ESSAYS ON COLLECTIVE REPUTATION AND AUTHENTICITY IN AGRI-FOOD MARKETS

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ABSTRACT

Authenticity in agriculture, food and resource markets has been an ongoing policy challenge to regulators and food industries, and a major concern to consumers given the complex nature of global food supply chains and the increasing spate of market fraud reports across the world. In a bid to boost their economic return, some firms may engage in illicit activities that comprise authenticity including: adulteration, substitution of substandard products, unapproved enhancements of food products, false and misleading quality claims. Such actions, often times, create negative reputation externalities for other agri-food firms in the sector, and may also result in trade conflicts and border rejections; while consumers incur transaction (search) costs in verifying product attributes due to quality uncertainty. This dissertation focuses on collective reputation and contributes to an understanding of authenticity issues in agri-food and resource markets. The analysis examines the role of industry-led quality assurance systems and evolving technologies in enhancing authenticity signals and reducing information asymmetry in the context of market fraud and collective reputation within food and resource supply chains.

This dissertation consists of three papers. Paper 1 examines technological solutions to authenticity issues in the context of international trade. The paper explores the role of an emerging authenticity technology, International Barcode of Life (IBOL) in strengthening the enforcement of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES). The focus of the analysis is CITES restrictions on commercial trade in the endangered species tree of Brazilian rosewood (*Dalbergia nigra*). The first paper provides an overview of the applications of the IBOL technology in species identification to date. A graphical partial equilibrium trade model examines three scenarios consisting of adoption of IBOL authenticity technology by a single major importing country, multilateral adoption, and adoption by the exporting country. The scenarios suggest that a threat of multilateral testing for the authenticity of imported rosewood could eliminate cross border commercial trade in the endangered species. Upstream testing and certification of authenticity in the exporting country could increase importers' confidence and the demand for legally harvested rosewood. The results suggest that technological solutions to authenticity issues in international markets have the potential to reduce quality uncertainty and could act as a complement to regulatory enforcement under CITES.

Paper 2 explores the industry-led Vintners Quality Alliance (VQA) quality assurance system for Canadian wines to examine how an industry seeks to signal authenticity assurances to protect its

collective reputation. Hedonic and Probit models are estimated using data on wine attributes sourced from the Liquor Control Board of Ontario (LCBO). Hedonic models examine whether VQA certification, versus other collective and individual reputation signals (region, winery), elicits a price premium. The Probit analysis examines factors that determine a winery's decision to seek VQA certification for a specific wine. The results suggest that while a number of attributes including VQA certification, percentage alcohol content, sweetness (sugar level), volume of wine supplied and vintage, have a significant influence on the price of wine, VQA adds a premium beyond other signals of reputation (winery and region). The magnitude of the effect of individual and collective reputation on the price of wine differs for the different types/colours of wine. The Probit model results suggest that wineries that supply large volumes of wine (more than 1000 cases) in Ontario and produce icewine and non-blended wines have a higher tendency of seeking VQA status. The results imply that VQA could be used as a shorthand for quality, while premium and reputation driven by authenticity in the wine industry could serve as an incentive for other agri-food industries to establish similar quality assurance systems.

Paper 3 examines the incidence of mislabelling and substitution in fish markets using supply, demand and welfare analysis. The paper focuses on incentives for the private sector (retailers) or a third party to adopt IBOL technology to protect their reputation and for supply chain monitoring. The feasibility of IBOL technology for a typical retail store in Canada is assessed using a simple simulation analysis. The analysis suggests that the costs of switching to the IBOL system, the number of retailers already using the technology and their market shares are likely to influence a retailer's adoption of the technology. The ease of catching cheaters along the fish supply chain through third party monitoring is expected to depend on the accuracy of the technology in detecting fraud, the sampling frequency (rate) and rate of species substitution; while enforcement of legal penalties and other costs would serve as a disincentive to cheat as these costs negatively affect expected profit. The simulation analysis suggests that presently IBOL technology appears to be feasible for a typical retail store in Canada if testing is done in an external facility, but may not be feasible if fixed and other costs associated with the IBOL system are considered. The paper suggests that reducing the size of the technology to a hand-held tool and coordination of small scale retailers are potential ways to make the technology affordable and expand its use.

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CHAPTER 1

INTRODUCTION

Authenticity in some agri-food and natural resource supply chains has become a major concern globally in recent years. The increasing publicized cases of food fraud in agricultural markets and cross border trade of unidentified or endangered species of plants and animals can reduce consumers' confidence in the food system, as well as the perceived capability of the regulators to assure the quality and safety of food products (Gallup, 2008). An authenticity (quality) scare caused by a firm can have aftermath effects on a large scale (Marucheck, 1987) and create negative spillover (reputation) effects that harm other firms in the sector. These have spurred government and industry-led investments in quality assurance, traceability and authenticity-enhancing technologies. It has also prompted consumers to become interested in the authenticity and origin of their food, as well as how it was produced.

The dissertation primarily focuses on the issues of collective reputation and authenticity in agri-food and resource markets, which have not been widely explored in the literature. Previous studies have tended to focus on traceability and other methods of signalling quality, such as third party certification and labelling. Reputation, which is the belief consumers have about a firm or an industry, is expected to play a major role in shaping consumers' perceptions of quality and therefore their purchase decisions (Anderson, 2002; Castriota and Delmastro, 2014) and can make or mar a firm or an industry, particularly those producing products with credence attributes. Reputation could reflect the authenticity (quality) and uniqueness of a firm's product, and can be individual or collective. Individual reputation refers to the reputation of a single firm, while collective reputation relates to that of an industry. Fraud in the context of agri-food markets is "the deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging; or false or misleading statements made about a product, for economic gain" (Spink and Moyer, 2011, p.158).

Authenticity in the context of this dissertation relates to the process of testing and validation of claims made by a producer on the product's label and at the same time identifying other components of the product that are absent or present but not declared by the producer. A producer has more information (e.g. quality, composition, origin) about his product than consumers, and may have an incentive to engage in fraudulent activities for economic gain. For example, a product described as "100% apple juice" may contain some percentage of pear. Verifying the truthfulness of the claims made on a product's label and other hidden information about the product helps to ascertain the genuineness of the product as well as uncover deceptive practices that are capable of misleading consumers and prevent them from making informed purchase decisions.

Globalization and trade liberalization have led to an increased volume of trade in agricultural products and complex agri-food supply chains. Food supply chains are becoming longer and interconnected (Roth *et al.* 2008; Whipple *et al.* 2009), hence these products pass though long distances and many intermediaries before reaching the end users. Potentially this creates opportunities for intentional illegitimate market activities for economic gain.

In the process of competing for economic gains in the market, firms along the food supply chain may engage in illegitimate market activities including: adulteration (e.g. addition of undeclared substances in order to increase the volume of a product), dilution (reducing the amount of valuable component of a product), substitution of substandard products, mislabelling and misrepresentation, false or misleading claims and unapproved enhancement of products. Prime examples have included: substitution and mislabelling of rosewood timber made from other species of Brazilian rosewood as timber from *Dalbergia nigra* which commands a premium, addition of melamine to infant milk formula (Roth *et al.* 2008) and pet food (Brown *et al.* 2007) to increase protein levels; substitution of cane and maize syrup for sucrose and natural sugars in honey production (Bogdanov and Martin, 2002) and the fake Canadian icewine produced and sold in Asian markets (AAFC, 2011). Such actions result in the classic 'market for lemons' (Akerlof, 1970) and create negative reputation externalities for other agri-food firms, transaction (search) costs for consumers, international trade conflicts and border rejections. These call for a more advanced timely and accurate method of detecting these fraudulent activities.

Recently, uncovering fraud and delivering authenticity assurances in agri-food and natural resource markets have been facilitated through alternative approaches. One of the approaches is technological innovations such as the recently emerged DNA barcoding (International Barcode of Life (IBOL) technology), which has been used to identify mislabelling and substitution of plants and animal species through DNA sequencing. A prime example is the recent horse and goat meat scandals in Europe and South Africa that were identified using DNA Barcoding technology. In addition, contractual agreements, supply chain monitoring and industry-led traceability and certification systems (e.g. Vintners Quality Alliance for Canadian wines) have also been used to enhance the delivery of quality and authenticity assurances. Emerging quality verification and monitoring technologies have helped in overcoming the limitations of the existing methods of signalling quality given the many avenues for fraud. For example, a traceability system can be used to trace the movement of a food product from the farm to the table, particularly when there is a food safety problem, but may not be sufficient to guarantee the authenticity of the product. Further, it has been argued that the effectiveness of third party certification has been undermined by the proliferation of third party certification agents (Anders *et al.* 2007). Consumers often find it difficult to determine the credibility of these agents (Auld and Gulbrandsen, 2010), and therefore, become confused regarding which agent to trust (Auriol and Schilizzi, 2003).

Food authenticity is a growing area of interest that has not been widely explored in the literature. Previous economic studies focus on the applicability, acceptance and economics of traceability systems (e.g. Hobbs, 2003, 2004; Golan *et al* 2004; Boecker *et al* 2013; Asioli *et al* 2014). A traceability system is primarily a tool to trace the origin of a food product should there be any problem along the supply chain, and does not necessarily guarantee authenticity (quality) and safety. A food product may be traceable based on the origin label but may not be genuine (authentic). Hobbs (2003) argues that although traceability systems enhance quality signalling to consumers and could serve as a motivation for safety practices by producers, some existing traceability systems do not efficiently provide *ex-ante* desired quality signals. Since much of the previous literature focuses on traceability, this creates a gap in the literature with regards to the concept of authenticity as a separate (albeit related) concept.

A product is authentic if there is no form of fraud. This study differs from previous studies by examining the issue of authenticity and its potential impacts on industry-wide collective reputation. There are relatively few economic studies of authenticity. This study draws insights from economic studies of authenticity and collective reputation, including: Fishman and Rob (2002), Caswell and Mojduszka (1996), Fombrum (1996), Costanigro and McCluskey (2007), Sundus (2008), Wong and Hanner (2008), Menapace and Moshini (2010), Castriota and Delmastro (2012, 2014), among others. Some of these studies emphasize the importance of reputation in agri-food markets. For example, Caswell and Mojduszka (1996) argue that reputation is very important for markets with credence attributes to operate successfully. Therefore, there is need to complement existing quality signalling methods with authenticity regimes to maintain and enhance genuineness along the food supply chain as well as protect the integrity and reputation of food industries.

Taking cognizance of these issues, this study examines the importance of quality verification and signalling in establishing authenticity assurances as a collective reputation building mechanism in agri-food and natural resource markets. The study explores the incentives to adopt authenticity technologies by private sector firms or third parties, and the implications of authenticity signals for industry-wide collective reputation.

The dissertation is comprised of three papers and therefore, organized in five chapters. Although each of these papers forms a stand-alone study, they are inter-linked and explore the adoption of authenticity technologies and verifications in international markets and in the Canadian agri-food sector. Chapter two presents the first paper that examines technological solutions to authenticity issues in an international trade context, and the role of an emerging authenticity technology, the International Barcode of Life (IBOL) in facilitating the enforcement of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES) trade restrictions. The focus of the analysis is an endangered tree species of Brazilian rosewood (*Dalbergia nigra*). The paper develops a partial equilibrium trade model to present a graphical analysis of three scenarios mapping potential outcomes of adoption of the IBOL authenticity technology by exporting or importing countries. Key research questions include: what potential role do testing and monitoring technologies (e.g. IBOL) have in providing a solution to authenticity issues in international trade? Can IBOL technology facilitate the enforcement of CITES trade restrictions for an endangered tree species of Brazilian rosewood? Verifying quality claims using authenticity and monitoring technologies could potentially reduce quality uncertainty and enhance industry-wide collective reputation.

Results of the analyses suggest that enforcement of CITES trade restrictions on the endangered tree species of Brazilian rosewood may be more effective through a multilateral implementation of regulations requiring authenticity testing by importing countries. Further, upstream adoption and implementation of testing and certification of authenticity in the exporting country may help differentiate timber made from different species of rosewood. Product differentiation in the exporting market potentially may reduce the equilibrium quantity and price of illegally harvested rosewood timber (*Dalbergia nigra*), and therefore would reduce the incentive for illegal harvesting.

The second paper, presented in Chapter three, is an empirical paper focusing on VQA quality assurance system for Canadian wines. In this paper, a hedonic regression model and Probit analysis respectively are used to examine the following research questions: does Vintners Quality Alliance (VQA) certification (versus collective and individual reputation signals) elicit a price premium and enhance the collective reputation of Canadian wines? What factors determine a winery's decision to seek VQA certification for a specific wine?

A hedonic pricing model was first estimated to identify the attributes that significantly influence the price of wine. The results indicate that, controlling for other reputation signals, there exists a premium for VQA certified wines suggesting that the VQA system appears to be valued by consumers. This result has implications for collective reputation and for the uptake of similar quality assurance programs by other agri-food industries. Despite the premium, not all wines have VQA certification. To identify the factors that shape a winery's decision to seek VQA certification for a specific wine, a Probit regression analysis is conducted. The results indicate that large wineries (wineries that supply more than one thousand cases of wine to retail outlets) in Ontario that produce icewine and non-blended wines have a higher tendency of seeking VQA status.

Chapter four (the third paper) examines potential incentives to adopt the IBOL technology for seafood (fish) species authentication in Canada by the private sector. Results of previous studies show that mislabelling and substitution in fish supply chains is high relative to other food products, and the IBOL technology, though not yet commercialized, has been used by the technology developers in market surveys to detect this opportunistic behaviour in the market. The paper addresses the following research questions: what are the potential incentives for private sector firms (e.g. retailers) or third parties to adopt IBOL technology for fish authentication in Canada? Is IBOL technology feasible for a typical retail store? The technology could be a more effective alternative in the authentication of fish species and could potentially help in protecting the collective reputation and integrity of the fish industry. Given the increase in publicized cases of fraud in fish markets and increase in Canadian imports of seafood and domestic consumption, there is the potential for mislabelling and substitution for economic gain.

A theoretical model is developed to illustrate incidence analysis (species substitution) in fish markets. The incentive by fish retailers to adopt IBOL technology to protect their reputations and third party (e.g. consumer/environmental group) for supply chain monitoring is modelled using a vertical market structure model under autarky situation. Whether the technology would be feasible for a typical retail store is evaluated and the potential for the technology to be commercialized discussed. Chapter five offers concluding comments.

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CHAPTER 2

Technological Solutions to Authenticity Issues in International Trade

2.1 Introduction

The paper examines technological solutions to authenticity issues in an international trade context and, using a partial equilibrium trade model, examines the role of an emerging authenticity technology, the International Barcode of Life (IBOL) in facilitating enforcement of trade restrictions for endangered species listed by the Convention on the International Trade in Endangered Species of wild fauna and flora (CITES).

Consumers, food industries and regulators have been faced with challenges including quality uncertainty, product misrepresentation in agri-food and resource markets, and escalation of high profile food related disease outbreaks. These have resulted in increased consumer awareness and demand for transparency, authenticity, credible information and quality reassurance. Consumers are now increasingly interested in where their food and other products come from and how they were produced. This is particularly the case for products with credence attributes.[1] Consumers' inability to identify these attributes serves as an economic incentive for producers/sellers and intermediaries to engage in fraudulent activities.

Fraud in agriculture, food and resource markets occurs in different forms including substitution and mislabelling. Examples include substitution and/or mislabelling of low-valued seafood (fish) species for high-valued species in food markets for economic gain. In resource (e.g. forest products) markets, price and availability of substitutes have been identified as major drivers of purchase decisions (FAO, n.d). For example, it has been argued that in timber markets, the price of a particular product (species) with unique attributes relative to others is a major factor that drives demand, and this has encouraged product substitution (FAO, n.d). A prime example is the case of Brazilian rosewood (*Dalbergia nigra*), an endangered species of tree that has been depleted

[1] Credence goods are products whose relevant attributes are difficult to ascertain prior to purchase and even after purchase without additional labelling or quality information (e.g. organic, origin) (Hobbs, 2001).

because of the premium for wooden products made using timber from the species as a result of some unique attributes including its waxy appearance, high resonance and resistance to insect attack (Taylor *et al.* 2012). Other closely related species of rosewood have been mislabelled and sold as *D.nigra* (Gasson *et al.* 2010).

It appears that these fraudulent activities have been going on in these markets with little or no success in identifying the sources, which gives the perpetrators a competitive advantage, and therefore, raises the question of whether the inability to prevent these activities in the domestic and international markets signals a regulatory oversight or inefficiency in existing testing and monitoring systems. This has resulted in some species of plants, animals and other resources (particularly those traded across national borders) going extinct, and therefore calls for routine and real-time monitoring. In the absence of labelling or other methods of signalling quality, this creates an information asymmetry problem, which often results in sellers' opportunistic behavior, and consequently market failure. Consumers in their efforts to identify product attributes *ex ante* before purchase incur transaction (search) costs. Credible verification of the authenticity and quality claims lowers these search costs.

Several mechanisms and/or actions have been taken by governments and firms to signal quality and ameliorate information asymmetry problems in markets. Prime examples of governments' actions include mandatory traceability and third party certification/labelling. On the other hand, firms signal quality through provision of warranties, product attribute information disclosure on labels and third party certification. Although some traceability systems provide consumers with information on where their products come from, help identify the source of food safety problems (in the case of food products) along the supply chain and facilitate the removal of affected products to reduce possible externality or spill-overs to other producers, traceability alone cannot provide information on quality (authenticity) claims, which requires verification using appropriate technologies and/or supply chain monitoring and auditing.

Migone and Howlett (2012) argue that certification enhances the achievement of the minimum standards set for a product, boosts consumer trust, and strengthens sustainable methods of production and quality control. It has been argued that proliferation and competition among certification agents has undermined its effectiveness (Anders *et al.* 2007), and it is often difficult to determine the credibility of the existing certification entities (Auld and Gulbrandsen, 2010). Consumers are therefore confused as to which agent to trust (Auriol and Schilizzi, 2003). Lizzeri (1999) also argues that certification, in some cases, is not credible to consumers as producers "*strategically manipulate information on labels*" (p.1). On the other hand, monopoly intermediaries sometimes do not fully disclose vital information about product attributes (credence) on the label.

Several technologies used in verifying quality claims and authenticity have recently emerged. Some of these technologies are linked to genomics and proteomics, involving the use of molecular markers in identifying species and products. They also have the potential of rapid confirmation of the authenticity and origin of products thereby reducing quality uncertainty and overcoming the limitations of market-based solutions to information asymmetry. Of the emerging technologies, this paper focuses on the International Barcode of Life (IBOL) technology specifically developed to identify plant and animal species through DNA sequencing. A potential application of the IBOL technology is in reduction of commercial trade in endangered species, which is the main objective of the Convention on the International Trade in Endangered Species of wild fauna and flora (CITES).

