in Figure 4-. Model 1’s optimal release windows are more sensitive to the increase in VoD price sensitivity than Model 2. The initial VoD release period is also decreasing with the increase of price sensitivity. Finally, the profit of Model 2 is decreasing with respect to price sensitivity increasing.

Comparing Model 1 and Model 2, when channel overlap is added, the sensitivity of Model 2 to the variables VoD decay rate, VoD zero price demand, and price sensitivity decreases. This decrease in sensitivity seems to occur due to the overlap of the distribution channels. Since the VoD release can occur both during a film’s theatrical release period and the DVD’s release period, these variables dealing mainly with DVDs are less sensitive.
Summary

The sequential distribution of movies plays an important role in the profits made by Hollywood studios. Hollywood movies made more than $10.8 billion in the North American box office, followed by $8.73 billion from DVDs sales, and $8.15 billion in DVD Rentals in the US in 2009. While the box office receipts and DVD rentals are up, DVD sales were down more than 13.2% in 2009. The sale of DVDs has been declining since its record high in 2005, and one way that Hollywood studios have been fighting the declining sales has been to decrease the theatrical to DVD release window. However, this solution has not been successful. One alternative that movie studios have been working on is the VoD release during or soon after a theatrical release.

In Chapter 4, I analyze the impact of Hollywood studios adding a VoD release after the release in a theater, but prior to the release on DVD. Previous literature has only look at the optimal timing of the theatrical to DVD release window of a movie. The literature has shown that the DVD release window for a movie should be shorter than the current window. The analysis in Chapter 4 indicates that adding a VoD channel will in fact cause the theatrical release window to shorten, however, it will not be as short as predicted in previous research. The addition of overlapping channels still shortens the VoD release window compared to no channel, however, the addition of overlap tends to decrease the DVD release window.

In Chapter 4, I a potential for Hollywood studios to benefit from the FCC ruling over analog signals, allowing Hollywood studios to release a movie over VoD close to or soon after a movie's theatrical release. One area of future research is to add the distribution of the movie cable or network television. The effect on the different optimal release windows for the different channels can be examined. A second area of
potential research includes examining the release order of the sequential distribution channel. Currently, it is assumed that the appropriate order of a movie release is theatrical, VoD, DVD, and over TV. However, certain conditions under this theatrical release order may not be optimal. Researching the optimal release order for the sequential distribution could potentially lead to higher optimal profits for Hollywood studios.
Figure 4-1. The release sequence of a movie from a Hollywood studio over the three distribution channels with channel overlap.

Figure 4-2. Lehmann and Weinberg [11] model timeline.
Figure 4-3. Comparison of the Baseline model and Model 1 release windows with respect to the theatrical decay rate.

Figure 4-4. Comparison of Model 1 and Baseline model release windows with respect to the VoD decay rate.
Figure 4-5. Comparison of Model 1 and Baseline model’s release windows with respect to VoD zero price demand for the VoD release period.

Figure 4-6. Comparison of Model 1 and Baseline model’s release window with respect to the VoD price sensitivity.
Figure 4-7. Release sequence of a movie from a Hollywood studio over the three distribution channels when channel overlap is allowed.

\[ \begin{array}{c|c|c|c}
\text{Theater} & \text{VOD} & \text{DVD/Rental} \\
0 & t_2 & t_3 & \infty \\
\Pi_1^C(t) & \Pi_1^B(t, t_2) & \Pi_2^B(x, t, t_2) & \Pi_2^A(x, t, t_3) \\
\Pi_3(t, t_3) & & & \\
\end{array} \]

Figure 4-8. Comparison of Model 1 and Model 2 optimal DVD order quantity respect to the theatrical decay rate.
Figure 4-9. Comparison of Model 1 and Model 2 optimal release windows with respect to the theatrical decay rate.

Figure 4-10. Comparison of Model 1 and Model 2 optimal release windows with respect to the VoD decay rate.
Figure 4-11. Comparison of Model 1 and Model 2 optimal DVD order quantity with respect to the VoD decay rate.

Figure 4-12. Comparison of Model 1 and Model 2 optimal release windows with respect to the VoD decay rate.
Figure 4-13. Comparison of Model 1 and Model 2 optimal release windows with respect to the price sensitivity.
Table 4-1 VoD notation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w$</td>
<td>Price for a consumer to watch a movie via VoD</td>
</tr>
<tr>
<td>$x$</td>
<td>Movie distributor fee per VoD shown</td>
</tr>
<tr>
<td>$F$</td>
<td>Fixed fee to purchase the rights to show the movie on VoD</td>
</tr>
<tr>
<td>$i_v$</td>
<td>VoD zero price demand</td>
</tr>
<tr>
<td>$S$</td>
<td>Price sensitivity</td>
</tr>
</tbody>
</table>

Table 4-2 DVD retailers optimal order quantity notation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V(u)$</td>
<td>Rental demand rate per DVD store at time $u=(t-t_s)$ after the DVD’s release $=v_i e^{-h} n e^{-v_i u}$</td>
</tr>
<tr>
<td>$p$</td>
<td>Cost per DVD to retailer</td>
</tr>
<tr>
<td>$r$</td>
<td>Rental fee per copy (assumed to be constant)</td>
</tr>
<tr>
<td>$n$</td>
<td>Number of rental turns per copy each time period, for example, three per week</td>
</tr>
<tr>
<td>$h$</td>
<td>Holding cost per period per unit</td>
</tr>
<tr>
<td>$l$</td>
<td>Out-of-stock lost sales cost per period</td>
</tr>
<tr>
<td>$q$</td>
<td>Number of DVDs ordered</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Time after DVD’s release at which DVD rental demand equals rental capacity for the store</td>
</tr>
<tr>
<td>$T$</td>
<td>Time horizon for which DVDs are held, at the end of which they have no salvage value</td>
</tr>
</tbody>
</table>
Table 4-3. Baseline numbers used to analyze model 1 with the baseline model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_T = .70$</td>
<td>Constant gross margin for the Hollywood studio in the theater channel</td>
</tr>
<tr>
<td>$M_V = .30$</td>
<td>Constant gross margin for the Hollywood studio in the DVD channel</td>
</tr>
<tr>
<td>$m^C_1 = 20.70$ (in millions of dollars)</td>
<td>Opening weekend box office receipts for the movie</td>
</tr>
<tr>
<td>$m_2 = d_1 = .36$</td>
<td>The decline rate of the movie after the weekend box office opening</td>
</tr>
<tr>
<td>$v_1 = 32.70$</td>
<td>Rentals per store</td>
</tr>
<tr>
<td>$v_2^A = v_3^A = v_2^B = .059$</td>
<td>The decline rate of the movie after it is released in the DVD channel</td>
</tr>
<tr>
<td>$p = $18.00$</td>
<td>Cost of movie per DVD for the rental store</td>
</tr>
<tr>
<td>$r = $5.00$</td>
<td>Price per DVD rental</td>
</tr>
<tr>
<td>$n = 3$</td>
<td>Number of rental turns per week</td>
</tr>
<tr>
<td>$I^B_2 = .45$</td>
<td>VoD zero price demand for the VoD release period</td>
</tr>
<tr>
<td>$S = .2$</td>
<td>Pricing sensitivity for VoD</td>
</tr>
<tr>
<td>$d_2 = .15$</td>
<td>The decline rate of the movie after it is released in VoD channel</td>
</tr>
</tbody>
</table>

Table 4-4. Additional VoD notation for model 2

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I^B_2$</td>
<td>VoD zero price demand when $t_2 \leq t \leq t_3$</td>
</tr>
<tr>
<td>$I^A_2$</td>
<td>VoD zero price demand when $t \geq t_3$</td>
</tr>
</tbody>
</table>
CHAPTER 5
CONCLUSION

Digital technology has brought many changes to the world. Two innovations derived from digital technology are digital products and digital distribution, have unique inherent qualities that have made traditional research methods inadequate. In this dissertation, based on the unique qualities of digital products and digital distribution, I investigate the effects of digital technologies on governments, consumers, and society.

In Chapter 2, I examine the effect of information leakage on traditional cultural policy tools, specifically when the government’s objective is to maximize. I find that the difference between domestic and foreign traditional entertainment or domestic and foreign Internet entertainment largely determines the effectiveness of each traditional cultural policy tool. When leakage is present, the smaller the difference between the quality of the Internet foreign product and domestic product, the greater the overall social welfare. The optimal protection tool to use in the presence of leakage is either a tariff or a subsidy. The selection of the optimal tool is determined by the quality of foreign traditional entertainment. A tariff or subsidy remains the optimal tool to use when piracy is added to the information leakage.

Chapter 2 offers several extensions for future research. In my stylized model, the domestic firm is competing against a foreign firm. One possible extension is to have many foreign firms competing against each other for access to the domestic market, resulting in a *de facto* perfect competition among foreign providers. My model can be easily adapted to examine this situation, which is a special case of my model because the foreign firms are then price takers under perfect competition, as opposed to a price setter in my model. The price of foreign entertainment in the perfect competition case,
$p_f$, becomes an exogenous parameter rather than a decision variable to be optimized by the foreign firm. The solution procedure remains essentially the same. In Chapter 2, I treat the quality levels of both foreign and domestic entertainment programs as exogenously given. It would be interesting to endogenize them and explore the effect of leakage on quality competition. Finally, it would be beneficial to study the effect of multiple types of leakage on the effectiveness of the cultural protection policy tools. The Internet provides one channel of leakage, but other channels of leakage, such as satellite TV, can potentially have a different quality level (more likely higher) than the Internet.

In Chapter 3 I examine two issues: 1) The effects of Internet leakage on a subsidy, tariff, and quota when governments use these cultural protection tools to guard the domestic industry, and 2) The effect Internet leakage on the cultural protection tools when a government’s purpose is to benefit the consumers. Examining the first issue, I show that a government using a quota when no leakage is present is the most beneficial to protect domestic firms. However, when leakage is introduced, a subsidy is shown to help the domestic firms more than a quota. If piracy is present in addition to leakage, either a quota or subsidy is the most beneficial cultural protection tool. The choice of which tool to use is based on the amount of unethical users present in the country. Researching the second issue, if leakage is not present, either a quota or tariff benefits the consumer the most, based on the quality difference between domestic and foreign products. A tariff is the most beneficial tool to consumers when used by a government in the presence of Internet leakage. The presence of Internet leakage and
piracy shows that either a subsidy or tariff benefits the consumer the most, based on the amount of unethical users.

In Chapter 4 I analyze the impact of adding Video on Demand (Vod) Hollywood studios’ sequential distribution of films. I show that when no overlap occurs between distribution channels, the addition of VoD does shrinks the DVD release window, however, not as much as it would if VoD was not added. Adding overlap between distribution channels affects both the VoD and DVD release windows. The addition of the distribution overlap shrinks both the VoD and DVD release windows. The optimal VoD release window with distribution overlap is smaller than when no channel overlap is present. In Chapter 4, I state that potential exists for Hollywood to benefit from the FCC ruling over analog signals, allowing Hollywood to release a movie over VoD close to or soon after a movie's theatrical release.

One area of future research is to add the distribution channel of cable or network television to examine the effect on the different optimal release windows for the different channels. A second area of potential research includes investigating the release order of the sequential distribution channel. Currently, studios assume that the appropriate order of movie release is theatrical, VoD, DVD, and on TV. However certain conditions may exist under which this theatrical release order may not be optimal. Researching the optimal release order for the sequential distribution could potentially lead to higher optimal profits for Hollywood studios.
APPENDIX A
PROOFS OF LEMMAS AND THEOREMS FROM CHAPTER 2

Proof of Lemma 2-1

Let $\theta_f$ be the marginal consumer who is indifferent between foreign and domestic entertainment, and $\theta_d$ be the marginal consumer indifferent between domestic entertainment and doing without. When $\bar{q} < \frac{2s_f - s_d}{4s_f - s_d}$, where $\frac{2s_f - s_d}{4s_f - s_d}$ is the optimal $\theta_b$ under free trade, the quota has no effect on the competition. The optimal prices follow from the standard free-trade results of two firms under vertical quality differentiation.

When $\bar{q} > \frac{2s_f - s_d}{4s_f - s_d}$, the demand for foreign firm is restricted by $1 - \bar{q}$. Since its profit function is concave, it will serve all the demand $1 - \bar{q}$. Thus at the point $\bar{q}$, Eq. (1) holds that $p_f = \bar{q}(s_f - s_d) + p_d$. The domestic firm solves the profit maximizing function $\max p_d = p_d Q_d = p_d \left( \frac{\bar{q} - p_d}{s_d} \right)$, which gives the best response function $p_d^* = \frac{\bar{q}s_d}{2}$. The optimal $p_f^*$ results from combining this best response function with Eq. (1). Q.E.D.

Proof of Theorem 2-1

The government decides the optimal quota to maximize the domestic social welfare, described as follows.

$$\max_{\bar{q}} \pi_d + \int_{\theta_f}^{\theta_d} (\theta s_d - p_d^*) d\theta + \int_{\theta_f}^{\theta_d} (\theta s_f - p_f^*) d\theta,$$

where

$$\pi_d^* + \int_{\theta_f}^{\theta_d} (\theta s_d - p_d^*) d\theta = \frac{s_d}{2} \left( \bar{q}^2 - \frac{\bar{q}^2}{4} \right) = \frac{3s_d}{8} \bar{q}^2,$$

and

$$\int_{\theta_f}^{\theta_d} (\theta s_f - p_f^*) d\theta = \frac{s_d}{2} + \frac{(s_d - s_a)}{2} \bar{q}^2 - \frac{(2s_d - s_a)}{2} \bar{q}.$$  

It can be easily confirmed that the second order condition (SOC) is positive when $s_f > s_d$. Thus, the profit function is convex in $\bar{q}$, and the corner solution is obtained. Comparing the two corners values $\frac{2s_f - s_d}{4s_f - s_d}$ and $1$ with the $\bar{q}_{\min} = \frac{4s_f - 2s_d}{4s_f - s_d}$, the profit
minimizing $q$ value, 1 is closer to $q_{\text{min}}$. Thus, the optimal quota should be set at $q^* = \frac{2s_f - s_d}{4s_f - s_d}$. Q.E.D.

**Proof of Theorem 2-4**

1. I first prove that $SW'(\sigma^*) > SW'(q^*)$.

Since $s_f > s_d$, I can write $s_f = s_d + \varepsilon$ (assuming that $\varepsilon > 0$).

$$SW'(\sigma^*) - SW'(q^*) = \frac{4(s_f^2 + 3s_fs_f - s_d^2)}{8(4s_f - s_d)} - \frac{4s_f^2 + 8s_fs_f - 3s_d^2}{8(4s_f - s_d)}$$

$$= \frac{4(3s_d^2 + 5s_d\varepsilon + \varepsilon^2) - (9s_d^2 + 16s_d\varepsilon + 4\varepsilon^2)}{8(3s_d + 4\varepsilon)} \quad \text{(Substitute } s_f = s_d + \varepsilon)$$

$$= \frac{s_d}{8}$$

Since $s_d > 0$ and $\varepsilon > 0$, both the numerator and the denominator are positive. This implies that $SW'(\sigma^*) - SW'(q^*) > 0$.