It has been argued that government policies on conservation of some plant and animal species, especially the ones threatened with extinction, are driven by the fact that the species may have commercial (e.g. food, tourism) and existence value (Metrick and Weitzman, 1996). Hence, some national governments have spent significant amounts of money in eradicating invasive species and recovering of some endangered species. For example, the United States federal and state agencies, within three years (1989 – 1991) spent the sum of $171.1m in recovering a total of ten animal species. These include: "Bald eagle ($31.3m), Northern spotted owl ($26.4m), Florida scrub jay ($19.9m), West Indian manatee (17.3m), Red-cockaded woodpecker ($15.1m), Florida panther ($13.6m), Grizzly bear ($12.6m), Least Bell's vireo (15.5m) American peregrine falcon ($11.6m) and Whooping crane (10.8m)" (Metrick and Weitzman, 1996, p.2). In the case of plants, the annual costs incurred by the U.S. government in recovering endangered plant species have always been higher than the actual amount allocated for conservation of the species by the Congress (Negrón-Ortiz, 2014).

Given the large size and growing demand for some plants and animal species (wildlife) in the international market, it has been argued that international trade is a major cause of overexploitation of species facing extinction (Alagappan, 1990; Broad *et al.* 2003). This, therefore, calls for adequate market and supply chain monitoring to curtail trade in these species with endangered status. Taking cognizance of these issues, the key research questions examined in this paper are: *what potential role do testing and monitoring technologies (e.g. IBOL) have in providing a solution to authenticity issues in international trade? Can IBOL technology facilitate the enforcement of CITES trade restrictions for an endangered tree specie of Brazilian rosewood?* Proper identification of the at-risk species in the markets would discourage illegal harvesting and enhance their sustainability.

The paper is structured as follows. Following the introduction, section 2 describes the IBOL technology and profiles a wide range of its application in species identification and verification of quality claims (authentication). Section 3 looks at the CITES regulatory frameworks, while section 4 models (using three scenarios) the potential role of technologies (IBOL) in authenticity and quality verification in the context of international trade using the case of an endangered tree species of Brazilian rosewood (*Dalbergia nigra*). Section 5 concludes.

2.2 International Barcode of Life (IBOL) Technology and the DNA Barcoding Process

IBOL technology is an emerging molecular-based authenticity technology that uses genetic markers to identify plants and animal species through DNA sequencing (Hebert *et al.* 2003). DNA barcode refers to "*a short gene sequence used to identify species taken from a standard position in the genome*" (Yancy, 2007, slide no.4).

The IBOL project started in Canada in 2003 with a group of scientists at the Biodiversity Institute of Ontario located at the University of Guelph. The project is aimed at application of "DNA barcoding to real world problems, such as forensics, conservation, market place regulation, control of diseases and ecosystem monitoring".[2] The scientists collect specimens from different species, generate and store barcode records from the specimens, and develop a comprehensive database and repository (reference library) for storage of the DNA barcode records and taxonomic information of different species. The consortium provides the public and private sectors open access to the reference library for easy cross-matching and identification of species as well as enhancing the discovery of new species. The process is designed to help in reduction of cross-border trade in harmful, invasive and endangered species, and other food (raw and processed) products.[3] The DNA barcoding process is explained further in the appendix to this paper.

The choice of IBOL over existing authenticity technologies for this study was informed by the following: first, it is a new authenticity technology involving the use of DNA molecules. Although not yet commercialized and used in a major way in food supply chains in Canada, the developers (Biodiversity Institute of Ontario) have conducted several market surveys and used the technology in species identification and food product authentication relative to other techniques. Most biological tissues contain DNA molecules, which have high stability relative to proteins, and therefore are a good alternative to existing protein-based analysis (Gachet *et al.* 1999; Lockey and Bardsley, 2000). DNA can be extracted from plant and animal products even in processed form, and is less sensitive to degradation (Nielsen and Hansen, 2008) unlike proteins that degrade at high temperatures.

Second, IBOL technology has been used in the identification of plant species. For example, the technology has been used to identify endangered tree species such as the incense tree (*Aquilaria sinensis*)[4] commonly found in South China (Jiao *et al.* 2013) and listed on the International Union for Conservation of Nature (IUCN) red list of threatened species.[5] In addition, the technology has been used in tracing illegal timber logging (Degen and Fladung, 2007; Lowe and Cross, 2011). Further, existing authenticating technologies (e.g. physical identification using external morphological features, Polymerase Chain Reaction (PCR), electrophoresis, chromatography,

[2] http://ibol.org/about-us/what-is-ibol/
[3]ibid
[4] Extract (resin) from the tree is used in the production of natural herbs and incense, while the back of the tree is used in paper production (http://www.greening.gov.hk/en/planting_knowledge/aquilaria_sinensis.html).

[5] www.iucnredlist.org

among others) have some inherent limitations that make authentication and identification difficult, and sometimes unreliable. For example, morphological features may be absent for processed products (e.g. wood) and, therefore, may not be effective in identification. The process will not only take some time, but may record little or no success. PCR is specie specific in identification and authentication (Wong and Hanner, 2008). Hence additional costs will be incurred in acquiring and adopting other techniques to cover a wide range variety of species found in the market today.

One major feature that distinguishes IBOL technology from other DNA-based authenticity technologies, such as PCR, is that IBOL can be used to detect the presence of several animal and plant species in a product and, therefore, goes a step further in identifying the particular specie of the animal or plant used and, possibly, the origin. For example, the widely publicized scandals involving the substitution of horse meat for beef in a number of processed food products (e.g. hamburgers) across Europe in 2013;[6] substitution of pork meat for beef in Halal meat pies and pasties supplied to UK prisons;[7] and substitution of donkey, water buffalo and goat meat for beef in sausages, burger patties and dry meats in South Africa[8] were all detected using DNA based technique (PCR).[9] Considering the case of substituting horse, goat and buffalo for beef in processed meat products that attracted media attention in 2013, IBOL technology would offer an advantage over the PCR technique by generating barcodes and using it to identify the species of horse, goat and water buffalo.

Fundamentally, the technology is designed to identify all biological species – fish, meat, insects, plants, among others. At the present time it has not been commercialized (adopted and used to verify quality claims by the private sector) but to an extent has been used on several products including timber (wood products) by the developers to test the accuracy of the technology in tree species identification. The reference library is maintained and managed by the IBOL consortium,

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[6]http://www.bbc.co.uk/news/world-europe-21406778
[7]http://www.standard.co.uk/news/uk/pork-dna-found-in-halal-prison-food-8478152.html

[8]http://www.bbc.co.uk/news/world-africa-21588575

[9] PCR is specie specific. For example, it can only detect the presence of a plant specie in a product (e.g. natural health or herbal products) but cannot be used to identify the specie of the plant in the product.

a research institute owned by the University of Guelph. Free access to the reference library is part of the agreement and a precondition for Canadian government and private sector funding. The technology is still under development on a test basis in terms of using it to identify other biological species. The next section examines the different areas in which the technology has been applied in species identification and authentication.

2.2.1 Application of IBOL technology in species identification and authentication

Essentially, IBOL technology (DNA barcoding) has potential in three major areas including authenticity, safety and sustainability, and has specifically been used in the identification of seafood, invasive alien species (including species listed on the Convention on the International Trade in Endangered Species of wild faura and flora (CITES)), natural health/herbal products, vectors of zoonotic diseases, among others.

2.2.1.1 Seafood and meat cuts

Seafood, particularly fish, is among the agricultural commodities traded in high volumes across the world (Anderson, 2003; Smith *et al.* 2010) with about one third being traded across national boundaries (FAO, 2012). According to FAO (2012), the global share of seafood products (fish) traded in international markets is consistently increasing with about 39 percent of commercial fishery production traded in 2010. This is driven by increasing consumers' awareness of the health benefits associated with fish consumption. Increased demand for fish products has led to competition between domestically produced and imported fish products in different countries (Tveteras *et al.* 2012); and has served as an incentive for some members of the fish supply chain to consciously misrepresent their products for economic gains.

Past decades have recorded an increasing trend in overexploitation and depletion of fishery stocks globally (UNEP, 2009). To address this problem, government policies have focused on market-based initiatives with emphasis on certification, which is expected to facilitate sustainable management of fisheries, value addition, as well as social and environmental benefits. Notable third party certification entities in the fishery sector include the Marine Stewardship Council

(MSC)[10], Marine Eco-label in Japan[11], UK Seafish Responsible Fisheries Scheme[12] and Friends of the Sea[13]. These certification bodies, along with international and regional-specific regulations (e.g. European Union control[14] and Illegal, Unreported and Unregulated (IUU) regulation[15]), have been used to promote sustainable fishery management practices, enhance traceability, reduce illegal, unreported and unregulated (IUU) fishing which comprises an estimated one fifth of the global catch (Agnew *et al.* 2009; Flothmann *et al.* 2010), and as a marketing strategy to signal quality. Despite the growth in the number of certification bodies, to the best of the author's knowledge studies have not shown any reduction in illegal fishing and there has been increasing publicized cases of fraud in fish markets which potentially have called into question the effectiveness of these schemes. IBOL technology has been used to identify some fish species that have been depleted (e.g. Atlantic cod, European hake) as a result of overexploitation and IUU (Nielsen *et al.* 2012), indicating its potential as a complement to certification.

Studies identify several cases of mislabelling and species substitution occurring at fish retail outlets in different countries (e.g. Jacquet and Pauly, 2008; Miller and Mariani, 2010). For example, the survey results of Jacquet and Pauly (2008) suggest that one third of all the fish products sold in the United States may be mislabelled. Results of other studies that show high levels of seafood (fish) mislabelling and species substitution in different countries include: Barbuto *et al.* (2010) and Filonzi *et al.* (2010) in Italy; Miller and Mariani (2010) in Ireland; Garcia-Vazquez *et al.* (2011) in Spain and Greece; Wong and Hanner (2008) in Canada; and Cawthorn *et al.* (2012) in South Africa. IBOL technology through DNA barcoding has been used to detect these fraudulent activities in fish markets. Prime examples include: identification of "puffer fish" mislabelled as "monk fish" in the United States in 2007 (Leschin-Hoar, 2011); farmed Atlantic salmon labelled as wild pacific salmon (Cline, 2012); and narrow-barred Spanish mackerel labelled as Japanese

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[10] http://www.msc.org/
[11] http://www.melj.jp/eng/index.cfm
[12] http://www.gtcert.com/responsible-fishing/
[13] http://www.friendofthesea.org/
[14] Council Regulation (EC) No 1224/2009 of 20 November. *Official Journal of the European Union L, L 343/1, 50* (2009).
[15] Council Regulation (EC) No 1005/2008 of 29 September. *Official Journal of the European Union L, 286/1, 32* (2008).

Mackerel *(Scomberomorus niphonius)* (Changizi *et al.* 2013).[16] The technology has also been successfully used in identifying fish species that were mislabelled in various markets such as red snapper (Warner *et al.* 2013); tuna (Terol *et al.* 2002; Warner *et al.* 2013); flat fish (Espineira *et al.* 2008); anchovy (Jerome *et al.* 2008); and sharks (Barbuto *et al.* 2010).

Interestingly, IBOL technology can be used to identify and distinguish between *farm raised* and *wild caught* fish only if they are different species. For example, the technology can distinguish farm raised Atlantic salmon from other species (e.g. Chinook, Coho, Chum, Pink, Sockeye) of wild caught salmon. It therefore, would not distinguish, for example, wild caught from acquacultured grouper if both are the same species. The inability or low accuracy of the traditional methods of fish species identification (e.g. use of morphological features), especially for fillets or processed fish products potentially diminishes sellers' incentives to play by the stipulated rules. Hence verifying the authenticity of the final product on the store shelves is very important.

2.2.1.2 Invasive alien species

Invasive alien species have been identified as one of the major causes of decline in biodiversity (Chapin *et al.* 2000; Pimentel *et al.* 2005). According to Bryan (1996) and Shine (2005), increased cross border trade has been a major pathway through which invasive alien species of plants and animals are introduced outside their natural place of habitation. Invasive species have the capability of contesting and in most cases, out-competing indigenous species, act as predators and transmit diseases (Dejean *et al.* 2012). They can also cause changes in the chemical and physical properties of the soil, and general functioning of the entire ecosystem (Weidenhamer and Callaway, 2010). Identification of these species, particularly at international borders has posed a great challenge using the traditional morphological features and can be time consuming and labour intensive. Hence, scholars such as Ball and Armstrong (2006); Darling and Blum (2007) advocate for a standard protocol that can identify these species at every stage of their life cycle.[17]

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[16] These incidences were detected using IBOL technology at the Biodiversity Institute of Ontario, University of Guelph where the tests were carried out.

[17] It is worth noting that not all alien species are invasive when introduced into a new environment. While some create negative environmental, economic and health impacts, others tend to be beneficial (Shine, 2005). For example, some exotic species of plants (e.g. corn, wheat) and animals (e.g. poultry) have greatly increased agricultural productivity across the world. On the other hand, the introduction of the golden apple snail specie into The Philippines as a good

DNA barcoding has been successfully used in detecting the presence of alien invasive plants and animal species in various parts of the world. Examples include:

a) Detection of American ‘bullfrog’ *Rona catesbeiana* (Dejean *et al.* 2012), an invasive species found in South-western France, which D’Amore (2012) describes as being among the worst 100 world’s invasive species.
b) Identification of invasive ‘lionfish’ *Pterois volitans* and their prey on coral reefs of the Mexican Caribbean, the world’s second largest reef system (Valdez-Moreno *et al.* 2012). Barcoding of the DNA identifies “fishes from five orders, 14 families, 22 genera and 34 species in the stomach contents” (p.1) as prey.
c) Identification of invasive agricultural insect pests such as ‘fruit flies’ *Tephritidae* (Armstrong *et al.* 1997), ‘tussock moths’ *Lymantriidae* (Armstrong *et al.* 2003) and ‘armyworm moths’ *Spodoptera spps* (Nagoshi *et al.* 2011).

Species identification using DNA barcoding has been generally more effective for animals than plants.[18] The major challenge is that plants contain secondary compounds (inhibitors) including cellulose, lignin, resins, waxes and hemicellulose which make DNA extraction and PCR reactions difficult (Lee and Cooper, 1995; Degen, 2013), particularly from processed wood. Despite this challenge, DNA barcoding of IBOL technology has been applied in the forest sector (dry woods) given the size of the industry and the impact it has on the environment. Application of PCR reagent that neutralizes the inhibitors facilitated DNA extraction from dry (including processed) wood products (Nielsen and Kjaer, 2008). Identification of morphologically indistinct species of wood would enhance reduction of illegal trade of protected or invasive species. This implies that the technology has a potential role in identification (and protection) of species listed under the Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES).

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protein source from Latin America caused damage estimated at US$1b to rice crops in the 1980s while it cost North Carolina US$19m to eradicate European gypsy moth in 1983 (Pimentel *et al.* 2000).

[18] Personal communication with Biodiversity Institute of Ontario

CITES is a "voluntary international agreement between governments"[19] and came into force on July 1, 1975. The agreement sets a common framework to be used by parties (member countries) in controlling cross border trade in selected plant and animal species that are endangered or threatened with extinction as a result of overexploitation. To date, the convention has 181 parties. Accurate identification and possible inclusion of additional species in CITES requires a reliable standard technique, taxonomical information and a well-established reference database containing common names of identified species. The potential role of IBOL technology in the identification of CITES listed species will be discussed in the next section.

2.2.1.3 Natural health and herbal products

Natural health products (NHPs) according to Health Canada refer to "vitamins and minerals, herbal remedies, homeopathic medicines, traditional medicines such as traditional Chinese medicine, probiotics and other products like amino acids and essential fatty acids". [20] In the United States, NHPs are referred to as supplements. NHPs are usually non-prescription products (i.e. such products can be bought over the counter without a doctor's prescription).

Aside from wood, there are numerous valuable products (e.g. roots, leaves, seeds, tree backs, etc) extracted from the forest, processed and used as medicines (natural health products), ornamentals and edibles (Laiou *et al.* 2013). Recently, natural health products are traded in high volumes in domestic and international markets. There is potential for misidentification and substitution of species, which may be intentional or as a result of morphological similarities among plant species. This could lead to severe health risks (Sundus, 2008) as it is difficult to recognize and identify them especially in processed form (Govindaraghavan *et al.* 2012). Previous studies (e.g. Techen *et al.* 2004; Song *et al.* 2009; Srirama *et al.* 2010; Heubl, 2010) have discovered adulteration and substitution in medicinal plant products given the increasing demand for herbal products globally.

IBOL technology has been used to verify and authenticate label claims on ingredients used for natural health products (Wallace *et al.* 2012). For example, in a recent study, Newmaster *et al.*

[19] www.cities.org/eng/disc/what.php

[20] http://www.hc-sc.gc.ca/dhp-mps/prodnatur/index-eng.php

(2013) used IBOL technology to detect contamination and substitution in herbal products sold in North America (Canada and United States). In the study, a blind test of 44 herbal products of 12 different companies was conducted. The result shows that 59% of the tested products contain DNA barcodes of plant species that are not listed on the label, while one-third of the products contain unlabelled contaminants (*Parthenium hysterophorus*, *Senna alexandrina*) and fillers (rice, soy, alfalfa). *S. alexandrina* is a laxative that could cause chronic diarrhea and liver damage if taken for a long period of time (Hietala *et al.* 1987; Spiller *et al.* 2003). The products of only 2 companies, out of 12, were found to be free from contamination, substitution and fillers.

2.2.1.4 Vectors of zoonotic diseases

Accurate identification and understanding of vectors that transfer pathogens and cause diseases in humans and animals would be a good step towards their effective management and control. DNA barcoding has been used to identify some vectors. For example, Gariepy *et al.* (2012) use the bloodmeal analytical method to identify ticks and their hosts. DNA barcoding has also been used to identify Sigmodontine rodents in Brazil (Muller *et al.* 2013). Taking cognizance of the discussion above, it suggests that IBOL technology has the potential of providing solutions to information asymmetry and authenticity issues in agriculture, food and resource markets.

There is potential for continued increase in the movement of goods and services across national boundaries due to globalization and trade liberalization. As stated earlier, the major pathway through which endangered and invasive plants and animal species are intentionally or inadvertently introduced is international trade (Bryan, 1996; Shine, 2005). Therefore, an increase in cross-border trade would potentially mean an increase in the spread (or depletion) of these species (Ruiz and Carlton, 2003, p.323). Although governments have established diverse frameworks aimed at reducing the spread of endangered and invasive species, and protect human health and the environment; successful achievement of this objectives would require the use of accurate mechanisms that will facilitate easy identification of these species, as well as coordinated efforts by governments of different countries.

In the next section of this paper, the CITES regulatory frameworks in reducing commercial trade in endangered plants and animal species are discussed.

2.3 The CITES regulatory framework to reduce illegitimate trade in endangered species

There are several international regulatory mechanisms in place to enhance international trade, and protect human and animal health, as well as the environment. These include: Convention on Biological Diversity (CBD)[21], Convention on Migratory Species of Wild Animals (CMSWA)[22], Convention on the International Trade in Endangered Species of wild fauna and flora (CITES)[23] Sanitary and Phytosanitary (SPS) of the World Trade Organisation (WTO), and other Multilateral Environmental Agreements (MEAs) (Morici, 2002; Burgiel and Foote, 2006). Of these mechanisms, CITES, an agreement by some governments to protect certain plants and animal species that are threatened with extinction, is examined as a backdrop to the analysis of the potential role of a technology such as IBOL in reducing trade in endangered species.

The main objective of CITES is to enhance the sustainability of species and prevent their over-exploitation, particularly those threatened with extinction, by regulating their cross border trade (IUCN, 2000). Species regulated by CITES are listed and/or categorized into three appendices with each category having specific regulatory measures as follows:

a. *Appendix I* contains the list of species that are threatened with extinction and are potentially affected by international trade. Trade in these species for commercial purposes is prohibited among member countries. Non-commercial trade is only allowed with export and import permits issued by the government and scientific authorities of the exporting and importing countries, indicating that the species would not pose any risks to the environment (Article III). The list contains 630 plus 43 sub species of animals and 301 plant species.[24]

b. *Appendix II* includes species that are not necessarily threatened with extinction but trade in these species needs to be strictly regulated to prevent them from going extinct. Trade for commercial purposes is allowed only with an export permit from the exporting country, and this permit must

[21] www.cbd.int
[22] www.cms.int
[23] www.cites.org

[24] www.cites.org/eng/disc/species.php

be verified and accepted by the importing country (Article IV). Included in this list are 4,827 plus 11 sub species of animals and 29,592 plant species.[25]

c. *Appendix III* includes species that individual CITES member countries recognize need protection, and requires the cooperation of other parties to assist countries in controlling trade in those species. Trade in these species requires only an export permit issued by the member country that solicits for the support of other parties. Nonetheless, if the species is not originally from the party that listed it, a certificate of origin must be presented to the authorities of the importing country by the exporter in the member country wishing to export the product (Article V). There are a total of 135 plus 13 subspecies of animals and 12 plant species in this group.

It is important to note that CITES permits trade with non-parties under the condition that the non-party state (exporter) must provide dual (export and import) permits certifying that the species would not pose any risk to indigenous species in the importing country (ICUN, 2000). Non-compliance or engagement in illegal trade between parties attracts a sanction in the form of a trade ban. A prime example is the trade ban instituted against the United Arab Emirates (UAE) from 1985 to 1987 for engaging in illegal trade in specimen (ivory)[26] of CITES listed species (African Elephant) that was depleted by 700,000 between 1979 and 1989 and listed in appendix I (CITES, 1987; 2014). Thus, the dual system of control, particularly for species listed under appendix I, and a continuous increase in the number of parties to CITES, would potentially facilitate international cooperation and regulation of illegal trade in these products.

Having listed the species, their proper identification, and possibly origin remains a challenge. Presently, CITES listed species are identified by non-species experts (customs officers) at the borders through physical examination using identification manuals containing pictures of various species (UNEP, 2009, pp.24-25). This raises a question of whether this method of identification

[25] ibid

[26] Ivory is the hard, smooth, yellowish-white tusk harvested from Elephants.

has been effective, particularly for transformed and species that "look-alike".[27] There is potential for exporters to misrepresent their products (e.g. misdeclaration of wood products at the border (Brack and Hayman, 2001, p.5)) even when the permit has been issued for a particular wood species. Credible enforcement of these regulatory measures requires appropriate and accurate testing methods to verify claims on the export permits, and to uncover illegitimate activities especially for processed products containing CITES listed species. Emerging technologies, such as the International Barcode of Life (IBOL) can be used to identify the listed species and processed products containing the species, as well as their country of origin given its wide range of applications to date. Complementing the existing method of identification (physical examination) by verifying claims on an export permit using authenticity technologies such as the IBOL would strengthen its credibility and potentially may serve as a safety assurance to the indigenous species and the environment in the importing country.

On the other hand, technologies could be used to complement and strengthen the existing physical identification method presently used to identify CITES listed plants and animal species. For non-listed species, adequate record keeping and frequent identification of a particular species using emerging technologies would potentially signal over-exploitation, and therefore, inform regulatory authorities of the need to regulate trade in those species for sustainability. Further, incorporating technological solutions in the monitoring system for listed species would enable the establishment of records on volume of trade in such species, which to the best of the author's knowledge is not available presently.

The regulatory framework of CITES involves export and import permits as preconditions to allow trade in the listed species for commercial purposes.[28] These are costs to the exporters. Additionally, payment for an export or import permit does not guarantee its approval as the species may not pass the "non-detriment finding" test conducted by the scientific authorities of both exporting and importing counties (ICUN, 2000). This could be an incentive for exporters to take the risk of

[27] In the case of invasive alien species, some countries, such as Argentina, carry out environmental impact assessment of any species at the border before it is allowed into the country (Di Paola and Kravetz, 1992). However, such method despite its advantages could be time consuming.
[28] http://www.cites.org/eng/disc/how.php

bypassing the borders and smuggling their products into the importing countries. Therefore, adequate control in trade of the endangered species requires extensive monitoring not only at the official border entries but on other avenues used by smugglers.

Although the costs of substituting and/or complementing existing methods used in monitoring cross border trade in plant and animal species with technologies (e.g. IBOL) may be high, these costs may be lower than the recurrent national budgets for promoting sustainability of these species. For example, in the case of invasive alien species, it may be more economical to invest in technologies that would rapidly and accurately identify these species at the borders and deny them access into the country than incurring significant costs in eradicating the alien species when introduced, in addition to the damages invasive alien species may cause to the environment and the entire ecosystem.

Potentially, species that are overexploited may be in high demand. Therefore, strict monitoring and regulation of trade in these species could enhance their sustainability. A validated reference library (e.g. IBOL database) for comparison and easy identification is an important feature of emerging technologies. Hence proper identification of species would inform when regulation is required for a particular species, facilitate possible inclusion of additional species that seem to be overexploited on CITES lists, and ultimately reduce the incidences of illegitimate trade in endangered species.

Regulation of international trade is assumed to be a major means of protecting certain plant and animal species listed by CITES from over-exploitation. This implicitly means that incorporating emerging technologies in monitoring, and regulating trade in these species, presumably at the borders, would have a negative effect on the supply of listed species. That is, the supply curve will shift inwards, as proposed by Burgiel and Foote (2006). Nonetheless, this would be true if the trade regulations are implemented and coordinated in such a way that there is little or no opportunity for trade diversion of the species threatened with extinction.

The next sub-section models the potential role of IBOL technology in the regulation of trade in endangered species using the Brazilian rosewood (*Dalbergia nigra*) tree as a case study. To the best knowledge of the researcher, this is the first attempt to model the implications of authenticity explicitly in the context of international trade.

2.4 Modelling authenticity and quality verification in international trade: CITES case study using Brazilian Rosewood

Brazilian rosewood (*Dalbergia nigra*), one of the most valuable trees in Brazil, is among the over 100 species of a genus found mostly in the eastern part of Brazil (Vales *et al.* 1999) including Bahia, Espirito Santo, Minas Gerais, Rio de Janeiro and Sao Paulo (Varty, 1998). Other countries import sawn wood made from rosewood (*D.*nigra) from Brazil. Wood from *D.nigra* is said to be characterized by its waxy appearance with variable colours, high resonance, resistance to insect attack and hardness, which makes it last longer (Flynn and Holder, 2001; Taylor *et al.* 2012). These characteristics mean that wood from *D.nigra* commands a premium and is used in the production of high priced furniture, cabinet, cutlery handles, musical instruments (e.g. piano, guitars, violins), among others (Taylor *et al.* 2012).

Wood from *D.nigra* tree was listed in Appendix I of CITES since June 11, 1992 and Annex 'A' of the European Union Wildlife Trade Regulation on July 20, 1992 (Taylor *et al.* 2012). The high demand for wooden items produced using *D.nigra* serves as an incentive to deplete the tree population through illegal and unreported logging (Anonymous, 2012). Hence following an assessment of *D. nigra* carried out by the International Union for Conservation of Nature (IUCN) in 1998 in which it was considered to stand a high risk of extinction if appropriate measures were not taken, *D.nigra* was included in the IUCN red list as a species threatened with extinction (Varty, 1998).

It has been argued that a major concern in regulating trade in *D.nigra* is "species identification" (Gasson *et al.* 2010, p.46; Taylor *et al.* 2012, p.12). That is distinguishing *D.nigra* from other *Dalbergia* species that are not threatened with extinction. There are several species of Brazilian rosewood (*Dalbergia*) with similar morphological characteristics. Of these species, *D.nigra* and *D.spruceana* have the closest physical similarity and can easily be exchanged for each other (Miller and Wiemann, 2006). Of these species, only *D.nigra* is listed in CITES Appendix I.

Physical identification with the aid of *CITES Identification* Guide (CITES, 2002) has been used in distinguishing these closely related species of rosewood. Attempts have been made using Chemical Analysis (Kite *et al.* 2010) and Principal Component Analysis (PCA) (Gasson *et al.* 2010) to distinguish *D.nigra* from other similar timber traded as rosewood. The PCA gave about 36.36 percent false positives, resulting in Gasson *et al.* (2010) advocating for an alternative approach with higher levels of precision in identification.

This paper examines the potential effects of using IBOL technology to implement a CITES commercial trade ban on *D.nigra* using a partial equilibrium trade model. This is analyzed in three scenarios. Assumptions are made for each scenario, and possible outcomes (e.g. trade effects) under each scenario are identified. The models start with a base case in which there is free trade and no testing with an authenticity technology, hence the timber (wood) market is undifferentiated (i.e. rosewood timber made from different tree species cannot be differentiated). The first scenario involves a situation where only the United States (a major importer) adopts the IBOL technology, and uses it as a monitoring tool to test for imported rosewood timber at the border. This is a trade diversion scenario as the regulation potentially will be weakened by Brazilian exporters diverting trade to a third country which does not observe CITES and where there is no testing regulation. The second scenario examines the potential outcomes when the U.S. and the rest of the world (ROW) adopt the technology (multilateral adoption of IBOL technology by all CITES member states) and use it to monitor imports of wood. Scenario three models potential upstream response (e.g. adoption of testing and certification systems) in the Brazilian wood supply chain and the possible implications that could arise from such a response.

Base case

This depicts a situation where there is free trade in rosewood timber between Brazil and importing countries without any testing for authenticity. A number of assumptions underlie the modelling of the base case:[29]

a) There are two importing countries, the U.S. and a third country (rest of the world). The United States is the largest single importer of sawn wood from Brazil. About 26 percent of

[29] The assumptions in the models are without loss of generality.

Brazilian sawn wood exports go to the U.S. while 74 percent are imported by the rest of the world.[30]

b) Rosewood is only produced in Brazil and neither of the importing countries produce rosewood. As a result, in the following model there is no domestic supply curve for rosewood in the importing countries.

c) The United States is a high priced market for rosewood relative to the third country. Hence the domestic demand curves for rosewood in the U.S. and third country cut the price axis at different points (U.S. at a higher price and third country at a lower price). The demand curves in the importing countries have different elasticities, with the demand curve in the U.S. being more inelastic than that of the third country.

d) Buyers of rosewood cannot differentiate wood made from different (legally and illegally traded) species of rosewood at the time of purchase. In other words, the markets are undifferentiated.

e) Legal rosewood is supplied at a higher cost relative to the illegal rosewood (*D.nigra*).

The illegal rosewood comprises the endangered species of rosewood (*Dalbergia nigra*) that is threatened with extinction and listed in appendix I of CITES with a ban on commercial trade, while the legal rosewood represents timber made from other species of rosewood that are not threatened with extinction. Figure 2.1 illustrates the base case with no testing for authenticity.

Figure 2.1 shows the base case where the market for rosewood is undifferentiated. In other words, there is no testing for authenticity, hence the importing countries cannot differentiate between the legal and illegal rosewood. In panel (a), D_b represents the domestic demand curve for rosewood in Brazil, S_I and S_L respectively represent the supply curves for illegal rosewood (*Dalbergia nigra*) and legal (other species of rosewood), while S_T is the total market supply of rosewood in Brazil (horizontal summation of S_I and S_L).[31] In panel (c), D_{us} is the demand curve for rosewood in the U.S. and in panel (d) D_{tc} represents the demand curve in the third country – another potential

[30] http://atlas.media.mit.edu/explore/tree_map/hs/export/bra/show/4407/2012/

[31] Following the CITES ban on commercial trade in *Dalbergia nigra* species of rosewood, in the context of this paper any species identified as *D.nigra* traded commercially within the Brazilian domestic markets or exported to the international market is illegal while commercial trade in other species of rosewood is legal.

importer of rosewood. Panel (b) represents the world market for rosewood, XS_I and XS_L represent the export supply curves for legal and illegal rosewood respectively, while XS_T is the total export supply curve derived from the intersection of the total market demand and supply curves in Brazil.

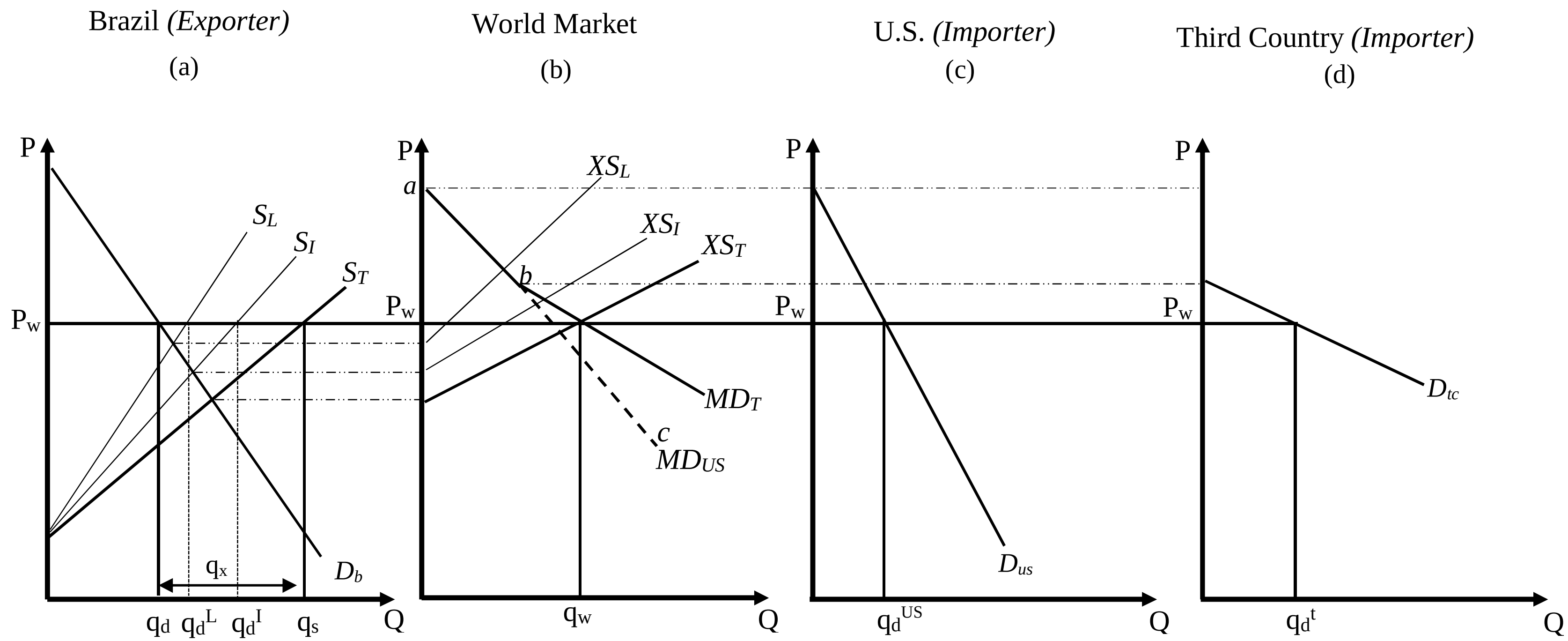

Figure 2.1: Base case: Undifferentiated rosewood market with no testing

In panel (b), MD_T represents the total import demand for rosewood, comprised of U.S. and third country imports. Line '*abc*' represents the U.S. import demand curve. At any price above '*b*' on MD_T, only the U.S. imports rosewood, so $MD_{US} = MD_T$ over the section '*a-b*'. At prices below '*b*', both the U.S. and third country are importers of rosewood. MD_T is the total import demand curve for the U.S. and the third country. Intersection of the total import demand and export supply curves in panel (b) gives rise to the equilibrium world market price, P_w and quantity, q_w. At P_w, Brazil exports q_x quantity of rosewood, while the U.S. and third country import q_d^{US} and q_d^t quantities respectively. Of the q_x quantity of rosewood exported by Brazil at price P_w, q_d^L *and* q_d^I represent export quantities of legal and illegal rosewood respectively. There is free flow of trade without any restriction, and the products are undifferentiated on the world market.

The next sub-section examines possible outcomes when a large importing country (U.S.) adopts an authenticity technology and uses it to test for rosewood at the border.

Scenario 1: Adoption of IBOL technology by the U.S. to test for rosewood at the border

This scenario illustrates a situation where the U.S. imposes a regulation requiring authenticity testing of rosewood at the border. Assumptions in this model, shown in figure 2.2, include:

a) U.S. adopts an authenticity technology (IBOL) for testing imports of rosewood at the border as a measure to enforce the CITES ban on commercial trade in Brazilian rosewood (*D.nigra*), while there is no technology adoption and testing in the third country.
b) Testing (monitoring) using IBOL is effective and involves some costs.
c) For simplicity, assume the U.S. imports all the legal rosewood, while the illegal rosewood goes to the third country (therefore XS_L intersects MD_T above point 'b'). That is the demand for legal rosewood in the U.S. is greater than the supply from Brazil.

Following the base case, all the curves in panels (a), (b), (c) and (d) in figure 2.2 remain as defined in the base case.