2. Prove that $SW'(\tau^*) > SW'(\sigma^*)$

Since $s_f > s_d$, I set $s_f = s_d + \varepsilon$ (assuming that $\varepsilon > 0$).

$$SW(\tau^*) - SW(\sigma^*) = \frac{s_f(2s_d^3 - 12s_d^2s_f + 13s_d s_f^2 + 16s_f^3)}{2(4s_f - s_d)^2(3s_f - s_d)} - \frac{(s_f^2 + 3s_ds_f - s_d^2)(4s_f - s_d)(3s_f - s_d)}{2(4s_f - s_d)^2(3s_f - s_d)}$$

$$= \frac{(s_d + \varepsilon) + (19s_d^3 + 62s_d^2\varepsilon + 61s_d s_d^2 + 16\varepsilon^3) - (3s_d + 4\varepsilon)(2s_d + 3\varepsilon)(3s_d^2 + 5s_d \varepsilon + \varepsilon^2)}{2(3s_d + 4\varepsilon)^2(2s_d + 3\varepsilon)} \quad \text{(Substitute } s_f = s_d + \varepsilon)$$

$$= \frac{(s_d^4 - 4s_d^2\varepsilon^2 + 4\varepsilon^4)}{2(3s_d + 4\varepsilon)^2(2s_d + 3\varepsilon)}$$

Since $s_d > 0$ and $\varepsilon > 0$, both the numerator and the denominator are positive. This implies that $SW(\tau^*) - SW(\sigma^*)$.

Thus, $SW'(\tau^*) > SW'(\sigma^*) > SW'(q^*)$ holds. Q.E.D.
Proof of Theorem 2-8

1. Take first derivative of \( SW^*(q^*_f) \) with respect to \( s_i \),
\[
\frac{\partial SW^*(\sigma^*_f)}{\partial s_i} = \frac{(s_i - s_d)(2s_i(-2s_f + s_i) + s_d(s_f + s_i))(s_i^2s_f - 2s_ds_is_f + 4s_i^2(-2s_f + 3s_i))}{(4s_i^2 - s_d^2)(s_d^2s_f - s_i(4s_f - 3s_i))^2}.
\]
The denominator is always positive due to each equation being squared. Since I know \( s_i > s_d \), \( s_i - s_d \) is always positive. However, I know that
\[
(2s_i(-2s_f + s_i) + s_d(s_f + s_i))(s_i^2s_f - 2s_ds_is_f + 4s_i^2(-2s_f + 3s_i))
\]
is positive when
\[
32s_f - 4s_i(32s_f - 4s_i)s_f - s_i > s_i(8s_i^3 - s_i^2s_f)(s_f - s_d) - s_i^2s_f^2(s_i - s_d),
\]
otherwise it is negative. Thus \( SW^*(\sigma^*_f) \) is increasing in \( s_i \) when
\[
32s_f - 4s_i(32s_f - 4s_i)s_f - s_i < s_i(8s_i^3 - s_i^2s_f)(s_f - s_d) - s_i^2s_f^2(s_i - s_d)
\]
and is decreasing in \( s_i \) otherwise.

2. Take first derivative of \( SW^*(\tau^*_i) \) with respect to \( s_i \),
\[
\frac{\partial SW^*(\tau^*_i)}{\partial s_i} = \frac{-7s_i^2 + 2s_ds_i - 4s_i^2}{6(4s_i - s_d)^2} < 0,
\]
given \( s_d < s_i < s_f \), thus \( SW^*(\tau^*_i) \) is decreasing in \( s_i \).

3. Take first derivative of \( SW^*(\sigma^*_i) \) with respect to \( s_i \),
\[
\frac{\partial SW^*(\sigma^*_i)}{\partial s_i} = \frac{3s_i^2}{8(4s_i - s_d)^2} > 0,
\]
thus \( SW^*(\sigma^*_i) \) is increasing in \( s_i \). Q.E.D

Proof of Theorem 2-9

1. I first prove that \( SW^*(\tau^*_i) > SW^*(q^*_f) \).
\[
SW^*(\tau^*_i) - SW^*(q^*_f)
= \frac{3s_f(4s_i - s_d) + 27s_ds_i + (s_f - s_i)(4s_i - s_d)}{24(4s_i - s_d)} - \frac{s_i(4s_i^2(s_f - s_i) - s_d^2(s_f + s_i) + s_ds_i(7s_f - 4s_i))}{2(4s_i - s_d)(s_f(4s_f - 3s_i) - s_d s_f)}
= \frac{(s_f - s_i)(12s_i^2(s_f - s_i) + s_f(s_i - s_d)(4s_i - s_d)) + 3s_ds_i(s_f - s_i)(s_i - s_d) + 3s_i^2(s_i - s_d)^2}{6(4s_i - s_d)(3s_f(s_f - s_i) + s_f(s_i - s_d))}
\]
Since \( s_d < s_i < s_f \), the numerator and the denominator are both positive. This implies that \( SW^*(\tau^*_i) - SW^*(q^*_f) > 0 \).

2. Next I show \( SW^*(\sigma^*_i) > SW^*(q^*_f) \).
\[
SW^*(\sigma^*_i) - SW^*(q^*_f)
\]

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\[
\begin{align*}
&= \frac{(4s_d - s_i - 4s_d^2 - s_d(s_f - 13s_i))}{8(4s_i - s_d)} - \frac{s_i\left(4s_i^2(s_f - s_i) - s_d^2(s_f + s_i) + s_d s_i(7s_f - 4s_i)\right)}{2(4s_i - s_d)\left(s_i(s_f - 3s_i) - s_d s_f\right)} \\
&= \frac{4s_d^3 s_f + s_d^2 s_f^2 - 21s_d^2 s_f s_i - 8s_d^2 s_i^2 - 16s_d^3 s_i^2 + 27s_d^2 s_f^2 s_i + 16s_d^3 s_f^2 - 23s_d^4 s_i^3 - 28s_d^3 s_f + 16s_d^4}{8(4s_i - s_d)\left(s_f(s_i - s_d)3s_i(3s_f - s_i)\right)} \\
&= \frac{8s_i s_f^2 (s_i - s_d) + 16s_i^3 (s_i - s_d) + 8s_i^2 s_f (s_f - s_i) + 21s_d s_f s_i (s_i - s_d)}{8(4s_i - s_d)\left(s_f(s_i - s_d)3s_i(3s_f - s_i)\right)} \\
&= \frac{+6s_d s_i^2 (s_i - s_f) + 16s_i^2 (s_i s_f - s_i^2) + 4s_f (4s_i^3 - 4s_d s_f) + s_d^2 (s_f - s_i)}{8(4s_i - s_d)\left(s_f(s_i - s_d)3s_i(3s_f - s_i)\right)} \\
&= \frac{3s_f (4s_i - s_f) + 27s_d s_i + (s_f - s_i)(4s_i - s_d) - \left(4s_f s_i - 4s_d^2 - s_d(s_f - 13s_i)\right)}{24(4s_i - s_d)} - \frac{8(4s_i - s_d)}{8(4s_i - s_d)} = 0.
\end{align*}
\]

Since \( s_d < s_i < s_f \), the numerator and the denominator are both positive. This implies that \( SW'(\sigma^*_d) - SW'(\alpha^*_d) > 0 \).