At the world market price P_w without any testing the market is undifferentiated, q_x quantity of legal and illegal rosewood is exported by Brazil while q_d^{US} and q_d^t quantities are imported by the U.S. and third country respectively, as in the Base case. If the U.S. imposes a regulation of adopting the

IBOL technology and uses it to test the species of rosewood at the border, there is a cost (monitoring) associated with such regulation. Testing at the U.S. border implies differentiating the products in the international market. The U.S. will import only the legal rosewood while the illegal rosewood will not be allowed into the U.S. Differentiating the products results in separate import demand functions/curves (MD_{US} and MD_{tc}) in the world market in panel (b), where MD_{US} is the US import demand function (only legally harvested rosewood), and MD_{tc} is the third country import demand function (undifferentiated rosewood). The testing regulation imposed by the U.S. will have some effects including:

1) An increase in the cost of importing rosewood into the U.S. The effect of the testing (monitoring) costs is shown as a downward shift in the U.S. domestic (D_{US}) and import demand (MD_{US}) curves by the amount of the testing cost. In other words the incidence of the testing cost will result in a decrease in demand for rosewood in the U.S. at all prices. Hence, the monitoring costs is modelled as the vertical distance (δ) between D_{US} and $D_{US'}$ in panel (c).[32] The rationale for considering a downward shift in the U.S. domestic and import demand curves instead of an inward shift in the import supply curve of legal rosewood to show the effect of the testing cost is because since the U.S. is adopting the technology, only legal rosewood is allowed into the country. We are more interested in the impact (welfare effects) of the testing costs (increase in the domestic price of legal rosewood and decrease in demand) on U.S. consumers.[33] Given the downward shift in the U.S. domestic demand curve which results in a downward shift in the U.S. import demand curve, the new equilibrium price (P_L^{US}) and quantity (q_w^{US}) for legally traded rosewood in the world market is derived by the intersection of the new U.S. import demand curve ($MD_{US'}$) and the export supply curve for legal rosewood (XS_L) in panel (b). The increase in price, all other factors remaining constant, will lead to a decrease in quantity of rosewood demanded in the U.S. (from q_d^{US} when the market is undifferentiated to $q_d^{US'}$ when only the legal rosewood is allowed into the U.S.) in panel (c). The new quantity ($q_d^{US'}$), at price P_L^{US}, reflects trade in the legal rosewood.

[32] An alternative way of modelling the monitoring cost is to have a shift (inward) in the export supply curve of the legal wood (i.e. from XS_L to $XS_{L'}$) in panel (b). The vertical distance between XS_L and $XS_{L'}$ would be the monitoring cost.

[33] The same applies in scenario 3 for the U.S. and rest of the world (ROW).

2) Being a large importing country of rosewood from Brazil, the U.S. testing regulation would have a decreasing effect on the world market price given the fall in demand for illegal rosewood. The new world market price ($P_{w'}$) is the price at which the illegal rosewood will be imported by the third country, hence $P_{w'} = P_{tc}$. The third country's new equilibrium price (P_{tc}) and quantity (q_w^{tc}) for illegal rosewood is derived from the intersection of the third country import demand curve (MD_{tc}) and the export supply curve (XS_I) for illegal rosewood in panel (b). The model therefore shows that while the legal rosewood is sold at a higher price in the U.S., the illegal rosewood is sold at a lower price in the third country.

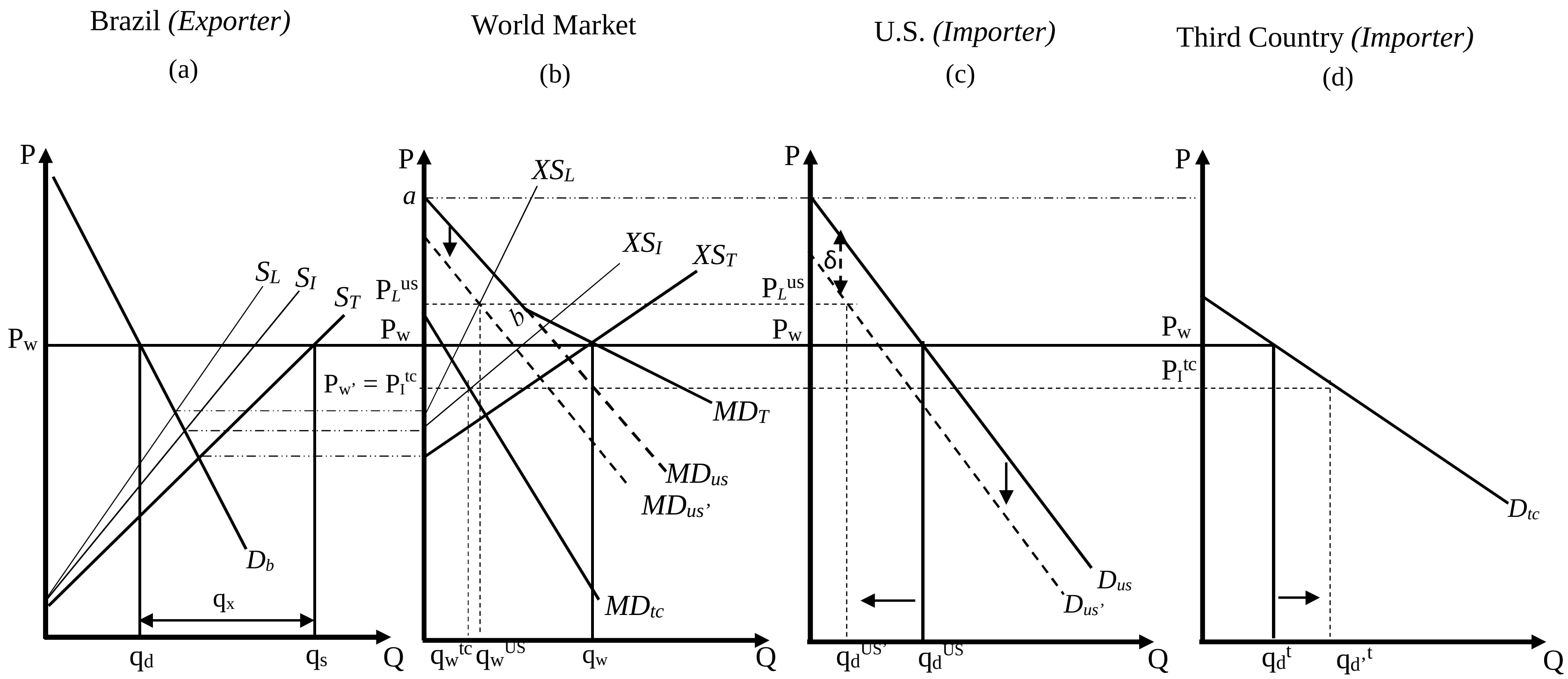

Figure 2.2: U.S. adoption of IBOL technology to test for illegal (endangered species) of Brazilian rosewood - *Dalbergia nigra*

The efficiency of the unilateral U.S. action (regulation) potentially would be offset by the incentive for Brazil to engage in trade diversion (reallocation of trade to other countries) as exporters in Brazil would have the option of diverting the illegal rosewood (*D.nigra*) to a third country where there is no testing regulation. The illegal wood from Brazil will be imported by the third country at a lower price P_I^{tc} which is equal to $P_{w'}$. Importing at a lower price P_I^{tc} would serve as an incentive for the third country to import more, hence quantity of imports will increase from q_d^t (before product differentiation to $q_{d'}^t$ after differentiation) in panel (d).[34] On the other hand, the decrease in the price of illegal wood would serve as a disincentive to harvest the illegal rosewood, *D.nigra*.

Comparing the welfare effects, since there are no supply curves in the U.S. and third country as they do not produce rosewood, we can only comment on the gains and/or losses to the consumers in the importing countries, as well as welfare impacts in Brazil. In the U.S., differentiation of the product due to testing primarily results in an increase in the U.S. price, and consequently a decrease in quantity demanded of rosewood. The price increase to P_L^{US} as well as the fall in quantity demanded result in a loss to consumers while suppliers of legal wood from Brazil will gain.[35] In addition, at price $P_{w'}$, there is a loss to Brazilian suppliers of illegal rosewood. The third country imports and sells illegal rosewood at a lower price P_I^{tc}. At this price, quantity demanded of the illegal rosewood in the third country increases which results in a gain in consumer surplus. Nevertheless, we cannot ascertain (with certainty) whether the gain by suppliers of legal wood to the U.S. is larger (lower) than the loss to suppliers of illegal wood to the third country.

The results of the analysis in this model convey some key messages. Adoption of an authenticity technology for testing imports of rosewood at the border by one country potentially may not be

[34] Although not directly shown on the graph (figure 2.2), there are indirect costs to the exporter when a shipment from Brazil fails the authenticity test. For example, if a shipment fails the test and is turned away at the U.S. border, the exporter will incur transaction (negotiation) costs in finding an importer who will accept delivery of the shipment (illegal rosewood) in the third country.

[35] If the quantity supplied of legal rosewood from Brazil is greater than the quantity demanded in the U.S., this implies that the U.S. will absorb part of the legal rosewood while the remaining will be diverted to the third country alongside the illegal rosewood. In such situation, there will not be any price difference between the legal and illegal rosewood in the third country's market; while the higher price for legal rosewood in the U.S. will be as a result of the testing costs.

effective at reducing commercial trade in the endangered species of Brazilian rosewood (*D.nigra*) as the regulation will be weakened through diversion of *D.nigra* by Brazil to a third country where there is no test for authenticity. In the U.S. (panel (c)), there is a decrease in the quantity demanded for rosewood presumably because the U.S. no longer imports illegally harvested rosewood. On the other hand, there is an increase in the quantity demanded (from q_d^t to $q_{d'}^t$) for illegal rosewood in the third country (panel (d)). The use of technologies (e.g. IBOL) to verify authenticity could enhance product differentiation (market segmentation) and reduce information asymmetry in rosewood timber within the wood supply chain of a country that uses the technology to test for authenticity.

The potential outcomes of multilateral implementation of testing regulation for rosewood is examined in the next scenario.

Scenario 2: The U.S. and the ROW impose testing regulation for rosewood timber

In this scenario, the potential outcomes of a multilateral (U.S. and the rest of the world) adoption of IBOL technology for testing rosewood are modelled. Assumptions in this model include:

a) All export markets for Brazilian rosewood are part of CITES and impose a regulation requiring authenticity testing for rosewood imports. In other words, the rest of the world (ROW) includes other CITES member countries outside the U.S.;
b) Testing for rosewood in the U.S. and ROW involve some costs and is effective in detecting fraud;
c) Brazil does not test for rosewood timber before it is exported and therefore does not enforce CITES ban on commercial trade in *D.nigra* in the domestic market; and
d) The U.S. and ROW import some quantity of legal rosewood. For this reason, the export supply curve for legal rosewood (XS_L) crosses the total import demand curve (MD_T) below point 'b' in the world market (unlike in the base case).

If the U.S. and ROW multilaterally impose regulations requiring testing of rosewood timber imports using an authenticity technology, it means that wood markets in the importing countries will be differentiated. Thus, only the legal rosewood will be traded in the world market and imported by the U.S. and ROW. Trade diversion of illegal rosewood will no longer be a possibility for Brazil due to strict compliance with the CITES regulation by the U.S. and ROW. This suggests that illegal rosewood can only be sold in the Brazilian market, as indicated in panel (a) of figure 2.3. Scenario 2 is different from scenario 1 in that the U.S. and ROW implement a testing regulation. This implies that the cost of importing rosewood in the importing countries will increase with the testing cost. With product differentiation in the importing countries, we will no longer have a separate import demand curve (undifferentiated rosewood) for the third country as was the case in scenario 1.

The demand curves (D_{US} and D_{tc} respectively) in the importing countries and the import demand curve will shift downwards by the amount of the testing cost (indicating the effect of the testing cost on the demand for imported legal rosewood). The vertical distance between the demand curves in each importing country shows the magnitude of the monitoring cost.[36] Prior to authenticity testing and product differentiation at the borders of the importing countries, the intersection of the total import demand and export supply curves gives rise to the world market price (P_w) and quantity (q_w). The new equilibrium price (P_L*) of legal rosewood is derived by the intersection of new total import demand curve ($MD_{T'}$) and the export supply curve for legal rosewood (XS_L) in the world market. The downward shift in the total import demand curve to $MD_{T'}$ in panel (b) follows the decrease in demand (downward shift in the demand curves) of the legal rosewood in the U.S. and ROW. At price P_L*, U.S. and ROW will import $q_d^{US'}$ and $q_d{}'^t$ quantities of legal rosewood respectively.

Comparing the welfare effects, suppliers of legal rosewood gain by selling at a high price in the U.S. and third country as there is no competition with lemons, while consumers in the importing countries lose as a result of the higher price and the lower quantity. Further, the low price P_I^b of illegal rosewood in Brazil makes the suppliers worse off.

Figure 2.3 shows that the testing regulation imposed by the U.S. and ROW reduced the quantity of illegal rosewood traded but does not completely eliminate illegal harvesting. As mentioned earlier, illegal rosewood can be sold in Brazil where the market is still undifferentiated. Since the

[36] Although not certain, it is possible that the amount of the testing cost might differ in the importing countries.

illegal rosewood cannot be exported to any country, the domestic supply exceeds demand. This reduces the equilibrium domestic price of illegal rosewood to P_I^b and quantity qd^I derived from the intersection of the domestic demand and supply curve for illegal rosewood in panel (a). Again, this could be a disincentive to harvest illegal rosewood in Brazil. The analysis in this scenario shows some interesting results. Testing for rosewood imports by the U.S. and ROW using an authenticity technology potentially eliminates cross border trade in illegal rosewood. Rather the trade is restricted to Brazil at a lower price and quantity (due to demand/supply factors) which may discourage illegal harvesting. In addition, with product differentiation only the legal rosewood is traded across national boundaries, and at a higher price.

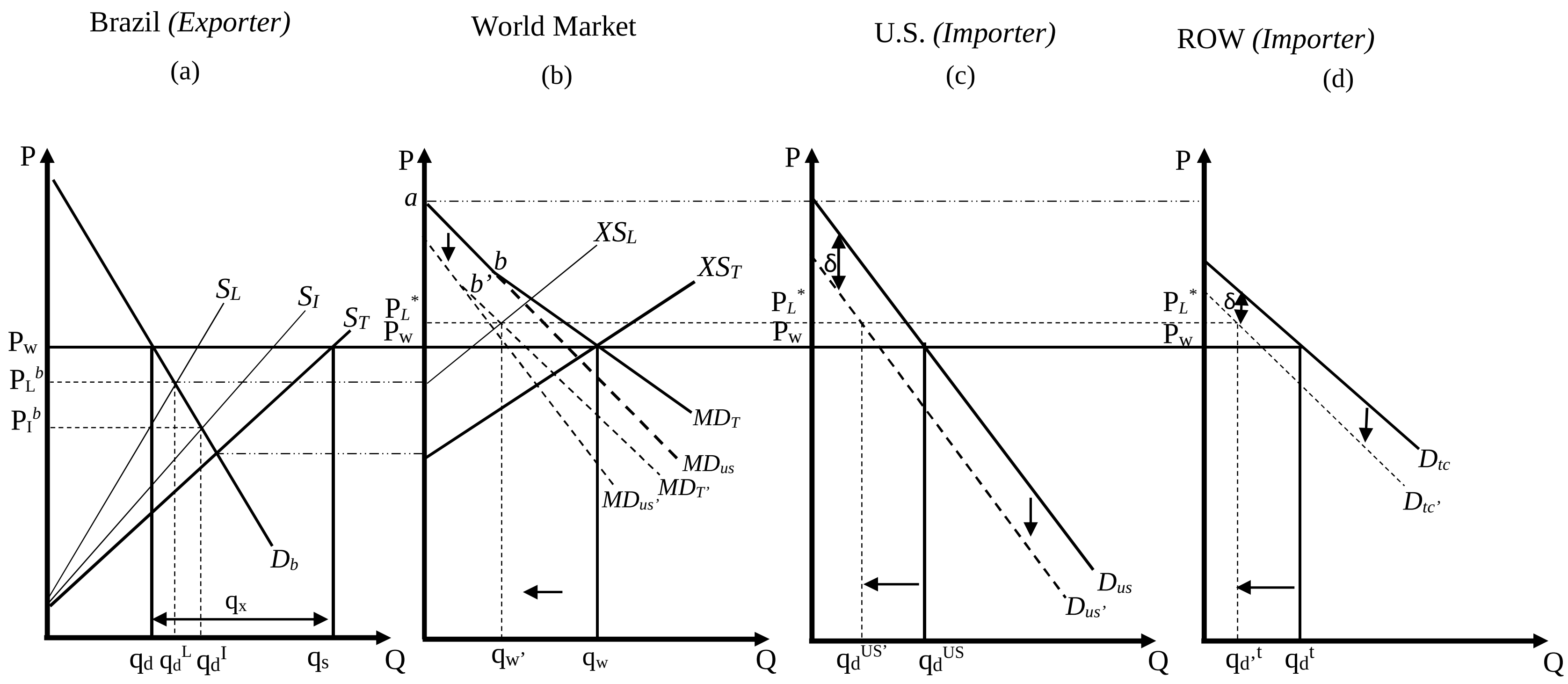

Figure 2.3: Multilateral adoption of IBOL technology for illegal (endangered species) of Brazilian rosewood - *Dalbergia nigra*

Scenario 3: Potential upstream response (testing and certification) in the exporting market

Multilateral implementation of the CITES ban on commercial trade in *D.nigra* through a threat of authenticity testing of imported rosewood potentially may trigger a pre-emptive upstream response to introducing testing and certification of authenticity by the exporting country, Brazil. Some assumptions are made in modelling this scenario including:

a) Brazil adopts an authenticity technology (IBOL) and a certification system, and uses them to differentiate legal and illegal rosewood on the world market;
b) Testing and certification in the Brazilian market are associated with some costs;
c) Consumers in Brazil are indifferent between timber made from legal or illegal rosewood;
d) Certification of authenticity for imported rosewood is seen as being credible in the U.S. and ROW markets, and leads to an increased demand in the importing countries due to the assurance that the wood is legally harvested; and
e) Both the U.S. and ROW import some quantity of legal rosewood, hence the export supply curve for legal rosewood crosses the total import demand curve below point 'b' in the world market (as in scenario 2).

This model has assumed that consumers in Brazil are not concerned about illegal harvesting and therefore about product differentiation in the domestic wood market, however, international pressure (through a threat of authenticity testing of imported rosewood by importing countries) may trigger an upstream response in Brazil. Such a response could be in the form of adopting an authenticity technology such as the IBOL, and the establishment of a credible certification system within the domestic wood supply chain. This is capable of boosting the collective reputation of Brazilian wood exporters/distributors and the integrity of the wood supply chain. It will also increase the confidence level of importers in Brazilian wood supplies assuming the certification system in Brazil is perceived to be credible by the importing countries.
This is shown in figure 2.4.

Prior to Brazil implementing testing, the base case situation prevails: at price P_w, wood markets in Brazil, U.S. and ROW are undifferentiated; hence q_x quantity of rosewood exported by Brazil (consisting of both legally and illegally harvested rosewood) is traded in the international market, while the U.S. and third country import q_d^{US} and q_d^{t} quantities respectively. Differentiating between legal and illegal rosewood in Brazil using an authenticity technology and a credible certification system is associated with some costs. The effect of the costs of testing and certification within the Brazilian supply chain for legal rosewood is shown as an upward shift in the supply curve (S_L to S_L') of legal rosewood in panel (a) by the amount of the testing and certification costs.[37] This causes the export supply curve (XS_L) for legal rosewood to shift to $XS_{L'}$ in panel (b).

Differentiating legal from illegal rosewood through testing and credible certification would mean signalling quality and reducing information asymmetry for buyers (domestic and importers), and this is assumed to shift the demand for certified (legal) rosewood outwards in the U.S. and ROW markets. The shift in domestic demand curves in the importing countries causes the import demand curve for legal rosewood (MD_T) to shift out to $MD_{T'}$ in panel (b).[38]

[37] The nature of the shift (parallel or pivotal) in supply curve affects the size of welfare distribution (Mensah and Wohlgenant, 2010), particularly producer surplus (Phillips and Khachatourians, 2001, p.274). Pivotal shift in the supply curve of legal rosewood was used (by assumption) because this is a theoretical analysis.

[38] It is important to note that from the international trade perspective, adoption of a testing regulation for rosewood either by the exporting country (Brazil) or importing countries yield equivalent results. If Brazil adopts an authenticity technology and uses it to test rosewood exports, the effect could be seen as an export tax. On the other hand, if the importing countries adopt and test rosewood imports, the effect could be described as an import tariff. The effect of an export tax is equivalent to that of an import tariff.

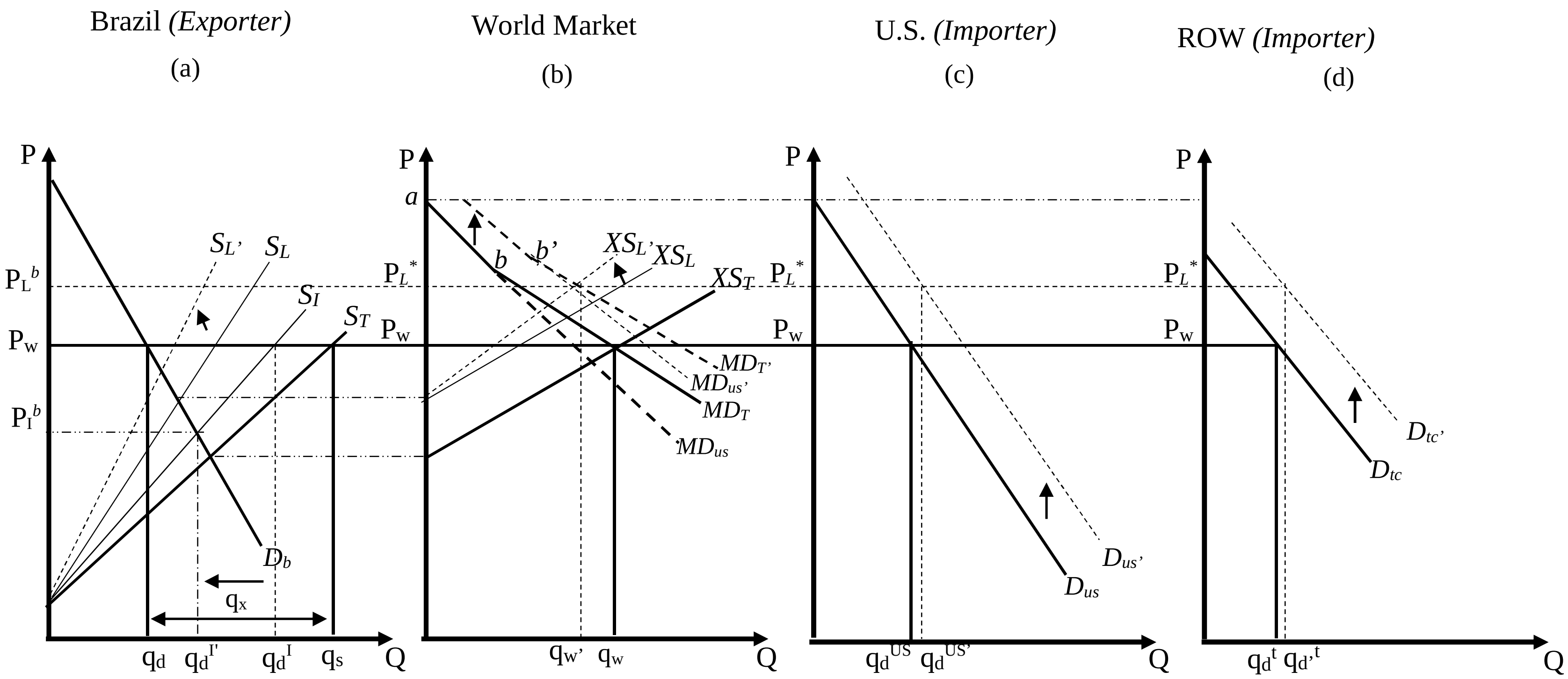

Figure 2.4: Potential upstream response by Brazil on the U.S. and ROW adoption of testing regulation for Brazil rosewood (*Dalbergia nigra*)

An increase in demand for legal rosewood by importing countries resulting from the authenticity assurance, all other factors remaining constant, would raise the price to P_L*, which is derived by the intersection of the new total import demand curve ($MD_{T'}$) and export supply curve ($XS_{L'}$) of legal rosewood in panel (b). The high price for legal rosewood in Brazil will serve as an incentive for firms in Brazil to cheat. This is why we assume perfect testing with IBOL technology. In addition, the decrease in quantity demanded (from q_d^I to $q_d^{I'}$) and price (from P_w in the base case to P_I^b) will further discourage illegal harvesting in Brazil. The certification system could be Green Labelling, which has been used in several countries including Singapore, Hong Kong, Denmark, France, Germany, among others[39]; and Forest Stewardship Council (FSC),[40] a certification body supported by international organization such as Greenspace and World Wildlife Fund (WWF).

Testing and certification of authenticity in Brazil would affect the quantities of legal and illegal rosewood as well as their prices. In terms of welfare, surplus (producer surplus) to suppliers of legal rosewood in Brazil depends on the price and quantity of legal rosewood supplied (size of the shift in supply curve) as well as the costs of implementing testing and certification. Although the increase in demand for legal rosewood in the U.S. and ROW due to authenticity assurances will be beneficial to suppliers of legal rosewood from Brazil as they will sell at a higher price, the actual outcome (magnitude of the producer surplus) depends on the degree to which the increase in demand for legal rosewood outweighs the costs of testing and certification. Suppliers of illegal rosewood in Brazil will lose by selling at a lower price P_I^b and lower quantity in Brazil. On the other hand, the higher price of legal rosewood in the importing countries create losses to consumers.

Results of this scenario have implications for the endangered species of rosewood. For example, while upstream certification of authenticity for the legally harvested species of rosewood supplies would increase the demand in the importing markets, the reduction in price and quantity of the illegal rosewood supplied (in panel (a)) will serve as a disincentive to supply the illegal rosewood, thereby reducing the overexploitation of the endangered species.

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[39] http://www.sec.org.sg/sgls/

[40] https://ca.fsc.org

Analyses of the three scenarios show some interesting outcomes. Implementation of a regulation requiring authenticity testing of imported rosewood by one country potentially may not be effective at reducing commercial trade in the endangered species (*D.nigra*) of Brazilian rosewood. This is because a testing regulation implemented by one country alone will give room for trade diversion to a third country where there is no testing. Nonetheless, multilateral testing of rosewood imports could eliminate cross border trade in illegal rosewood, thereby restricting the trade only in Brazil. An upstream adoption of an authenticity technology for testing, and certification system in Brazil as a response to a threat of authenticity testing of imported rosewood by importing countries would mean signalling authenticity assurances, which potentially could increase importing countries' confidence in supplies from Brazil. Signalling authenticity through credible certification would increase demand for legal rosewood in importing countries, and consequently the market price. This implies that enforcement of CITES trade regulation on the endangered species of Brazilian rosewood using authenticity technologies potentially may create market for timber made from rosewood species that are not threatened with extinction.

On the other hand, although illegal harvesting may not be completely eliminated, product differentiation through testing and certification of authenticity in Brazil potentially would reduce the domestic demand and price of illegal rosewood. This would serve as a disincentive for illegal harvesting, and therefore, enhance the sustainability of the endangered species.

The results of the analyses in the different scenarios are intended to lay out potential outcomes which are driven by a number of factors, particularly the assumptions underlying the models. A prime example is the magnitude of the testing costs. Perhaps the exporting country (Brazil) only tests and certifies once while the importing countries require multiple testing. Going by this presumption, it may cost Brazil less to test than the importing countries. As mentioned earlier, the size of the testing costs will determine the magnitude of the surplus accruing to suppliers of legal rosewood. In addition, the size of the demand shift in the importing countries would implicitly show the extent to which the upstream testing and certification of authenticity is credible and valued in the importing countries. The assumptions underlying the models also have welfare implications in the exporting and importing countries. For example, if testing is done by the importing countries, consumers in the importing countries will lose due to high domestic price of legal rosewood and reduced demand. On the other hand, suppliers of legal rosewood in Brazil will gain from the increase in price of legal rosewood at the international market, while illegal harvesters lose. In contrast, if testing is done by the exporting country, consumers in the importing country will lose due to high price although there would be an increase in demand for legal rosewood in the importing countries. Further, the results are contingent on who adopts the technology for testing imports of rosewood and where, as well as the degree to which countries become CITES member states.

2.5 Conclusions

The paper examines technological solutions to authenticity issues in international agri-food and resource markets, and discusses the role of technology in verifying authenticity, and enhancing the enforcement of trade regulations on endangered species (Brazilian rosewood – *Dalbergia nigra*) listed by the Convention on the International Trade in Endangered Species of wild fauna and flora (CITES). Information asymmetry and quality uncertainty in agriculture, food and resource markets have eroded consumers' confidence, particularly for products with credence attributes; and spurred their demand for authenticity and quality reassurance. Government regulatory policies and industry-led initiatives aimed at providing credible product information to ensure that price of products reflect their true quality and consumers make informed choices are imperfect as there have been several reported cases of fraud. Results of recent studies have reinforced the potential of technologies in the identification and authentication of products. These technologies are capable of removing credence characteristics or verifying if the attribute is present in the products, thereby saving consumers, government and industries the cost of searching for these attributes, supply chain monitoring and negative externalities or spillovers associated with fraud.

Emerging technologies, such as the IBOL technology, potentially have a role to play in enhancing the implementation of regulations regarding cross border trade and sustainability of endangered species, which is the major objective of the Convention on the International Trade in Endangered Species of wild fauna and flora (CITES). Using the case of an endangered tree specie, Brazilian rosewood (*Dalbergia nigra*), the theoretical analysis maps out the potential outcomes of adopting an authenticity technology (e.g. IBOL) to test for imported Brazilian rosewood at the international borders under different scenarios (pathways) including: a base case (undifferentiated markets) where there is free trade without any testing regulation, the adoption of IBOL technology by a major importer (U.S.) in which trade diversion occurs and export of the endangered species are diverted to a third country; the adoption of IBOL technology and timber testing by all major importers (CITES member countries representing the rest of the world), and potential upstream adoption of an authenticity technology and certification system within the wood supply chain of the exporting country (Brazil).

The outcomes of the analyses, which are primarily driven by assumptions underlying the models, also depend on who adopts the technology, when and where; as well as the extent to which countries are signatories to CITES. The theoretical analysis presented in this paper provides a basis for future research on international trade regulation of endangered species listed by CITES. The analysis is limited by non-availability of data such as the volume and economic impacts of trade in endangered species. Availability of such data would inform an empirical analysis to quantity some of the outcomes, and test the consistency and reliability of the theoretical results. Future studies could use data on costs/economic impacts of trade in endangered species to explore the costs/benefits trade off in using IBOL technology to enforce CITES trade regulation in these species.

Results of the analyses suggests that testing of rosewood imports by only one country would not yield the desired outcome of reducing commercial trade in the endangered species. Rather a multilateral enforcement of testing regulations, though it may not put to an end illegal harvesting, could eliminate cross border trade in *D.nigra* if opportunities for trade diversion are curtailed. Upstream implementation of testing and certification of authenticity in the exporting country potentially would increase demand for legal rosewood if importing countries perceive the authenticity testing and certification system in the exporting country to be credible. Nonetheless, the magnitude of the costs associated with testing and certification, and the size of the demand shift in the importing markets determine the size of the gain (surplus) to suppliers of legal rosewood, and also the extent to which there is an incentive for the exporting country to adopt testing and reduce illegal harvesting.

Essentially, certification to signal quality in the wood supply chain or that of any product could be tenable, but verifying the authenticity of the certified product through testing with a monitoring and authenticity technology would make the certification system more reliable, acceptable and credible to consumers and importers. In the light of these issues, testing and monitoring technologies have a potential role in providing a solution to information asymmetry and authenticity issues in international markets, and are likely to act as a complement to, rather than a substitute for, regulatory enforcement. In the case of endangered species, the CITES commercial ban on international trade in *D.nigra* species of Brazilian rosewood could be more effectively enforced through multilateral testing of imported rosewood, rather than testing by one country irrespective of the market size, while upstream adoption of testing and certification systems in the exporting country may enhance product differentiation and sustainability of the species threatened with extinction.

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Appendix

The DNA Barcoding Process

Bio-identification for animals is done using the mitochondrial gene *cytochrome c oxidase* sub unit I (COI) (Hebert *et al.*, 2003; Ward *et al.*, 2005)[41]; while two-locus system (*rbcL* + *matK)* is used for plants (CBOL, 2009)[42]. In the IBOL system, a tissue sample is taken from a specimen to be identified after a high resolution photograph of the specimen is taken for scanned digital images that will be stored in the reference library. Taxonomy information about the specimen is recorded. The DNA is extracted from the standard (specific gene region) part of the genome from the sample tissue. The next step involves the amplification of the barcode region (COI) using the Polymerase Chain Reaction (PCR) and generation of a barcode using a DNA sequencer. The barcode is matched and/or compared with sequenced reference barcodes in the library database for appropriate identification.[43]

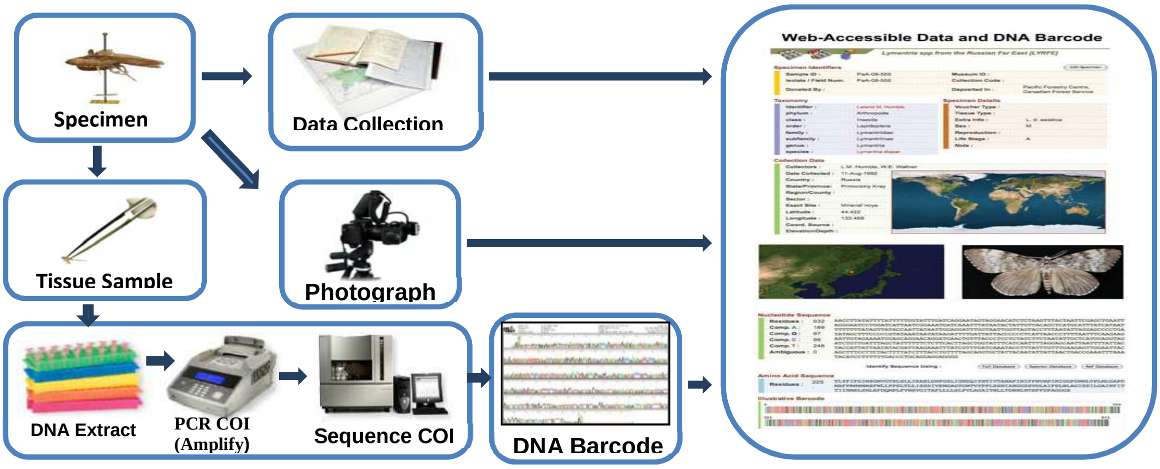

Figure A.2: DNA barcoding process
Sources: Floyd *et al.* (2010), Yancy (2007)

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[41]The region of DNA used to generate a barcode must contain unique identifiers, be short enough to allow sequencing in a single reaction, and contain matching regions which can be used to establish universal primers (Rubinoff, 2006).

[42] This was recommended as the standard plant barcode by the plant working group of the Barcode of Life based on their assessments of "recoverability, sequence quality and levels of specie discrimination after comparing the performance of seven leading DNA plastid regions of *atpF-atpH* spacer; *matK*gene; *rbcL* gene; *rpoB* gene*; rpoC1* gene; *psbK-psbI* spacer; and *trnI-psbA* spacer."

[43] http://ibol.org/about-us/what-is-dna-barcoding/

CHAPTER 3

Authenticity, Collective Reputation and Quality Signals: An Empirical Analysis of VQA wines

3.1 Introduction

The paper explores authenticity, quality signals and collective reputation in the agri-food sector by examining the role of Vintners Quality Alliance (VQA) in ensuring the authenticity and quality signalling of wines produced in Canada, and the factors that influence a winery's decision to seek VQA certification. The wine industry is chosen because it is an agri-food industry with a well-established authenticity and quality assurance system.

Authenticity of food products has become a global concern given the increasing spate of food fraud cases. Food fraud encompasses illegitimate market activities including: adulteration, dilution, substitution of substandard products for legitimate gains, false or misleading claims, among others. Such actions often create negative reputation externalities for other agri-food firms resulting in the classic 'market for lemons'. These serve as an incentive to take appropriate measures aimed at protecting not just an individual firm's reputation but also collective industry reputation. While food quality uncertainty has spurred consumers' interest and demand for quality assurance, the food industry is making investments in quality, authenticity and reputation-enhancing programs, such as the industry-led VQA system for Canadian wines in order to gain consumer confidence, collective reputation and market share.

A prime example is the fake icewine issue the Canadian wine industry has faced in China. Canada has unique weather conditions for icewine production and Asia, particularly China, is a major export market for icewine. Canada exported icewine worth about $8.6 million to China in 2012. This represents 55 percent of the total quantity of icewine exported by Canada in 2012 (FATDC, 2013). Wine consumption has been on the increase in China particularly in urban centers. However, China does not have a grading and quality assurance system for wines and, therefore, Chinese wines are often rated low in terms of quality and taste by wine experts (AAFC, 2011).

Canada is a major producer of icewine in the world and the Canadian wine industry has a credible quality assurance system, the VQA, which ensures the authenticity of Canadian wines. The price premium commanded by Canadian icewine serves as an economic incentive for some Chinese local wineries to produce counterfeit icewine labelled "made in Canada" (AAFC, 2011).

In the context of agri-food markets, the term *reputation* refers to consumers' beliefs about a firm, which could reflect the authenticity (quality) and uniqueness of its product. A consumer's belief about a firm provides an indication of whether the consumer has trust and confidence in the firm's product based on past experience with the firm's product (Fombrum 1996; Gosti and Wilson, 2001; Fishman and Rob, 2002) or prior belief (reputation) about the firm (Menapace and Moschini, 2010). Reputation could be individual or collective. Individual reputation relates to the reputation of a single firm, while collective reputation refers to that of an industry. In the context of the Canadian wine sector, individual reputation reflects the reputation of a single winery while collective reputation relates to the reputation of a wine producing region, such as the Niagara Peninsula in Ontario or the Okanagan valley in British Columbia, or the reputation of a wine producing country, such as Canada. It has been argued that reputation is a paramount factor that influences consumers' wine purchases (Castriota and Delmastro, 2014). The reputation of a firm or an industry is driven by the quality of its products, especially products with experience and credence attributes whose quality consumers cannot ascertain at the time of purchase (Costanigro and McCluskey, 2007).