3. Next I show that
\[
s_i = \frac{4s_f - 11s_d + \sqrt{313s_d^2 - 104s_d s_f + 16s_f^2}}{8}.
\]

\[
SW'(\tau^*_i) - SW'(\sigma^*_d) = 0
\]

\[
\iff \frac{3s_f (4s_i - s_f) + 27s_d s_i + (s_f - s_i)(4s_i - s_d) - \left(4s_f s_i - 4s_d^2 - s_d(s_f - 13s_i)\right)}{24(4s_i - s_d)} - \frac{8(4s_i - s_d)}{8(4s_i - s_d)} = 0.
\]

\[
\iff 4s_i^2 + s_i\left(11s_d - 4s_f\right) + s_d s_f - 12s_i^2 = 0
\]

\[
\iff s_i = \frac{4s_f - 11s_d \pm \sqrt{313s_d^2 - 104s_d s_f + 16s_f^2}}{8}.
\]

Since
\[
\frac{4s_f - 11s_d \pm \sqrt{313s_d^2 - 104s_d s_f + 16s_f^2}}{8} = 3s_d\left(s_f - s_d\right) < 0 \text{ when } s_d = s_i \text{, and}
\]

\[
\frac{4s_f - 11s_d \pm \sqrt{313s_d^2 - 104s_d s_f + 16s_f^2}}{8} = 12s_d\left(s_f - s_d\right) > 0 \text{ when } s_f = s_i \text{, I get}
\]

\[
s_i = \frac{4s_f - 11s_d \pm \sqrt{313s_d^2 - 104s_d s_f + 16s_f^2}}{8}, \text{ Q.E.D.}
\]

**Proof of Theorem 2-13**

First I examine the specific tool by taking the derivative with respect to the variable being examined. In this proof, I will look specifically at the effect of proportion of ethical users’ \( \alpha \) on optimal tariff. The rest of the tools are also solved in the same fashion for both \( \alpha \) and the cost of piracy.

I first derive that
\[
\frac{\partial \alpha^*}{\partial \alpha} = -\frac{(s_f - s_g)(s_f - s_i)(c_s + s_i - s_g)}{3(s_f - \alpha s_g - (1 - \alpha)s_i)^2}.
\]
The numerator of the above partial derivative is positive since $s_g < s_f$, $s_i < s_f$, and $s_g = s_i$ and the denominator $3(s_f - s_g - (1 - \alpha)s_i)^2$ is positive. Thus, the partial derivative is negative, and the optimal tariff $\tau_p^*$ is decreasing with respect to $\alpha$. Q.E.D.
### APPENDIX B
RESULTS, PROOFS OF LEMMAS, AND PROOFS OF THEOREMS FROM CHAPTER 3

<table>
<thead>
<tr>
<th>Optimal Tool</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $q^*$</td>
<td>$s_f \left(s_f - s_d\right) \left(4s_f - 3s_d\right)$ \over \left(12s_f^2 - 9s_ds_f + 2s_d^2\right)$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
<td>$s_d \left(s_f - s_d\right)$ \over \left(12s_f^2 - 9s_ds_f + 2s_d^2\right)$</td>
</tr>
</tbody>
</table>

Optimal Tool when solving for the domestic firm profits under the baseline case

<table>
<thead>
<tr>
<th>Optimal Tool</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $q^*$</td>
<td>$2 \left(2s_f - s_d\right)$ \over \left(4s_f - 3s_d\right)$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
<td>$s_f \left(s_f - s_d\right) \left(4s_f - 3s_d\right)$ \over \left(12s_f^2 - 9s_ds_f + 2s_d^2\right)$</td>
</tr>
<tr>
<td>Subsidy, $\sigma^*$</td>
<td>$s_d \left(s_f - s_d\right)$ \over \left(12s_f^2 - 9s_ds_f + 2s_d^2\right)$</td>
</tr>
</tbody>
</table>

Optimal tool when solving for the under consumer surplus the baseline case

<table>
<thead>
<tr>
<th>Optimal Tool</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota, $q^*$</td>
<td>$1 \left(s_f - s_i\right)$</td>
</tr>
<tr>
<td>Tariff, $\tau^*$</td>
<td>$s_d \left(s_i - s_d\right)$ \over \left(12s_i^2 - 9s_ds_i + 2s_d^2\right)$</td>
</tr>
</tbody>
</table>

Optimal tool when solving for the domestic firm profits under the leakage case
Optimal Tool

| Quota, $\bar{q}^*$ | \[
\frac{(4s_i - s_d) (2s_f (2s_f - s_i) - s_d (s_f + s_i))}{4s_i^2 (4s_f - 3s_i) - s_d s_f (8s_f - s_i) + s_d^2 (s_f + 2s_i)}
\] |
|---|---|
| Tariff, $\tau^*$ | \[
\frac{1}{3} (s_f - s_i)
\] |
| Subsidy, $\sigma^*$ | \[
\frac{s_d^2 (s_f - s_d)}{12s_i^2 - 9s_d s_f + 2s_d^2}
\] |

Optimal tool when solving for the consumer surplus under the leakage case

**Piracy Consumer Surplus**

Consumer surplus under quota in the presence of piracy

\[ CS(n_t) = \]
\[
\{ -2 (-1 + n_t) s_d (s_d - 4 n_t) (2 n_t (2 s_f - s_i) + s_d (s_f + s_i)) (s_f (3 s_f - 8 (-1 + n_t) n_t) + (-1 - 9 n_t) s_d + 2 (-1 + n_t) n_t) - 4 s_d^2 (1 + 4 (-1 + n_t) n_t + 4 s_d n_t) \} -
\[
\{ -1 + n_t \} (2 s_f - 4 s_d) n_t^2 -\{ 4 s_f - 4 (-1 + n_t) n_t \} (2 n_t - 4 (-1 + n_t) n_t) (s_f (s_f - 4 s_d n_t) - s_d) - s_d n_t (s_f - (-1 + n_t) n_t) (s_f - 4 s_d n_t) + 2 (-1 + n_t) n_t) -
\]
\[ a_d n_t s_d (1 - n_t) + \{ (4 (-5) n_t) - (4 - 4 n_t) n_t + 2 s_d (4 (-1 + n_t) n_t + (-4 + 7 n_t) s_d) \} -
\]
\[ n_t \{ -5 a_d s_d (4 (-1 + n_t) n_t - (4 + 5 n_t) n_t) (s_f - (1 + n_t) n_t - (4 n_t) n_t) \} +
\]
\[ 4 s_d a_d (\{ 0 (-1 + n_t) n_t - (20 - 3 n_t) n_t \} + 3 a_d^2 (s_f (-1 + n_t) n_t - s_d) + 2 s_d^2 [3 (9 (-1 - n_t) n_t - 4 (-1 - n_t) n_t \} + 2 (-1 + n_t) n_t + (4 + 6 n_t) n_t \} -
\]
\[ a_d \{ (1 - n_t) s_f^2 + s_d + s_f \} (2 (-1 + n_t) n_t + (4 + 6 n_t) n_t \} + s_d \{ (1 - n_t) s_f^2 + s_d + s_f \} (2 (-1 + n_t) n_t + (4 + 6 n_t) n_t \} +
\]
\[ 3 a_d^2 \{ (1 - n_t) n_t + 2 s_d \} + 3 a_d^2 (4 (-1 + n_t) n_t) + 3 a_d \} + 3 a_d \} + a_d \} + s_d \} + (8 + a (-1 - n_t) n_t \} s_d \} + (8 + a (-1 - n_t) n_t \} s_d \} +
\]
\[ a_d^2 \{ (15 (-1) n_t) n_t + 3 a_d^2 \} + s_d \} \} + a_d \} + a_d \} + a_d \} + a_d \} + a_d \} + a_d \} + a_d \} + a_d \} + a_d \} + a_d \} +
\]
\[ 2 s_d, (s_f - 4 s_d)^2 (s_f, (4 s_f - 4 (-1 + n_t) n_t - (-4 + 6 n_t) n_t + (2 n_t (4 (-1 + n_t) n_t) + (-7 + a (-5 + 14 a) n_t e_d) e_d)) /
\]
\[
\}
\]
Consumer surplus under subsidy in the presence of piracy

\[ (1-\epsilon)\frac{\partial C}{\partial \epsilon} \sim \frac{1}{\epsilon} \frac{1}{\epsilon^3} \]