Wine is one of the commodities whose quality consumers have difficulty in ascertaining *ex-ante* or prior to purchase (Charters *et al.*, 1999), and often make purchase decisions based on information provided on the label, including: producer name (winery), its region of origin and reputation; grape variety used in production; year of production and third party rating provided by wine experts (Ling and Lockshin, 2003). Potentially, many consumers may neither look at the quality rating nor have the time to go through the information provided on wine labels and therefore, may pay a premium for low quality wines. This raises the question, could VQA be a signal and/or a short hand for quality and reduce transaction (search) costs for consumers?

Previous studies (e.g. Oczkowski, 1994; Combris *et al*., 2000; Schamel and Anderson; 2003, Rabkin and Beatty, 2007; Kwong *et al*., 2011) have used hedonic models to estimate the marginal contributions of perceived wine attributes to the market price of different types of wines in different regions. However, only Rabkin and Beatty (2007) estimate the marginal contribution of VQA certification to wine prices in British Columbia. This paper is different in scope and approach. It uses data for wines from Ontario and British Columbia and includes wineries and appellation of origin to separate the effect of individual and collective reputation on the price of wine. In addition to estimating the implicit values of wine attributes, particularly VQA, using hedonic models, it also estimates a Probit model to identify the factors that influence a winery's decision whether to seek VQA status, which (to the author's knowledge) no previous study has examined. The VQA system is voluntary, and it is of interest to identify empirically the factors that influence its uptake, despite the costs associated with using the VQA system.

In light of these issues, the key research questions examined in this paper are as follows: Does VQA certification (versus collective and individual reputation signals) elicit a price premium and enhance the collective reputation of Canadian wines? What factors determine a winery's decision to seek VQA certification for a specific wine? These questions are important for several reasons. VQA is the only quality assurance system in the Canadian wine industry. It is therefore pertinent to determine empirically the value of VQA certification, which will indicate the difference in prices of VQA and non-VQA wines. In addition, it is clear that not all wineries seek VQA certification on all their wines. The data set include wines from the same winery both with and without VQA certification. It is also important to know why and what could trigger a winery to apply for VQA certification on some of its wines. The first question is addressed by estimating a hedonic pricing model to determine the marginal value of VQA certification and other relevant wine and winery attributes to the market price of wine. This will inform whether VQA certification contributes to boosting the collective reputation of Canadian wines. For the second question, a Probit model is estimated to identify the factors that shape a winery's decision to use the VQA system for specific wines.

The paper is organized as follows: section 2 examines the wine industry and industry-led quality assurance systems. Section 3 discusses the methodology (analytical techniques) used in the analysis. Section 4 presents the empirical results and discussion, while section 5 summarizes the implications of the results and draws some conclusions.

3.2 Quality Assurance Systems/Programs in the Wine Sector

The increasing cases of food adulteration and counterfeiting have resulted in many consumers becoming mindful of quality. In the wine sub-sector, wine industries in different countries have engaged in quality assurance (QA) and sustainability programs to promote and gain support for regional wines. According to Falcheck (2008), the increase in uptake of quality assurance programs by wineries are driven by two major factors – "consumer bias" for regional wines and the proliferation of wineries across regions.

Wine industries in various countries have different industry-led quality assurance programs that operate in a similar way. Examples include: Vintners Quality Alliance (VQA) for Canadian wineries, the Common Wealth Quality Alliance (CWQA) for Virginia wineries, the Washington Wine Quality Alliance (WWQA) established in 1999, California Sustainable Wine established in 2001 by the California Association of Winegrape Growers, and California Wine Institute's wine growers, among others. A common feature of these quality assurance programs is that wines approved by each of the programs must be made with 100% grapes grown in the region and bear the logo/seal of the quality assurance system on the bottles to signal quality and enable consumers to make informed choices. However, each QA program has slightly different standards. For example, quality verification for wines by VQA starts from the grape field where grapes are inspected before harvest to ensure that they are harvested at the appropriate ripening stage, while for some QA programs (e.g. CWQA for Virginia wineries); bottled or pre-bottled wines could be submitted for analysis.[44] However, the Canadian wine industry is the main focus of this paper; hence VQA will be examined in detail.

The rationales for examining wine quality assurance in this study include:

[44] http://www.vawine.org/quality_ap.html

a) the Canadian wine industry uses an industry-led QA system (VQA) to ensure authenticity, signal origin and quality to consumers and protect the collective reputation of the industry, and
b) data on wine prices are available from the Liquor Control Board of Ontario (LCBO).

3.2.1 Authenticity in the Canadian Wine Industry through Vintners Quality Alliance (VQA)

The Canadian wine industry consists of producers (vintners) who are involved in the production of wine and brandy using grapes and other types of fruits (AAFC, 2012). Wine production in Canada started in 1862 in southern Ontario, while Canadian wine became available in the international market in 1981 (VanSickle, 2011). Wine is produced in four provinces in Canada including: Ontario and British Columbia, which together produce about 98% of total production; with Quebec and Nova Scotia together producing only 2% of total production (VanSickle, 2011).

The total number of licensed wineries in Canada increased from 299 in 2006 to 432 in 2011.[45] Of this number in 2011, 49.1% (212 wineries) are located in BC while 30.1% (130) are in Ontario. In Ontario, as at March 2013, the number of registered wineries increased to 172[46] out of which 140 (81.4%) are registered with VQA (VQA, 2013, p.12). Of the 140 registered VQA wineries, 6 operate on a large scale (over 750,000 litres of VQA wine annually), 21 medium (between 100,000 and 750,000 litres annually) and 113 small (up to 100,000 litres of VQA wine annually) (VQA, 2013, p.12). This presumably suggests that many wineries are becoming interested in authenticity and recognize the importance of signalling quality to consumers. VQA participating wineries pay a fee of $250 for every wine sample tested and certified by VQA, and a mandatory check-off of 4 cents per litre of every VQA wine sold through any channel across Canada goes to VQA.[47] It is therefore of interest to empirically verify whether there exists a price premium for VQA wines as a reward for authenticity, quality and origin.

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[45]www.winebusiness.com/news/?go=getArticle&dataId=102231

[46] http://www.ontariowinesociety.com/about/ows-resources/ontario-wineries-by-region/

[47] Personal Communication with VQA staff. This serves as a source of revenue to VQA.

Canadian wine producers started production with Labrusca grapes grown in Canada (the Okanagan valley in British Columbia and the Niagara region of Ontario), along with riesling, cabernet sauvignon, chardonnay and merlot grape juice imported from Europe.[48] The industry made a land mark achievement in 1988 during which 100% Canadian wine was produced from home grown vinifera grapes. The same year, the Vintners Quality Alliance (VQA)[49] was established and Canada also signed a free trade agreement with the U.S. which paved the way for competition from U.S. wines and created a stronger incentive for quality improvements in the Canadian wine industry. Wines produced in Canada include: fruit wines, table wines, ciders, and icewines. Canada is known to be the largest producer of icewine in the world because of its extreme cold winter weather that favours production of icewine.[50]

Canadian icewine attracts a price premium because of its quality resulting from its unique processing method favoured by Canadian climatic conditions (AAFC, 2013). The harvest time of grapes used in making icewine is usually delayed, with a greater risk of animals and birds feeding on the grapes, reducing production volumes. Harvesting of grapes used for icewine production occurs during the winter when the temperature is below -10 degrees Celsius (14°F). At this temperature, the grapes are naturally frozen on the vines and contain less juice than normal, which makes the wine sweeter. Throughout the production process, there is no artificial refrigeration of grapes and juice used in making icewine "except for tank temperature cooling during fermentation and/or cold stabilization prior to bottling."[51] VQA supervises the production process to ensure that wineries use only grapes grown within Canada are used and without addition of artificial sugar

[48]http://winesinniagara.com/2011/07/how-the-wine-industry-got-started-in-canada-and-the-men-who-dared-to-dream/

[49]Vintners Quality Assurance (VQA) is Canada's symbol of quality wine and is similar to other regulatory systems in other countries such as Appelletion d' origine Controlee (AOC) in France; Denominazione di OrigineControllata (DOC) in Italy; and QualitätsweinmitPrädikat (QMP) in Germany. Its name was later changed to Vintners Quality Alliance.

[50]www.winesofcanada.com

[51]http://www.winesofcanada.com/icewine_standards.html

(AAFC, 2013).[52] In addition, production of icewine requires intensive and specialized labour and output is usually small relative to other wines. For example, a 375ml bottle of icewine is produced using 3.5kg of grapes, whereas this quantity of grapes would produce about six bottles (375ml) of ordinary table wine.[53] These factors, presumably along with a growing demand for this premium wine, explain the difference in price between icewine and ordinary wine, and therefore, serve as an incentive for counterfeiting, especially in China where there have been reports of fake icewine labelled 'made in Canada' in Chinese markets (O'Donnell, 2011; AAFC, 2011). About 74% of Canadian icewines are exported to Asian markets, with China being the second biggest market after Japan (AAFC, 2011). The uniqueness and price premium for Canadian icewine serves as an incentive for some Chinese wine producers' to produce fake wine by bottling and packaging water mixed with colourant, grape juice and alcohol, and labelling the fake product as "Canadian icewine" (AAFC, 2011).

Several key agencies have played major roles in the development of the Canadian wine industry including: industry organizations (e.g. Canadian Wineries Association (CWA)), support institutions (e.g. Liquor Control Boards across the provinces), and wine regulatory bodies and/or agencies (e.g. Vintners Quality Alliance). The CWA is an organization that represents wineries and promotes the adoption of production-enhancing innovations that improve grape and wine production (Pelling and Hira, 2012).

The provincial Liquor Control Boards (LCBs) help in marketing imported and Canadian made wines, and alcoholic beverages in each province (Carew and Florkowski, 2012). The LCBs also engage in wine promotion practices, except in Alberta where wine distribution was privatized in 1993 (AGLC, n.d). The LCBs promote wine sales by creating consumer awareness on physical and sensory attributes of wines, such as "tasting notes, wine critics ratings, measured sulphite contents in the case of organic wines, and organic/biodynamic certification status, among others" (Kwong *et al.* 2011, p.362). In addition, the LCBs control which wines can be imported and

[52] The sugar content of icewine exclusively comes naturally from the grapes. This is why the production process is monitored by VQA.

[53] http://winecountryontario.ca/media-centre/icewine

distributed in each province, thereby acting as a monopoly that inhibits the diversity of wines available. Consequently, wine producers face the challenge of having their wines pass through the provincial monopolies (LCBs) in order to be distributed and sold. Further, retail prices set by the LCBs do not always result in high profit margins for wine producers, and inter-provincial trade restrictions make it difficult to sell wines produced outside of a province as they are seen as imports (Madill *et al.* 2001).[54] The Ontario Liquor Control Board has a standard mark-up price for all domestic and imported wines irrespective of whether the wine has VQA certification. See appendix 3.I for an example of how LCBO sets retail prices of wines.

How does VQA regulate and ensure the authenticity of Canadian wine? VQA is the first industry-led quality assurance system established to enforce standards that support quality and ensure authenticity in the Canadian wine industry (Hira and Bwenga, 2011). Vintners Quality Alliance started in Ontario as a non-profit organization in November 26 1988 and has been given the responsibility of implementing the provincial Vintners Quality Alliance Act enacted on May 4 1999 and passed into law on June 29 2000.[55]The VQA Act sets up a designation of origin which consumers can use to identify quality wines produced in Ontario and other wine producing regions of Canada using home grown grapes, the production method and other set standards.[56]

The VQA system was adopted by the provincial government of British Columbia in 1990. Ontario and BC VQAs are managed under different provincial legislations (Rabkin and Beatty, 2007) although they have some common standards.[57] Registration and use of VQA is voluntary for wineries, and wines that pass VQA authenticity tests bear the VQA logo on the bottle label to signal quality. Consumers can use the logo to identify quality wines with assured regulated production practices and produced using 100% regionally grown grapes.

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[54] A provincial Liquor Control Board restricts quantities of wines produced in other provinces that can be sold within the province.

[55]http://www.vqaontario.ca

[56] ibid

[57] For the different standards, see www.winesofcanada.com/bc_standards.html and www.vqaontario.ca/wines/Qualitystandards

VQA has the mandate of ensuring authenticity of all VQA wines produced in Canada. It is also responsible for the development of standards and regulations that govern VQA Canadian wines. For example, VQA establishes quality and process standards for grapes used by wineries, carries out tests to ensure authenticity (i.e. ensuring that the wine is made from 100% Canadian grown grapes in designated regions), and reviews wine labels to ensure that the wine inside the bottle correctly reflects what is on the label before the wine is placed on the shelf (VQA, 2004). Wines that meet VQA standards can carry the VQA symbol on their labels.

In the area of regulation, VQA regulates the grape varieties used in wine production and the specific level of ripeness at which the grapes must be harvested to ensure quality wine. The monitoring is usually carried out by the representatives of the Grape Growers' Association (GGA) within each province. In addition, techniques used in wine making, labelling requirements, and sensory/chemical criteria for finished wine are also standardized and regulated by VQA.[58]

As a rule, a wine receives VQA approval and is certified as of Canadian origin after passing a series of quality assurance tests including: taste, laboratory analysis and packaging review tests. Further, the VQA carries out on-site audits of all wineries every 5 – 8 months as well as random wine inspection at Canadian retail stores in order to ensure that the packaging and labelling standards are strictly observed by wineries using the VQA symbol.

3.3 Methodology

3.3.1 The data

Secondary data on Canadian wines sold in Ontario and sourced from the Liquor Control Board of Ontario (LCBO) were used for the analysis. The data comprise 1537 observations on wines produced in Ontario (89.86%) and British Columbia (10.14%) and sold in Ontario between 2007 and 2012. Of this number, 1340 (87.18%) are VQA wines (547 red, 608 white, 92 icewine, 45 rose and 48 sparkling) and 197 (12.82%) are non-VQA wines (76 red, 94 white, 10 rose and 17

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[58]The regulation ensures that only authorized grapes of Canadian origin are used in wine production. VQA monitors the grapes before harvest to ensure that a minimum level of ripeness is reached before use in wine production. Details of the regulation and standards can be found in the VQA Act 1999 at www.e-laws.gov.on.ca/html/regs/english/elaws_regs_000406_e.htm

sparkling). Each observation contains information on the following attributes: LCBO retail price, certification status (i.e. VQA or non-VQA), percentage alcohol content, varietal, sweetness (sugar or brix level), vintage (year of production), product score (ranking by wine experts), colour, and the name of the wine, from which it was possible to identify the winery and the region.

The data set contains multiple observations of some wines produced by the same winery. For the same wine, the prices are the same for some observations and vary for other observations. Nevertheless, for the same wines produced by a winery that appear multiple times with different prices in the data set, the data did not indicate the different years these wines were sold. Rather, the data set shows only the year each wine was produced. We cannot observe the prices over time for a particular wine that appears multiple times in the data set as information on the year each wine was sold was not available. For this reason, it was not possible to carry out a panel data analysis using the data set. If the data set had provided price information on wines with multiple observations and the different years they were sold to allow for a panel data analysis, the data could have been arranged in clusters and estimated using robust standard errors. This would address the issue of clustering of standard errors.

The data set shows that wines with high alcohol content are sold at higher prices. This leaves one to wonder whether wineries could intentionally increase the alcohol content of their wines to enjoy higher prices. If this is the case, then potential endogeneity exists between the percentage alcohol content of a wine and its price. A potential way to address this issue is to include the lagged values of wine price in the model as an independent variable to ascertain if the current percentage alcohol content of a wine is determined by the previous year's price of the wine. Unfortunately we do not have such information in the data set.

3.3.2 Analytical techniques

To address the research questions, the data were analyzed using two econometric approaches: hedonic pricing and probit models. The hedonic model is used to determine the marginal contributions of wine attributes (including VQA certification) to the market price of wine. Clearly not all wineries choose to pursue VQA certification on all their wines. Therefore, to identify who would choose VQA and factors that would influence a winery's decision whether or not to seek

VQA certification for a specific wine, a Probit analysis was carried out. A major assumption in the models is that the error term is independently and identically distributed with zero mean and constant variance, which supports OLS but does not work for a panel data analysis where the error term is assumed to be uncorrelated with the independent variables (i.e. *strict exogeneity* assumption). This assumption implies that the OLS estimates of the models will be unbiased.

3.3.2.1 Hedonic Pricing Model

The hedonic pricing model has been widely employed in wine research in the economics literature to estimate the relationship between the price of wine and its underlying attributes (Rosen, 1974).

The theoretical foundation of hedonic studies, which has served as a basis for all studies that utilize hedonic analysis, is Lancaster's (1966) consumer theory and Rosen's classic paper of 1974. In hedonic pricing analysis, the price (market value) of a product or good is determined by estimating the contributory market values of each of the attributes associated with that good. It is therefore used to estimate the price differential of goods based on their characteristics. A prime example is the price differential between a wine that has certification for quality and one that did not pass through a quality assurance system.

In a competitive market where information on products' attributes and quality signals are available, it is expected that price should have a strong relationship with quality (Combris *et al.* 2000). However, the choice of appropriate functional form in hedonic price analysis remains an issue of concern in the literature (Linneman, 1980; Halvorsen and Pollakowski, 1981, Cropper *et al.,* 1988; Coelli *et al.,* 1991, Halstead *et al.,* 1997) as economic theory provides little guidance on the choice of a particular functional form for hedonic price analysis (Butler, 1982; Walpole and Lockwood, 1999). Choice of appropriate functional form is very important as incorrect functional form could result in parameter estimates that are inconsistent (Goodman, 1978; Bloomquist and Worley, 1981). Hedonic pricing models assume several functional forms, including linear and nonlinear forms. Several studies have utilized different functional forms chosen using certain criteria. For example, Rosen (1974) assumes a non-linear relationship, which was chosen using "goodness-of-fit criterion" determined by a likelihood ratio test that was derived through a flexible Box-Cox transformation (Box and Cox, 1964). This was widely used by early studies that applied hedonic pricing models (e.g. Rasmussen and Zuehlke, 1990).

There were many critics of the goodness-of-fit criterion adopted by Rosen (1974). For example, Cassel and Mendelson (1985) argue that a Box-Cox transformation does not give an accurate estimate of the implicit marginal price of each attribute, while Linneman (1980) maintained that a Box-Cox transformation cannot be applied to binary (dummy) variables, which according to So *et al.* (1996) are often used to represent discontinuous factors or attributes. Recursive residual of Ordinary Least Squares (OLS) is another technique used to detect model misspecification in hedonic price analysis (Brown *et al.,* 1975). A suggested rule of the thumb is that if the hedonic price model is correctly specified, the recursive residuals would be normally, independently distributed with zero mean and constant variance, and the residuals will not sum to zero (Sumner, 1990).