Consumer surplus under subsidy in the presence of piracy

\[ \epsilon (1-\epsilon) \frac{\partial C}{\partial \epsilon} \]

Proof of Proposition 3-1

Under the baseline case, when there is neither Internet leakage nor piracy, the domestic firm is better off under a subsidy while \( s_d < 0.852 s_f \), and under a tariff when \( s_d > 0.852 s_f \). Furthermore, the domestic firm profits under a quota are dominated by domestic firm profits under a quota while \( s_d \leq 0.933 s_f \) and is always dominated by the domestic firm profits produced under atariff.
\[ \pi_d \left( q^* \right) = \frac{s_d}{4} \]
\[ \pi_d \left( \tau^* \right) = \frac{4s_d s_f \left( s_f - s_d \right) \left( 2s_f - s_d \right)^2}{\left( 12s_f^2 - 9s_d s_f + 2s_d^2 \right)} \]
\[ \pi_d \left( \sigma^* \right) = \frac{s_d s_f \left( s_f - s_d \right) \left( 3s_f - s_d \right)^2}{\left( 12s_f^2 - 9s_d s_f + 2s_d^2 \right)} \]
\[ \pi_d \left( q^* \right) - \pi_d \left( \tau^* \right) = \frac{s_d}{4} - \frac{4s_d s_f \left( s_f - s_d \right) \left( 2s_f - s_d \right)^2}{\left( 12s_f^2 - 9s_d s_f + 2s_d^2 \right)} \]
\[ \Rightarrow s_d \left( 12s_f^2 - 9s_d s_f + 2s_d^2 \right) - 16s_d s_f \left( s_f - s_d \right) \left( 2s_f - s_d \right)^2 \]
\[ \Rightarrow \left( 12s_d s_f^2 - 9s_d^2 s_f + 2s_d^3 \right) - \left( 4s_d^2 s_f - 20s_d s_f^3 + 32s_d^2 s_f^3 - 16s_d^3 s_f^4 \right) \]
\[ \Rightarrow 4s_d^5 - 20s_d^4 s_f + 49s_d^3 s_f^2 - 88s_d^2 s_f^3 + 80s_d s_f^4 \]
\[ \Rightarrow s_d \left( 4s_d^4 - 20s_d^3 s_f + 49s_d^2 s_f^2 - 88s_d s_f^3 + 80s_f^4 \right) \]
\[ \Rightarrow 4s_d^4 + 21s_d^3 s_f^2 - 8s_d^2 s_f \left( s_f - s_d \right) + 80s_d^3 \left( s_f - s_d \right) + 20s_d s_f^2 \left( s_f - s_d \right) \]
\[ \Rightarrow 4s_d^4 + 21s_d^3 s_f^2 + \left( s_f - s_d \right) \left( 8s_f^3 - 8s_d^2 s_f + 72s_f^3 + 20s_f^2 \right) \]
\[ \Rightarrow 4s_d^4 + 21s_d^3 s_f^2 + \left( s_f - s_d \right) \left( 8s_f^3 \left( s_f - s_d \right) + 72s_f^3 + 20s_f^2 \right) \]

Since I know that \( s_f > s_d \), the numerator will always be positive.

\[ \pi_d \left( \tau^* \right) - \pi_d \left( \sigma^* \right) = \frac{s_d s_f \left( s_f - s_d \right) \left( 3s_f - s_d \right)^2}{\left( 12s_f^2 - 9s_d s_f + 2s_d^2 \right)} - \frac{4s_d s_f \left( s_f - s_d \right) \left( 2s_f - s_d \right)^2}{\left( 12s_f^2 - 9s_d s_f + 2s_d^2 \right)} \]

Since I know that \( s_f > s_d \), the denominator \( 4 \left( 9s_f \left( s_f - s_d \right) + 3s_f^2 + 2s_d^2 \right) \), will always be positive.

\[ \Rightarrow s_d s_f \left( s_f - s_d \right) \left( 3s_f - s_d \right)^2 - 4s_d s_f \left( s_f - s_d \right) \left( 2s_f - s_d \right)^2 \]
\[ \Rightarrow -3s_d s_f^2 + 13s_f^3 s_f^2 - 17s_d^2 s_f^3 + 7s_d s_f^4 \]
\[ \Rightarrow s_d s_f \left( -3s_d^3 + 13s_d^2 s_f - 17s_d s_f^3 + 7s_f^3 \right) \]
\[ \Rightarrow s_d s_f \left( 7s_f - 3s_d \right) \left( s_f - s_d \right)^2 \]

Since I know that \( s_f > s_d \), the numerator will always be positive.
Proof of Proposition 3.4
When there is leakage of foreign entertainment products though the Internet, a subsidy generates the most domestic firm profits than a quota, and a quota generates more than a tariff, that is, \( \pi^*_d(\sigma^*_i) > \pi^*_d(\bar{q}^*_i) > \pi^*_d(\tau^*_i) \).

Proof \( \pi^*_d(\sigma^*_i) > \pi^*_d(\bar{q}^*_i) \)

\[
\pi^*_d(\sigma^*_i) = \frac{s_d\left(s_i - s_d\right)(3s_i - s_d)^2}{s_i(4s_i - s_d)^2}
\]

\[
\pi^*_d(\bar{q}^*_i) = \frac{s_d s_i\left(s_i - s_d\right)\left(2s_i\left(s_f - s_i\right) - s_d\left(s_f + s_i\right)\right)^2}{(4s_i - s_d)^2\left(s_d s_f - s_i\left(4s_f - 3s_i\right)\right)^2}
\]

\[
\frac{s_d\left(s_i - s_d\right)(3s_i - s_d)^2}{s_i(4s_i - s_d)^2} \geq \frac{s_d s_i\left(s_i - s_d\right)\left(2s_i\left(s_f - s_i\right) - s_d\left(s_f + s_i\right)\right)^2}{(4s_i - s_d)^2\left(s_d s_f - s_i\left(4s_f - 3s_i\right)\right)^2}
\]

\[
\Rightarrow \frac{s_d\left(s_i - s_d\right)(3s_i - s_d)^2}{s_i(4s_i - s_d)^2} - \frac{s_d s_i\left(s_i - s_d\right)\left(2s_i\left(s_f - s_i\right) - s_d\left(s_f + s_i\right)\right)^2}{(4s_i - s_d)^2\left(s_d s_f - s_i\left(4s_f - 3s_i\right)\right)^2} \geq 0
\]

Since \( s_i \) is positive and \( (4s_i - s_d)^2\left(s_d s_f - s_i\left(4s_f - 3s_i\right)\right)^2 \) is always positive, I know that the denominator is always positive. I now expand the numerator.

\[
\Rightarrow s_d\left(s_i - s_d\right)(3s_i - s_d)^2\left(s_d s_f - s_i\left(4s_f - 3s_i\right)\right)^2 - s_d\left(s_i - s_d\right)\left(2s_i\left(s_f - s_i\right) - s_d\left(s_f + s_i\right)\right)^2 \geq 0
\]

\[
\Rightarrow s_d\left(s_f - s_i\right)^2\left(s_f - s_i\left(5s_i - s_d\right) + s_i\left(s_f - s_i\right)\left(11s_i - 2s_d\right)\right)\left(s_f - s_d\right)^2 + s_f\left(s_f - s_i\right)\left(7s_i - s_d\right) \geq 0
\]

Since I know that \( s_f > s_i > s_d \), the numerator is always positive. Since the denominator and numerator are always positive, I know that \( \pi^*_d(\sigma^*_i) > \pi^*_d(\tau^*_i) \).