Galpin and Hawkins (1984) argue that regression residuals are not suitable to detect model misspecification as they may be correlated, have the same variance, the scatter plots particularly for a large data set may not reveal useful information patterns, and their distribution is dependent on an observational matrix as the residuals will not be independently or identically distributed.

Another standard test for choice of functional forms in hedonic price models, which has been widely used in the literature (e.g. Oczkowski, 1994; Anglin and Gencay, 1996; Walpole and Lockwood, 1999; Kwong *et al.,* 2011) is the Ramsey Regression Equation Specification Error Test (Ramsey's RESET) (Ramsey, 1969). RESET is used to identify the correct functional form. This is a test of linear (null) against non-linear (alternative) functional form specifications, where the correct specification is not indicated. The functional form is tested with an F-test. If the F-statistic is greater than the F-critical value, we reject the null hypothesis of linear specification.

Misspecification of variables is another problem associated with hedonic pricing models. This could be in the form of omitting an important explanatory variable in the model (i.e. under-specification), which could yield biased and inconsistent estimates; or inclusion of an irrelevant explanatory variable (over-specification), which could give unbiased and consistent estimates that are inefficient (Chin and Chau, 2002). The latter may not be a serious problem as it does not affect properties of OLS estimators, although the included irrelevant variable may correlate with another variable thereby resulting in multicollinearity. The problem of misspecification could be avoided through the use of homogenous data set[59], which supports the use of the hedonic price technique (Chin and Chau, 2002).

In this paper, a hedonic price equation for Canadian wine is estimated to determine whether there is a premium for VQA certified wines. Several studies (e.g. Oczkowski, 1994; Combris *et al.* 2000; Schamel and Anderson, 2003; Fogarty, 2006; Rabkin and Beatty, 2007; Costanigro *et al.* 2007; Yang *et al.* 2009; Carew and Florkowski, 2010) have applied the hedonic technique to wine pricing. Wine is assumed to comprise a bundle of qualitative attributes, while the market value of a particular wine is assumed to be the summation of the implicit values of the individual attributes. The estimated value of each attribute measures the willingness to pay for that attribute.

As stated earlier, hedonic theory gives little guidance on the choice of specific functional form. The study therefore explored the two approaches (linear and log-linear) widely employed in the literature. Each approach has its unique characteristics. For example, for a linear hedonic price function, the marginal effect or price increase (premium) induced by a wine attribute will be constant for all levels of attributes affecting the price (Champ *et al.* 2003; p.353). On the other hand, interpretation of coefficients is easier in log-linear models since coefficients represent the percentage change in wine price as a result of a unit change in attributes (Rodriguez and Castillo, 2009).

The choice of the correct functional form for this study was based on classic econometric tests including: RESET for model specification and Breusch-Pagan and/or White's test for heteroscadasticity widely used in the literature on wine hedonic models. To reduce the possible effect of multicollinearity, a dataset with a large number of observations was used and the variables carefully defined and measured. In addition, a correlation analysis of the independent variables was carried out to test for multicollinearity. The result is shown in appendix 3.II.

[59]A homogenous data set is one that comes from a single source. For example, a data set for a single product (e.g. wine) in a province.

Previous studies on wine (e.g. Oczkowski, 1994; Landon and Smith, 1998; Combris *et al*., 2000; Ling and Lockshin, 2003; Schnettler and Rivera, 2003; Schamel and Anderson, 2003; Geve, 2005; Rabkin and Beatty, 2007; Cardebat and Figuet, 2009;Ortuzar-Gana and Alfranca-Burriel, 2010; Kwong *et al*., 2011) identify colour, region of origin, alcohol content, vintage, varietals, sweetness (sugar level) and winery as important attributes that influence wine prices. However, Rabkin and Beatty (2007), in addition to these also identified VQA certification as an attribute that affects the price of Canadian wines. Therefore, the choice of attributes for this study was informed by the research questions and the economics of wine literature. Of the attributes chosen for this study, the attribute of VQA certification is particularly of interest as the study seeks to determine whether VQA certification is associated with a price premium, and enhances the collective reputation of Canadian wines.

Following Brentari and Levaggi (2010), assume a brand of Canadian wine has "n" attributes that influence its price, implicitly described as:

$$X = (X_1, X_2, \dots, X_n) \tag{3.1}$$

where X represents an attribute. Given that the market price of the wine implicitly depends on the values of the attributes, equation (3.1) can be rewritten as

$$P(X) = P(X_1, X_2, \dots, X_n) \tag{3.2}$$

Equation (3.2) can be explicitly expressed as

$$P_i = \alpha_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i \quad i = 1, \dots, n \tag{3.3}$$

where,
P = Observable market retail price of a Canadian wine
X_i = Vector of attributes of wine *i* (discussed below)
n = Number of wine attributes
β_i = Estimated coefficient of attribute *i* (i.e.$\beta_i = \frac{\delta P}{\delta X_i}$)
ε_i =Stochastic error term that accounts for unobserved attributes

Functional form specification

Results for the standard tests (RESET for model specification error or incorrect functional form, Breusch-Pagan/Cook-Weisberg and White's tests for heteroscedasticity) are shown in Tables 3.1, 3.2, and 3.3 below.

Ramsey specification test

This test identifies model specification problems. In hedonic models, linear and non-linear functional forms are used. The RESET test is used to identify the appropriate functional form that gives a better interpretation of the relationship between the dependent and independent variables in the model. The null hypothesis is that the correct functional form is linear and the alternative is non-linear. The suggested decision rule is that at the 5 percent level, if the F-statistic is greater than the F-critical value (F-tab), we reject the null hypothesis that the true specification is linear and accept the alternative (non-linear). The test result shows that the non-linear form is significant at the 5 percent level (p-value less than 0.05) and the F-stat > F-tab indicating that the log-linear functional form appears to better describe the data.

Table 3.1: Ramsey RESET Specification Tests and Summary Statistics

Functional Form		P-Values (Pr > F)
Linear	RESET(2) ~ F(3, 1527) = 1.93	0.1547
	$R^2 = 0.1602$ $R^{-2} = 0.1561$	
	N = 1537 D.F = 1529	
Log-Linear	RESET(2) ~ F(3, 1527) = 50.40	0.0000
	$R^2 = 0.3129$ $R^{-2} = 0.3032$	
	N = 1537 D.F = 1530	

Data Source: Liquor Control Board of Ontario (LCBO), 2013.

Breusch-Pagan and White's general tests

Both Breusch-Pagan and White's general tests for heteroscedasticity were conducted. The reason is that there are different forms of heteroscedasticity including linear and non-linear. The Breusch-Pagan test specified by "*hettest*"[60] in Stata specifically identifies linear forms of heteroscedasticity, and therefore, does not work well for non-linear forms. The White's test (White, 1980) is a special case of Breusch-Pagan that can detect heteroscedasticity in non-linear functional forms. However,

[60] 'Hettest' in Stata was used because it has the advantage of testing all the variables in the model together.

in each case, the decision rule is that a smaller value of chi-square indicates that heteroscedasticity is probably not a problem. Based on the results of the three tests, the log-linear functional form gives a better predictive performance and is therefore used to analyze the data.

Table 3.2: Breush-Pagan/Cook-Weisberg Test for Heteroscedasticity

Functional Form	Hypothesis/Chi2	Prob> chi2
Linear	Ho: Constant variance Variables: Fitted values of wine price (price) Chi2(1) = 4404.66	0.000
Log-Linear	Ho: Constant variance Variables: Fitted values of wine price (lnprice) Chi2(1) = 36.48	0.000

Data Source: Liquor Control Board of Ontario (LCBO), 2013.

Table 3.3: White's Test for Heteroscedasticity

Functional Form	Hypothesis/Chi2	Prob> chi2
Linear	Ho: homoscedasticity Ha: unrestricted heteroscedasticity	0.000
Log-Linear	Chi2(24) = 4405.09 Ho: homoscedasticity Ha: unrestricted heteroscedasticity Chi2(24) = 34.62	0.000

Data Source: Liquor Control Board of Ontario (LCBO), 2013.

Having chosen the log-linear model for analysis, the dependent variable (observable wine retail price) in equation (3.3) is transformed into logarithmic form. This transformation will modify how the coefficients are interpreted. In this case, the coefficients will be interpreted as the percentage change in the price of the attribute. This implies that if the i^{th} attribute changes by one unit, the price of wine will change by approximately $\beta_i * 100$ percent.

Taking note of that, following Brentari and Levaggi (2010) and transforming equation (3.3), we have:

$$Ln(P_i) = \alpha_0 + \sum_{i=1}^{n} \beta_i X_i \quad i = 1, \dots, n \tag{3.4}$$

where,

$Ln(P_i)$ = Natural logarithm of wine price

β_i = Percentage change in price of i^{th} attribute (e.g. VQA certification over non-VQA wines)

i.e. $\frac{\delta P}{\delta X_i} = \beta_i * P$

Table 3.4 contains the list of variables included in the hedonic pricing model, their abbreviations, definitions, and how they are measured.[61]

Table 3.4: Definition and measurement of variables

Variable	Abbreviation	Definition	Measurement
Price	Price	LCBO retail price per unit (standard 750ml bottle size)[d] of wine	Continuous
Ln(Price)	Ln(Price)	Natural logarithm of wine price	Continuous. Icewines are sold in 200ml and 375ml bottles only. The price is therefore normalized to the standard 750ml base volume using [(750/bottle size)*Price]
VQA	VQA	Describes whether a wine received certification from VQA quality assurance.	Dummy variable.1= Certification and 0 = otherwise
Volume of wine supplied	Volume	This is the volume of wines in the data set supplied by a winery to the Ontario retail market.	Classified into large (≥1000 cases), medium (500~999 cases), small (200~499 cases) and very small (≤ 200 cases). A case contains 12 standard 750ml bottles of wine. Dummy variables are used for each volume category (1 = volume; 0 = otherwise). *Very small* volume is used as the base category in the regression.
Wineries	wineries	These include individual wineries in the data set	The six biggest (in terms of volume of wines produced) wineries were represented individually while the remaining were grouped as “others”. *Others* is used as the base (reference category) for each regression.
Colour	Colour	Different wine colours and/or types which consumers consider important in making purchase decisions. For wines sold in Ontario, they are classified based on the following types: red, white, rose, sparkling and icewine.	Dummy variables are used for each colour (1= colour; 0 = otherwise). *Rose* is used as the base colour.
Region	Region	This describes appellation of origin (i.e. the region where a wine is produced).	Dummy variables are used for each region – Niagara, Lake Erie, Prince Edward County and Okanagan (BC) (1 = region; 0 = otherwise). *BC* is used as the base region for each regression.
Varietal	Varietal	Defines the type of grape variety used in wine production in Ontario. Blend represents a mixture of (non-single) varietals.	Dummy variable is used for each varietal and the following varieties are controlled for: Chardonnay; gewürztraminer; Riesling; sauvignon

61 Since the dependent variable of the hedonic model is in logarithm form, the independent variables that are not in logarithmic form (dummy variables) are interpreted as exponent of the estimated coefficients. That is, wine price changes by 100($e^{\beta i}$ -1)% for a unit increase in any of the independent dummy variables (Halvorsen and Palmquist, 1980).

			blanc; blend; pinot grigio and pinot gris (1 = varietal; 0 = otherwise for white wine)[a], while blend; cabernet franc; cabernet sauvignon; gamay noir; merlot; pinot noir and syrah/shiraz (1 = varietal; 0 = otherwise for red wine)[b]. For the individual regressions, *Pinot noir* is used as the base varietal for red wines, *chardonnay* for white, and *cabernet franc* for icewine in the regression for each wine type/colour.
Ln(alcohol) content	Alcohol%	Percentage of alcohol in the standard 750ml bottle of wine.	Continuous. Exact number indicated on the bottle
Vintage	Vintage	Year of wine production. This shows the different years each wine distributed was produced.	Dummy variable (1 = vintage for a particular year under consideration; 0 = otherwise). ≤ 2005 is used as the base year
Sweetness	Sweetness	Amount of sugar in the wine. Each wine sold in Ontario has a sweetness code – sweet (S), medium sweet (MS), dry (D), medium dry (MD) and extra dry (XD)	Categorical variable for the pooled regression and dummy variable for individual regressions.[e] Measured on a 5-point scale (XD=5; D=4; MD=3; MS=2; and S=1) for the pooled regression and dummy for different levels in individual regressions. For individual wine regressions, *extra dry* is used as the base sugar level.
LCBO Product score[c]	Prod. Score	Rating given by the LCBO wine experts. A maximum score of 5 points is given.	3.0-5.0 points are measured as 'high' and below 3.0 are measured as 'low'. Dummy (1 = high; 0 = low)

Notes: [a,b]Other varietals that are not listed are grouped as 'others' and are therefore, assigned zero

[c]Many of the wines do not have product score and such observations were dropped.

[d]icewines are sold in 200ml and 375ml bottles

[e]Measuring 'sweetness' as a categorical variable for individual regressions would result in few observations and loss of degrees of freedom. It was measured as a series of dummy variables to have more observations and degrees of freedom, as well as to capture the effects of different levels of sweetness (dry, extra dry, medium dry, etc) for the individual regressions.

It is important to note that the VQA label is voluntary. The decision of whether to choose VQA potentially starts from the vineyard as part of the vineyard's problem. In this case, the vineyard chooses the type of grape to plant and other production and/or management practices to adopt. The question that arises is whether vineyards/wineries seek VQA for high priced wines or whether VQA certification leads to high wine prices. A test of endogeneity (causality test) is carried out using the Hausman specification or *t*-test in section 3.4.2 to resolve this issue.

The summary tables with descriptive statistics of Canadian wine prices sold in Ontario according to colour/type, VQA certification, region, varietals and the volumes of wines produced by different categories of wineries are presented in Tables 3.5 and 3.6.[62] Table 3.5 shows that 87.18 percent (1340 of 1537) of wine samples in the data set have VQA certification while 12.82 percent (197of 1537) have no VQA certification. Further, on average, the price of red, white, ice and sparkling VQA wines appear to be higher than their non-VQA counterparts in the same category. In addition, red and white wines comprise 86.21 percent of the total sample while ice, rose and sparkling wines constitute the remaining 13.79 percent (212 of 1537).

Within the VQA category, icewine commands the highest price followed by red, white and sparkling wines respectively. The difference in price presumably is attributed to processing and grape production costs, and demand (Rabkin and Beatty, 2007). Icewine takes more time to produce, the process is very rigorous and requires specific climatic conditions, as described earlier.

The high price of Canadian icewine, both in domestic and international markets, potentially could be the reason why all the icewines in the sample passed through the VQA certification system. There are 172 wineries in the dataset with large, medium, small and very small wineries (by Ontario sales volume) comprising 1.74, 4.06, 19.77 and 74.43 percent respectively.

[62] Data was sourced from Ontario LCB but about 10 percent of the wines are from BC. Thus, the actual volume of wine produced by each of the BC wineries in the dataset was not accurately captured. Hence, a large winery, such as, “Mission Hill” falls under the category of small wineries in terms of the volumes supplied to the Ontario market.

Table 3.5: Canadian wine prices by colour/type, VQA certification status, varietal and sales volume

Certification status	Varietal	No. of observations	Mean (CAD$)	Min (CAD$)	Max (CAD$)	Std. Dev
Red wines						
VQA	Cabernet franc	60	25.61	10.95	110	15.71
	Cabernet sauvignon	38	27.17	11.95	75.2	13.46
	Gamay noir	18	17.65	9.45	29.95	6.18
	Merlot	62	23.71	10.95	81.95	13.29
	Pinot noir	97	30.27	9.95	75.00	13.71
	Syrah/shiraz	26	25.66	10.95	48.2	10.24
	Blend	224	22.28	3.5	93.95	14.57
	Others[1]	22	22.81	9.95	48.2	11.99
Non-VQA	Cabernet sauvignon	9	17.62	7.20	42.95	13.91
	Merlot	11	19.14	7.95	39.95	12.46
	Pinot noir	1	10.95	10.95	10.95	-
	Syrah/shiraz	11	19.77	8.95	42.95	13.64
	Blend	43	16.45	3.60	40.95	9.14
	Others[2]	1	10.95	10.95	10.95	-
White wines						
VQA	Chardonnay	235	24.31	3.95	71	11.99
	Gewurztraminar	34	17.49	7.95	29.95	5.69
	Riesling	122	18.04	8.70	35.20	6.07
	Sauvignon blanc	44	17.28	3.50	34.95	5.33
	Pinot grigio	15	13.97	4.95	21.00	3.54
	Pinot gris	21	19.38	13.95	35.00	4.63
	Blend	92	15.31	7.95	48.20	5.79
	Others[3]	45	18.50	8.25	40.15	6.89
Non-VQA	Chardonnay	14	21.15	3.45	41.95	14.03
	Gewurztraminar	2	15.2	10.45	19.95	6.72
	Riesling	3	20.97	9.95	36.95	14.17
	Sauvignon blanc	12	17.5	6.95	38.95	12.54
	Pinot grigio	16	18.43	6.95	42.95	11.32
	Blend	41	19.92	6.45	39.95	9.99
	Others[4]	6	16.96	9.45	35.95	9.16
Ice-wines						
VQA	Cabernet franc	15	119.99	63.4	206.06	35.71
	Riesling	19	114.12	74.81	159.90	25.18
	Vidal	41	91.08	29.90	159.90	27.34
	Cabernet sauvignon	4	187.63	93.38	399.90[a]	143.61
	Others[5]	13	134.24	63.90	229.95	41.83
Rose wines						
VQA	Rose	45	15.00	7.95	34.95	3.93
Non-VQA	Rose	10	15.45	7.95	32.95	9.08
Sparkling wines						
VQA	Sparkling	48	25.12	11.70	44.95	7.98
Non-VQA	Sparkling	17	14.42	5.90	78.00	16.77
Total		1537				
Region						
Ontario		1381	22.79	3.45	199	14.71
BC		156	28.55	7.95	99.95	16.30
Volume of wines supplied (in the Ontario market)						
Category	Large	3		1075	1527	232.03
	Medium	7		542	850	123.07
	Small	34		206	443	78.69
	Very small	128		8	197	52.28
Total wineries		172				
%Alcohol content		1331	12.49	6.50	15.90	1.13

Vintage						
Category	≤2005	35	n/a	n/a	n/a	n/a
	2006	40	n/a	n/a	n/a	n/a
	2007	93	n/a	n/a	n/a	n/a
	2008	112	n/a	n/a	n/a	n/a
	2009	158	n/a	n/a	n/a	n/a
	2010	153	n/a	n/a	n/a	n/a
	2011	74	n/a	n/a	n/a	n/a
	2012	266	n/a	n/a	n/a	n/a
Sweetness						
Category	Sweet (S)	64	n/a	n/a	n/a	n/a
	Medium sweet (MS)	124	n/a	n/a	n/a	n/a
	Medium Dry (MD)	2	n/a	n/a	n/a	n/a
	Dry (D)	601	n/a	n/a	n/a	n/a
	Extra dry (XD)	538	n/a	n/a	n/a	n/a

[1]Includes: baco noir, malbec, marechal foch, nebbiolo, petit verdot, and pinot meunier.
[2]Includes: moscato
[3]Includes: aligote, auxerrios, chenin blanc, fume blanc, moscato, pinot blanc, Semillon, seyval blanc, vidal, and viognier
[4]Includes: moscato and vidal
[5]Includes: blend, chardonnay, chenin blanc, gewurztraminar, muscat, pinot blanc, sauvignon blanc, Semillon, and syrah/shiraz.
[a]Produced using muscat grape variety, the oldest domesticated grape

A breakdown of the totals according to wine colour or type and summary statistics of data on the price of red, white, ice, rose and sparkling wines are shown in Table 3.6. The table shows that a greater percentage of the wines in the dataset (87.8% of red, 86.61% of white, 81.82% of rose and 73.85% of sparkling) have VQA certification, while all the icewines are certified by VQA. Icewine has the highest average price (CAN$115.38), while rose wines have the lowest average price (CAN$15.08) per 750ml bottle.