Proof \( \pi^*_d(\bar{q}^*_i) > \pi^*_d(\tau^*_i) \)

\[
\pi^*_d(\bar{q}^*_i) = \frac{s_d s_i\left(s_i - s_d\right)\left(2s_i\left(s_f - s_i\right) - s_d\left(s_f + s_i\right)\right)^2}{(4s_i - s_d)^2\left(s_d s_f - s_i\left(4s_f - 3s_i\right)\right)^2}
\]

\[
\pi^*_d(\tau^*_i) = \frac{s_d s_i\left(s_i - s_d\right)}{(4s_i - s_d)^2}
\]
\[ \frac{s_d s_i (s_i - s_d)}{(4s_i - s_d)^2} \left( s_d (s_f - s_i) - s_d (s_f + s_i) \right)^2 \geq \frac{s_d s_i (s_i - s_d)}{(4s_i - s_d)^2} \]

\[ \frac{s_d s_i (s_i - s_d)}{(4s_i - s_d)^2} \left( s_d (s_f - s_i) - s_d (s_f + s_i) \right)^2 \geq \frac{s_d s_i (s_i - s_d)}{(4s_i - s_d)^2} \left( s_d s_f - s_i \left( 4s_f - 3s_i \right) \right)^2 \]

\[ \frac{s_d s_i (s_i - s_d)}{(4s_i - s_d)^2} \left( s_d (s_f - s_i) - s_d (s_f + s_i) \right)^2 \geq \frac{s_d s_i (s_i - s_d)}{(4s_i - s_d)^2} \left( s_d s_f - s_i \left( 4s_f - 3s_i \right) \right)^2 \]

Since \((4s_i - s_d)^2\) and \(s_d s_f - s_i \left( 4s_f - 3s_i \right)^2\) are always positive, I know that the denominator is always positive. I now expand the numerator.

\[ s_d s_i (s_i - s_d) \left( 2s_i (s_f - s_i) - s_d (s_f + s_i) \right)^2 - s_d s_i (s_i - s_d) \left( s_d s_f - s_i \left( 4s_f - 3s_i \right) \right)^2 \]

\[ s_d s_i (s_i - s_d) \left( 2s_i (s_f - s_i) - s_d (s_f + s_i) \right)^2 - \left( s_d s_f - s_i \left( 4s_f - 3s_i \right) \right)^2 \]

\[ s_d s_i (s_i - s_d) \left( 2s_i^2 s_i^2 + s_d^2 s_i^2 - 10s_D s_i s_f + 4s_d s_i^2 + 8s_i s_f - 5s_i^2 \right) \]

\[ s_d s_i (s_i - s_d) \left( 5s_i (s_f - s_i) + 2s_f (s_i - s_d) + s_i (s_f - s_d) \right) \]

Since I know that \(s_f > s_i > s_d\), the numerator is always positive. Since the denominator and numerator are always positive, I know that \(\pi_d^* (\sigma_i^*) > \pi_d^* (\tau_i^*)\).

**Proof of Proposition 3-5**

*When there is leakage through the Internet and piracy is present, the domestic firm profit under the socially optimal quota, subsidy, and tariff are increasing in the cost of piracy \(c_g\) and in the percentage of ethical users \(\alpha\).*

Proposition 3-14 is proved through numerically examining the derivative of the domestic firm profits with respect to alpha under the following conditions \(s_d = .25, c_g = .02, s_i = s_i,\) and \(s_f = 1\). The following graph shows the derivative of the domestic firm profits when a quota is used.
Derivative of the domestic firm profits with respect to alpha under the following conditions: \( s_d = 0.25 \), \( c_g = 0.02 \), \( s_g = s_r \), and \( s_f = 1 \).

**Proof of Proposition 3-6**

When there is no leakage, the consumer surplus produced by a quota and subsidy are dominated by consumer surplus produced by a tariff, \( \text{CS}\left(\frac{\tau}{\sigma}\right) > \text{CS}\left(\frac{q}{\sigma}\right) \) and \( \text{CS}\left(\frac{\tau}{\sigma}\right) > \text{CS}\left(\frac{q}{\sigma}\right) \) quality.

\[
\text{CS}\left(\frac{\tau}{\sigma}\right) > \text{CS}\left(\frac{q}{\sigma}\right)
\]

Since 8\( (4s_f - s_d)^2 \) and \( (3s_f - 2s_d)^2 \) are always positive, I know that the denominator is always positive. I now expand the numerator.

\[
4s_f^2 \left( 10s_d^3 - 9s_d^2s_f - 40s_ds_f^2 + 48s_f^3 \right) - (3s_f - 2s_d)^2 \left( s_d^3 - 12s_d^2s_f + 20s_ds_f^2 + 16s_f^3 \right) \geq 0
\]
\[
\left(40s_d^3s_f^3 - 36s_a^3s_f^3 - 160s_d^3s_f^3 + 192s_f^3\right) - \left(4s_f^3 - 60s_d^3s_f^3 + 233s_d^3s_f^3 - 284s_d^2s_f^3 - 12s_a^3s_f^3 + 144s_f^3\right) \geq 0
\]
\[
-4s_d^3 + 60s_d^3s_f - 193s_a^3s_f^3 + 284s_d^2s_f^3 - 148s_a^3s_f^3 + 48s_f^3 \geq 0
\]
\[
(s_f - s_d)\left(4s_d^3 - 45s_d^3s_f^3 + 148s_d^2s_f^3 - 100s_a^3s_f^3 + 48s_d^3\right) + 11s_d^3s_f^3 > 0
\]
\[
(s_f - s_d)\left(s_f (s_f - s_d)\left(45s_d^2 - 52s_d^2s_f - 48s_f^2\right) + 51s_d^2s_f^3 + 4s_d^3\right) + 11s_d^3s_f^3 > 0
\]
\[
(s_f - s_d)\left(s_f (s_f - s_d)\left(12s_f - s_d\right) + 41s_d^3\right) + 51s_d^2s_f^3 + 4s_d^3\right) + 11s_d^3s_f^3 > 0
\]
Since I know that \(s_f > s_d\), the numerator is always positive. Since the denominator and numerator are always positive, I know that \(CS' (\tau^{'}) > CS' (\sigma^{'})\).

\[
CS' (\tau^{'}) > CS' (\bar{q}^{'})
\]
\[
s_f^2\left(10s_d^3 - 9s_d^2s_f^3 - 40s_d^2s_f^3 + 48s_f^3\right) \geq \frac{2s_f^2 - 13s_d^3s_f^3 + 23s_d^2s_f^3 - 7s_a^3s_f^3 + 4s_d^4}{2 (4s_f - s_d)^2 \left(3s_f - 2s_d\right)^2}
\]
\[
\frac{s_f^2\left(10s_d^3 - 9s_d^2s_f^3 - 40s_d^2s_f^3 + 48s_f^3\right)}{2 (4s_f - s_d)^2 \left(3s_f - 2s_d\right)^2} > \frac{2s_f^2 - 13s_d^3s_f^3 + 23s_d^2s_f^3 - 7s_a^3s_f^3 + 4s_d^4}{2 (4s_f - s_d)^2 \left(3s_f - 2s_d\right)^2} > 0
\]
\[
\frac{s_f^2\left(10s_d^3 - 9s_d^2s_f^3 - 40s_d^2s_f^3 + 48s_f^3\right)}{2s_f \left(4s_f - s_d\right)^2 \left(3s_f - 2s_d\right)^2} - \frac{3s_f^2 - 2s_d^2}{2s_f \left(4s_f - s_d\right)^2 \left(3s_f - 2s_d\right)^2} \left(2s_d^4 - 13s_d^3s_f^3 + 23s_d^2s_f^3 - 7s_a^3s_f^3 + 4s_d^4\right) > 0
\]
Since \(2s_f \left(4s_f - s_d\right)^2\) and \(3s_f - 2s_d\) are always positive, I know that the denominator is always positive. I now expand the numerator.
\[
s_f^3\left(10s_d^3 - 9s_d^2s_f^3 - 40s_d^2s_f^3 + 48s_f^3\right) \geq \left(3s_f - 2s_d\right)^2 \left(2s_d^4 - 13s_d^3s_f^3 + 23s_d^2s_f^3 - 7s_a^3s_f^3 + 4s_d^4\right) > 0
\]
\[
\left(10s_d^3s_f^2 - 9s_d^2s_f^3 - 40s_d^2s_f^3 + 48s_f^3\right) - \left(8s_d^3 - 76s_d^3s_f^3 + 266s_d^2s_f^3 - 421s_a^3s_f^3 + 307s_d^3s_f^3 - 111s_a^3s_f^3 + 36s_d^6\right) > 0
\]
\[
\left(s_f - s_d\right)^2 \left(8s_d^3 + 60s_d^3s_f - 138s_d^2s_f + 95s_a^3s_f + 12s_f^4\right) > 0
\]
\[
\left(s_f - s_d\right)^2 \left((s_f - s_d)\left(8s_d^3 - 31s_a^3s_f^3 + 107s_d^2s_f^3 + 12s_f^3\right) + 21s_a^3s_f^3\right) > 0
\]
\[
\left(s_f - s_d\right)^2 \left((s_f - s_d)\left(31s_a^3s_f (s_f - s_d) + 8s_f^3 + 76s_d^2s_f^3 + 12s_f^3\right) + 21s_a^3s_f^3\right) > 0
\]
Since I know that \(s_f > s_d\), the numerator is always positive. Since the denominator and numerator are always positive, I know that \(CS' (\tau^{'}) > CS' (\bar{q}^{'})\).

**Proof of Proposition 3-7**

Proposition 3-7 is solved in a similar fashion as Proposition 3-4.

**Proof of Proposition 3-8**

Proposition 3-8 is proved in a similar fashion as Proposition 3-5.
**APPENDIX C**
SOLUTIONS FROM CHAPTER 4

**Solving for $w^*$, $q^*$, $t^*_2$, $t^*_3$, and $x^*$**  
**Model 1**

**Solving for $w^*$ in Model 1**

First simplify the equation $P_{VoD}$

$$P_{VoD} = (w-x) \left( \int_{0}^{t_{2}} m_2^B (w) e^{-d_2 t} e^{-\rho t} \, dt \right) - F$$

$$P_{VoD} = (w-x) \left( \int_{0}^{t_{2}} m_2^B (w) e^{-l(t_{3}+\rho)} \, dt \right) - F$$

$$P_{VoD} = (w-x) \left( \frac{m_2^B (w)(-1+e^{-(d_2+\rho)(t_{3}-t_{2})})}{(d_2+\rho)} \right) - F$$

$$P_{VoD} = \left( w-x \right) \left( -1+e^{(d_2+\rho)(t_{3}-t_{2})} \right) \left( wS-I_2^{bl} \right) - F$$

Solve for the derivative of $P_{VoD}$ with respect to $w$:

$$\frac{\partial P_{VoD}}{\partial w} = S (w-x) \left( -1+e^{(d_2+\rho)(t_{3}-t_{2})} \right) + \frac{(Sw-I_2^{bl})(-1+e^{-(d_2+\rho)(t_{3}-t_{2})})}{\rho+d_2}$$

$$\frac{\partial P_{VoD}}{\partial w} = \frac{(-1+e^{(d_2+\rho)(t_{3}-t_{2})})(2Sw-Sx-I_2^{bl})}{\rho+d_2}$$

Set $\frac{\partial P_{VoD}}{\partial w} = 0$ and solve for $w$.

$$\frac{\partial P_{VoD}}{\partial w} = \frac{(-1+e^{(d_2+\rho)(t_{3}-t_{2})})(2Sw-Sx-I_2^{bl})}{\rho+d_2} = 0$$

$$2Sw-Sx-I_2^{bl} = 0$$

$$w = \frac{Sx+I_2^{bl}}{2S}$$

**Solving for $q^*$ in Model 1**

First simplify the equation $P_{r}$
\begin{align*}
P_r &= r \left[ \int_0^T q(n \alpha u + \frac{\bar{r}_1}{\nu_3} e^{-\nu_3 t} du - pq \alpha T - \frac{\nu_3}{\nu_1} \left( k \alpha e^{-\frac{\nu_3 t}{\nu_1}} - nq \right) du \right] \\
\frac{\partial P_r}{\partial p} &= nrq + r \frac{k_1}{\nu_3} e^{-\nu_4 \alpha} - p - hT - \frac{\nu_3}{\nu_1} \left( k \alpha (1 - e^{-\frac{\nu_3 t}{\nu_1}}) - nq \right) \\
\text{Solve for the derivative of } P_r \text{ with respect to } q : \\
\frac{\partial P_r}{\partial p} &= nrq \frac{\partial \alpha}{\partial p} + nr \frac{\partial \alpha}{\partial p} e^{-\nu_3 \alpha} + \frac{\nu_3}{\nu_1} \left( \frac{\nu_3}{\nu_1} \right) e^{-\nu_3 \alpha} \\
\text{Set } \frac{\partial P_r}{\partial p} &= 0 \text{ and solve for } q^* \\
q^* &= \frac{k_1}{n} e^{-\nu_4 \alpha} \\
\text{Set } h = 0 \text{ and } l = 0 \\
q^* &= \frac{k_1}{n} e^{-\nu_4 \alpha} = \frac{v_1}{n} e^{-\nu_4 \alpha} e^{-\nu_3 \alpha} \\
\text{Solving for } t_2, t_3 \text{ and } x \text{ in Model 1} \\
\text{Studio's optimal release time to the retailer} \\
P(x, t_2, t_3) &= \int_0^{t_2} \Pi_1 (t) e^{-\alpha t} dt + \int_{t_2}^{t_3} \Pi_2 (x, t_2, t_3) e^{-\alpha t} dt + \int_{t_3}^{\infty} \Pi_3 (t, t_3) e^{-\alpha t} dt \\
P(x, t_2, t_3) &= \int_0^{t_2} M_T m e^{-\alpha t} dt + \int_{t_2}^{t_3} x (I_2^{11} - wS) e^{-\alpha t} dt + \int_{t_3}^{\infty} M_1 q^* (t_3, p) e^{-\alpha t} \\
P(t_2, t_3, x) &= M_T \frac{m}{(d_1 + \rho)} \left( 1 - e^{-\frac{t_2}{d_1 + \rho}} \right) \frac{x (I_2^{11} - wS) \left( 1 - e^{-\frac{t_3}{d_2 + \rho}} \right)}{(d_2 + \rho)} + M_1 \frac{v_1}{n} e^{-\nu_4 \alpha} e^{-\nu_3 \alpha} \\
P(t_2, t_3, x) &= M_T \frac{m}{(d_1 + \rho)} \left( 1 - e^{-\frac{t_2}{d_1 + \rho}} \right) + \frac{x (I_2^{11} - xS) \left( 1 - e^{-\frac{t_3}{d_2 + \rho}} \right)}{2(d_2 + \rho)} + M_1 \frac{v_1}{n} e^{-\nu_4 \alpha} e^{-\nu_3 \alpha} \\
\end{align*}
\[ P(t_2, t_3, x) = \frac{M_t m_i^C(1-e^{-x_i d_i})}{d_1} + \frac{x(\bar{F}_B - xS)(1-e^{d_2(t_2-t_3)})}{2d_2} \]
\[ + M_v \frac{1}{n} e^{-x_i^{\beta} t} e^{-x_i^{\beta} t} \]

Define \( C_1 = M_t m_i^C \) and \( C_2 = M_v \frac{1}{n} e^{-x_i^{\beta} t} \). Then

\[ P(t_2, t_3, x) = \frac{C_1(1-e^{-x_i d_i})}{d_1} + \frac{x(\bar{F}_B - xS)(1-e^{d_2(t_2-t_3)})}{2d_2} + C_2 e^{-x_i^{\beta} t} \]

**Solve for \( x \)**

\[ \frac{\partial P(t_2, t_3, x)}{\partial x} = \frac{(\bar{F}_B - 2Sx)(1-e^{d_2(t_2-t_3)})}{2d_2} = 0 \]
\[ x^* = \frac{\bar{F}_B}{2S} \]

Put \( x^* \) back into \( P(t_2, t_3, x) \) simplified to:

\[ P(t_2, t_3) = \frac{C_1(1-e^{-x_i d_i})}{d_1} + \frac{(\bar{F}_B^2)}{4S}(1-e^{d_2(t_2-t_3)}) + C_2 e^{-x_i^{\beta} t} \]

**Solve for \( t_2 \) and \( t_3 \)**

Set \( \frac{\partial P(t_2, t_3)}{\partial t_2} = 0 \)

\[ \frac{\partial P(t_2, t_3)}{\partial t_2} = C_1 e^{-x_i d_i} - \frac{(\bar{F}_B^2)}{8S} e^{d_2(t_2-t_3)} = 0 \quad (*) \]
\[ \frac{\partial P(t_2, t_3)}{\partial t_3} = 0 \]
\[ \frac{\partial P(t_2, t_3)}{\partial t_3} = \frac{(\bar{F}_B^2)}{8S} e^{d_2(t_2-t_3)} - \bar{v}_3 B C_2 e^{-x_i^{\beta} t} = 0 \quad (**) \]

Add (*) to (**) \[ C_1 e^{-x_i d_i} - \frac{(\bar{F}_B^2)}{8S} e^{d_2(t_2-t_3)} + \frac{(\bar{F}_B^2)}{8S} e^{d_2(t_2-t_3)} - \bar{v}_3 B C_2 e^{-x_i^{\beta} t} = 0 \]
\[ C_1 e^{-x_i d_i} = \bar{v}_3 B C_2 e^{-x_i^{\beta} t} \]
\[ e^{-x_i d_i} = \frac{\bar{v}_3 B C_2}{C_1} \]
\[
\ln e^{-t_2d_1 + v_3^B t_3} = \ln \frac{v_3^B C_2}{C_1}
\]

\[
v_3^B t_3 - t_2d_1 = \ln \frac{v_3^B C_2}{C_1}
\]

\[
t_3 = \frac{1}{v_3^B} \left( t_2d_1 + \ln \frac{v_3^B C_2}{C_1} \right)
\]

Subtracted \( t_2 \) from \( t_3 \)

\[
t_3 = \frac{1}{v_3^B} \left( t_2d_1 + \ln \frac{v_3^B C_2}{C_1} \right)
\]

\[
t_2 - t_3 = t_2 - \frac{1}{v_3^B} \left( t_2d_1 + \ln \frac{v_3^B C_2}{C_1} \right)
\]

\[
t_2 - t_3 = \frac{1}{v_3^B} \left( v_3^B t_2 - t_2d_1 - \ln \frac{v_3^B C_2}{C_1} \right)
\]

Substitute \( t_2 - t_3 \) into (*)

\[
C_i e^{-t_2d_i} = \frac{\left( I_2^{B_1} \right)^2}{8S} e^{\frac{d_1}{v_3^B} \left[ v_3^B t_2 - t_2d_1 - \ln \frac{v_3^B C_2}{C_1} \right]} = 0
\]

\[
C_i e^{-t_3d_i} = \frac{\left( I_2^{B_1} \right)^2}{8S} e^{\frac{d_1}{v_3^B} \left[ v_3^B t_2 - t_2d_1 - \ln \frac{v_3^B C_2}{C_1} \right]}
\]

\[
\frac{e^{-t_2d_i}}{e^{\frac{d_1}{v_3^B} \left[ v_3^B t_2 - t_2d_1 - \ln \frac{v_3^B C_2}{C_1} \right]}} = \frac{\left( I_2^{B_1} \right)^2}{8S} \frac{C_1}{C_i}
\]

\[
\frac{e^{-t_3d_i}}{e^{\frac{d_1}{v_3^B} \left[ v_3^B t_2 - t_2d_1 - \ln \frac{v_3^B C_2}{C_1} \right]}} = \frac{\left( I_2^{B_1} \right)^2}{C_1 8S}
\]

\[
-t_2d_1 - d_2 \left( \frac{1}{v_3^B} \left( v_3^B t_2 - t_2d_1 - \ln \frac{v_3^B C_2}{C_1} \right) \right) = \ln \left( \frac{\left( I_2^{B_1} \right)^2}{C_1 8S} \right)
\]

\[
-t_2d_1 - \left( d_2 t_2 - \frac{1}{v_3^B} t_2d_2d_2 - \frac{d_2}{v_3^B} \ln \frac{v_3^B C_2}{C_1} \right) = \ln \left( \frac{\left( I_2^{B_1} \right)^2}{C_1 8S} \right)
\]

\[
\frac{1}{v_3^B} t_2d_2d_2 - t_2d_1 - d_2t_2 + = \ln \left( \frac{\left( I_2^{B_1} \right)^2}{C_1 8S} \right) - \frac{d_2}{v_3^B} \ln \frac{v_3^B C_2}{C_1}
\]

\[
t_2 \left( \frac{1}{v_3^B} d_2d_2 - d_1 - d_2 \right) = \ln \left( \frac{\left( I_2^{B_1} \right)^2}{C_1 8S} \right) - \frac{d_2}{v_3^B} \ln \frac{v_3^B C_2}{C_1}
\]
\[ t_2^* = \frac{\ln \left( \frac{I_2^{B_1}}{I_2^{B_1}} \right)^2 - \frac{d_2}{v_3^B} \ln \frac{v_3^B C_2}{C_1}}{C_1 8S - \frac{d_2}{v_3^B} - d_2 - d_1} \]

Substitute \( t_2^* \) into \( t_3^* \)

\[ t_3^* = \frac{1}{v_3^B} \left( \ln \left( \frac{I_2^{B_1}}{I_2^{B_1}} \right)^2 - \frac{d_2}{v_3^B} \ln \frac{v_3^B C_2}{C_1} - d_1 + \ln \frac{v_3^B C_2}{C_1} \right) \]

Substitute \( x^* = \frac{I_2^{B_1}}{2S} \) into \( w = \frac{Sx + I_2^{B_1}}{2S} \)

\[ w = \frac{S \left( \frac{I_2^{B_1}}{2S} + I_2^{B_1} \right)}{2S} \]

\[ w = \frac{I_2^{B_1} \left( \frac{1}{2} + 1 \right)}{2S} \]

\[ w^* = \frac{I_2^{B_1} 3}{4S} \]

**Solving for Model 2**

Both \( w^* \) and \( q^* \) are solved in a similar fashion as Model 1. However, I am unable to solve for a closed form solution of \( t_2, t_3, \) and \( x \). We solve for \( t_2, t_3, \) and \( x \) using a program to solve for each numerically.
LIST OF REFERENCES


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BIOGRAPHICAL SKETCH

Sean R. Marston was born in Fort Worth, Texas. His family moved around many times but settled in Chamblee, Georgia in the early 1990’s. Sean graduated from St. Pius the X Catholic High School in 1994 and earned his Bachelor of Engineering degree in computer engineering in 1999 from the Georgia Institute of Technology. He spent four years working for companies in the area of IT and network technology. Looking to expand his career opportunities, Sean returned to the Georgia Institute of Technology for a Masters of Business Administration degree in operations management, graduating in 2005. Then he attended the University of Florida to earn his doctorate in Business Administration. He received his Ph.D. in business administration from the University of Florida in August 2010.