Table 3.6: Summary statistics of wines by colour/type

Colour	No. of obs.	VQA	Non-VQA	Mean (CAN$)	Min. (CAN$)	Max. (CAN$)	Std. dev. (CAN$)
Red	623	547	76	24.47	3.50	150.00	16.17
White	702	608	94	20.05	3.45	154.00	10.91
Ice	92	92	0	115.38	29.90	399.90	56.97
Rose	55	45	10	15.08	7.95	34.95	5.13
Sparkling	65	48	17	22.31	5.90	78.00	11.81
Total	1537	1340	197	N/A	N/A	N/A	N/A

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Note: N/A = Not applicable

The hedonic price equation for Canadian wines sold in Ontario is therefore, stated as follows:

$$Ln(Price) = \alpha_0 + \beta_i VQA + \ln(alcohol\%) + \sum_{j=1}^{J} \beta_j Colour_j + \sum_{k=1}^{K} \beta_k Region_k \sum_{l=1}^{L} \beta_l Varietal_l$$
$$+ \beta_m Sweetness_m + \sum_{n}^{N} \beta_n Vintage_n + \sum_{p}^{P} \beta_p Volume_p + \sum_{q}^{Q} \beta_q Winery_q \qquad (3.5)$$

The variables included in this model help address the research questions. For example, the coefficient of VQA status is used to determine whether there is a premium for VQA certified wines. Wineries and regions (appellation of origin) are included in the model in order to separate the effect of individual and collective reputations on the price of wine, while other variables are believed to be relevant attributes that would influence the price of wine. The data set provided only the names of wines. The researcher used these names to identify the wineries and regions of production for each wine. This is how the variables, *region* and *winery*, were created to separate the effect of individual and collective reputations on the price of wines. The variable, *volume of wine supplied*, was constructed using the volume of wine supplied by wineries to the Ontario retail market for sale.

An additional attribute, product score, was initially included in the model. This is a third party subjective judgment which gives an indication of quality assessment by wine experts (some of whom are local wine writers/critics selected by the LCBO) and this presumably would have a direct relationship with wine price. Product score serves to provide information for consumers in helping them make a more informed purchase decision "as an expert has tasted and endorsed the product."[63] For some wines in the data set, the product scores range from 1 to 100 percent, while for others, they rank them between 1 and 5. For consistency, however, all the scores were converted to a 5-point scale.[64]

This variable was eventually dropped from the hedonic model for several reasons. First, of the 1537 observations, only 302 (19.6 percent) observations have product scores. Of the 302 observations with this attribute, 298 are VQA wines, while only 4 are non-VQA wines. When

[63] Personal communication with LCBO, September 2014.

[64] For wines with product scores ranging from 1 to 100 percent, the scores were converted to a 5-point scale by dividing the posted score by 100 and multiplied by 5.

LCBO was contacted, they confirmed that this was not a coincidence. Wines exclusively released for experts' ranking are mostly VQA than non-VQA and International Canadian Blends (ICBs)[65] suggesting that product score is biased towards VQA wines. Second, a greater percentage of non-VQA wines are blends of imported and domestic grown grapes, hence most wines submitted by wineries for experts' evaluation are wines of origin (often VQA). Third party ratings are mostly used in marketing wines of origin (wines produced in a particular region).[66] Third, when the data were sorted based on product score, there were very few observations (less than 10 for rose and sparkling wines) left for the regression, which would affect the degrees of freedom.

Taking note of these issues, a correlation analysis and hedonic model estimation were carried out on the data sorted based on "product score." In the two analyses, the variable, product score, correlates closely with "VQA", which suggests that experts' ranking of Canadian wines sold in Ontario favours mostly VQA wines. In addition, only one variable (percentage alcohol content) was statistically significant in the result of the hedonic model for the sorted data based on "product score". These issues, therefore, informed the decision to drop the variable from the model.

3.4 Empirical results and discussion

3.4.1 Hedonic model

The hedonic price regression was carried out in two stages. The first stage is the general (pooled) regression that shows the effect of VQA certification on the price of different types/colours of wine.[67] The second stage involves individual regressions for red, white, ice, rose and sparkling wines respectively, showing grape varieties used for each type and years of production (vintages).[68] To avoid the problem of the dummy 'variable trap' (collinearity between dummy variables), a reference (base category) is used for each set of dummy variables in the same category. However, the choice of the base category is arbitrary. The estimated coefficient of the reference dummy variable is used as a comparative benchmark – coefficients of other dummy variables within the same category are interpreted relative to the base category (Ling and Lockshin,

[65] ibid

[66] Personal communication with VQA office in Ontario, September 2014.

[67] Each wine type/colour has a separate column on the spreadsheet and a dummy variable (1 for any wine with the colour under consideration and 0 otherwise) is used.

[68] The data were sorted based on these colours and each category was used for an individual regression.

2003; Troncoso and Aguirre, 2006; Gujarati and Porter, 2009, p.281). Further, following Halvorsen and Palmquist (1980), the coefficient of each dummy variable in the hedonic model is interpreted as a semi-elasticity obtained by subtracting 1 from the anti-log of the estimated coefficient of the dummy variable, and multiplying by 100%. That is: $100[e^{\beta_i} - 1]\%$.

VQA signifies quality, authenticity and origin. To capture these reputation effects and also separate the effect of individual and collective reputation on the price of wine, attributes of origin (the wine-growing region) and individual wineries were included at every stage of the hedonic regression. Further, different levels of sweetness were included in the individual regressions for red, white and sparkling wines in order to identify the sweetness level that significantly affects the price of wine. Some observations for the variable "sweetness" were missing in the data; hence such observations were dropped to avoid problems arising from missing data.[69] The hedonic regression results are shown below.

Red, white, ice, rose and sparkling wines (pooled):
Table 3.7 shows the hedonic model results for the pooled regression (first stage as indicated earlier). The dependent variable of the hedonic model is in logarithm form. Therefore, independent variables that are binary (and non-logarithm) are interpreted as exponents of the estimated coefficients as indicated above. This implies that wine price changes by [100($e^{\beta i}$ -1) %] for a unit increase in any of the independent dummy variables. The results show that the estimated coefficient for VQA certification is positive and significant at the 1 percent level. This reveals that collectively there is a premium for VQA wines sold in Ontario. The result indicates that on average, the price of VQA wines sold in Ontario is 16.72 percent higher than non-VQA wines.

The results further show that alcohol content and sweetness have positive and significant influences on the price of wine at the 1 and 5 percent levels respectively. The effect of percentage alcohol content represents an increase of 10.64 percent in the price of wine for a 1 percent increase in alcohol content. The result suggests that as wines get drier (moving up the 1 to 5 scale), the premium increases. Ice, red, sparkling and white wines have positive and significant effects on

[69] This is the reason why the number of observations in the pooled and individual regressions is less than the numbers in Table 3.6.

price relative to rose wines that have the lowest average price and number of sales in the data set. Further, Niagara wines are discounted relative to the base category (BC wines). The average price of BC wines in the dataset is $5.75 (20.14 percent) higher than Ontario wines (Table 3.5). A surprising observation during a casual survey of some wine stores in Ontario is that most BC wines sold in Ontario are high priced wines. A possible explanation for this is the inter-provincial restriction on wines and/or presumably it may be more economical to ship higher priced wines to Ontario given transportation costs. The results also show that most individual winery coefficients are not statistically significant.

Table 3.7: Parameter estimates for hedonic function - type/colour of wine (pooled regression)

Variable	Level	Coef (β)	$(e^{\beta i}$ -1)100%	Std. error	Pr(>|t|)
Intercept		3.6316***		0.4331	0.000
VQA		0.1546***	16.72	0.0839	0.000
Ln(alcohol)		0.1064***		0.0213	0.002
Sweetness		0.0492*		0.0222	0.027
Colour/type	Icewine	0.9799***	98.01	0.1440	0.000
	Red	0.2998***	34.96	0.1057	0.000
	Rose	base	base	base	base
	Sparkling	0.2350***	26.49	0.1479	0.000
	White	0.2905**	33..71	0.1035	0.005
Region	Niagara Peninsula	-0.1552**	-14.38	0.0489	0.002
	Prince Edward county	0.0636	6.57	0.0741	0.391
	Other Ontario	-0.1871*	-17.06	0.0777	0.016
	Lake Erie North Shore	-0.2361	-21.03	0.1367	0.085
	British Columbia	base	base	base	base
Vol. supplied[a]	>1000 cases (large)	-0.1528	-14.17	0.0921	0.098
	500 < X^1 ≤ 1000 (medium)	0.0947	9.93	0.1225	0.419
	500< X ≤ 200 (small)	0.1130**	11.96	0.0357	0.002
	0< X ≤ 200 (very small)	base	base	base	base
Wineries	Henry of Pelham	-0.2217	-19.88	0.1842	0.229
	Jackson-Triggs	-0.2165	-19.47	0.1598	0.176
	Cave Springs	-0.5019	-39.46	0.5083	0.324
	Peller Estates	0.4168**	51.71	0.1412	0.003
	Pelee Island	0.0025	0.25	0.2019	0.990
	Inniskillin Wines	0.2174	24.28	0.1290	0.093
	Others[b]	base	base	base	base
vintage	≤ 2005	base	base	base	base
	2006	-0.5220***	-40.67	0.1023	0.000
	2007	-0.4169***	-34.09	0.0887	0.000
	2008	-0.5377***	-41.59	0.0858	0.000
	2009	-0.4327***	-35.12	0.0853	0.000
	2010	-0.5045***	-39.62	0.0854	0.000
	2011	-0.6915***	-49.92	0.0931	0.000
	2012	-0.6491***	-47.75	0.1242	0.000
R^{-2}	0.3329	n/a	n/a	n/a	n/a
F-statistics	18.82	n/a	n/a	n/a	0.000
N	662	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
n/a = Not applicable

[a]X = Number of cases

[b]These include individual wineries that supply less than 700 cases of wine.

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Further, small wineries (defined by volume of sales in the Ontario market) sell their wines at a price about 11.30 percent higher relative to very small wineries (the base category). The results also show that the year a wine is produced has a significant influence on its price. The intercept is positive and significant indicating that the mean value of wine price is statistically different from zero when the marginal values of all attributes are zero. The adjusted R-squared is reasonably high for a hedonic model, indicating that the variation in wine price is well explained by the attributes included in the model.

To separate the effect of VQA from other forms of collective reputation (winery sub-region and province, and individual winery), three separate hedonic regressions were run including VQA at every stage while controlling for individual winery and collective reputation (regional) using the pooled data. The idea is that it is possible that winery and sub-region, sub-region and province, etc may be correlated. The models include:

1) a model that includes province (Ontario and BC)[70] but no winery region or winery;
2) a model that includes winery region (but not winery); and
3) a model that includes winery (but not winery region)

The results are shown in Appendices 3.III (a), 3.III (b) and 3.III (c) and show that the estimated coefficient for VQA is positive and significant at the 1 percent level in all the models. When region (province) was included and winery dropped (Appendix 3.III (a)), the goodness of fit reduced by 18.68 percent compared to the R^{-2} reported in Table 3.7 (the model with VQA, region and winery). In addition, the R^{-2} for the second (Appendix 3.III (b)) and third (Appendix 3.III(c)) models are 10.48 and 9.37 percent respectively less than that of Table 3.7. The estimated coefficients for the Niagara Peninsula and Lake Erie North Shore sub-regions in Ontario are negative but statistically significant at 5 and 10 percent respectively relative to BC. This suggests that regional (collective) reputation has an effect on the price of wine. Further, when region was dropped and winery included (Appendix 3.III(c)), the estimated coefficients of two wineries, Peller estates and

[70] In this regression, Ontario sub-regions were aggregated.

Inniskillin wines, are positive and significant at 10 and 5 percent respectively relative to other wineries (others) in the data set. This also indicates that individual wineries' reputations have an effect on the price of wine, separate from the VQA reputational effect.

The positive and significance of the VQA variable in all three regressions (models) implicitly shows the value of VQA as a collective reputation signal. The VQA result is robust across the three model formulations. This suggests that the collective reputation signal of VQA seems to be fairly consistent. Comparing the size of VQA coefficient across the models, the model that includes VQA and region (Appendix 3.III (b)) has the largest VQA coefficient, followed by the model with winery (Appendix 3.III(c)). This suggests that although collective reputation and individual winery reputation are important and have significant effects on wine price, collective reputation appears to have a larger effect on the price of wine relative to individual winery reputation, holding everything else constant.

Red wines

The hedonic regression result for red wines is shown in Table 3.8. The results show that the estimated coefficient for red wines with VQA certification is positive and statistically significant at 1 percent, indicating that VQA red wines command a price premium (21.42 percent higher than the non-VQA base red wines, holding all other factors constant). The results further show that the estimated coefficient for medium dry (level of sweetness) is positive and significantly affects the wine price. Medium dry red wines are about 4.16 percent higher in price relative to extra dry red wines. This suggests that consumers' have a higher willingness to pay for medium dry red wines relative to extra dry red wines.

Further, the coefficient on alcohol content is positive and has a significant effect on the price of red wines in Ontario. A closer look at the data set and survey of wine stores shows that the higher the percentage alcohol contents of a wine, the higher tends to be the price, therefore this result confirms *a priori* expectations. This is particularly the case for red dessert wines.[71] Table 3.8 also

[71] For example, the price for a 750 ml bottle of "*Sand Hill*" red wine with 13% alcohol content is $30 while the price for 13.5% of another wine from the same winery ranges between $45 and $75. In addition, "*Inkameep*" red wines with 14% alcohol sells for $20.35 while another wine from the same winery with 14.5% sells for $51.45. Percentage alcohol content may be one factor that explain this difference in price.

indicates that the coefficient for wineries with small volume of sales in the Ontario market is positive and significantly affects the price of red wines relative to wineries with very small sales volume.

Table 3.8: Parameter estimates for hedonic function - red wines

Variable	Level	Coef. (β)	$(e^{\beta i}$ -1)100%	Std. error	Pr(>|t|)
Intercept		-3.2275*		1.3247	0.015
VQA		0.1941***	21.42	0.0872	0.000
Ln(alcohol)		0.0989***		0.0444	0.000
Sweetness	Dry	-0.0510	-4.97	0.0538	0.344
	Medium dry	0.0408***	4.16	0.0152	0.000
	Extra dry	base	base	base	base
Region	Niagra Penninsula	-0.0885	-8.47	0.0822	0.282
	Prince Edward county	0.1456	15.67	0.1223	0.235
	Other Ontario	-0.1092	-10.34	0.1177	0.354
	Lake Erie North Shore	-0.0757	-7.29	0.1644	0.646
	British Columbia	base	base	base	base
Vol. supplied[a]	>1000 cases (large)	-0.2473	-21.91	0.1553	0.112
	500 < X[1] ≤ 1000 (medium)	0.1867	20.53	0.4746	0.694
	500 < X ≤ 200 (small)	0.1394*	14.96	0.0565	0.014
	0 < X ≤ 200 (very small)	base	base	base	base
Wineries	Henry of Pelham	-0.2793	-24.37	0.5177	0.590
	Jackson-Triggs	-0.3720	-31.06	0.4983	0.456
	Cave Springs	-0.3400	-28.82	0.4355	0.436
	Peller Estate	0.5729*	77.34	0.2337	0.015
	Pelee Island	0.0444	4.54	0.2705	0.870
	Inniskillin Wines	-0.1232	-11.59	0.2447	0.615
	Others (base)	base	base	base	base
Varietals	Cabernet franc	-0.1486	-13.81	0.0894	0.098
	Cabernet sauvignon	-0.2375*	-21.14	0.0976	0.016
	Gamay noir	-0.1978	-17.95	0.1669	0.237
	Merlot	-0.2711**	-23.75	0.0864	0.002
	Pinot noir (base)	base	base	base	base
	Syrah/shiraz	-0.2848***	-24.78	0.1087	0.009
	blend	-0.1587*	-14.67	0.0712	0.027
	others	-0.5870***	-44.40	0.1434	0.000
Vintage	≤2005	base	base	base	base
	2006	-0.5469***	-42.13	0.1557	0.001
	2007	-0.1925	-17.51	0.1195	0.108
	2008	-0.4150***	-33.97	0.1243	0.001
	2009	-0.2774*	-24.22	0.1223	0.024
	2010	-0.3741**	-31.21	0.1213	0.002
	2011	-0.5870***	-23.78	0.1434	0.000
R^{-2}	0.3180	n/a	n/a	n/a	n/a
F-statistics	15.53	n/a	n/a	n/a	0.000
N	317	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
n/a = Not applicable
[a]X = Number of cases

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Taking pinot noir as a reference category for red wine grape varieties, cabernet sauvignon, merlot and blended red wines have about 21.14, 23.75 and 14.67 percent lower prices respectively relative to pinot noir red wines in the dataset. Comparing the results of this model with that of the pooled regression with respect to the measurement of individual and collective reputation, VQA is the only collective reputation signal that has a significant influence on the price of red wines. Regional reputation does not have significant influence, and only one individual winery reputation (Peller Estate) has a significant effect on the price of red wines. Nevertheless, comparing the size of the coefficients, the magnitude of the coefficient for the individual winery reputation is larger relative to collective reputation (VQA). The adjusted coefficient of multiple determination indicates that about 31.80 percent of total variation in the price of red wines is explained by the model.[72]

White wines

White wines constitute about 46 percent of the total wine in the sample, while about 87 percent received VQA certification. The result of the hedonic regression for white wine is shown in Table 3.9. The estimated coefficient for VQA is positive and statistically significant at the 5 percent level. This indicates that the price of VQA white wines is 13.58 percent higher than the non-VQA base white wines. In addition, coefficients for attributes such as alcohol content and vintage have a significant effect on the price of white wine, as is the case in the previous models. Of the three levels of sweetness, dry and medium dry attributes tend to have a negative price effect relative to extra dry wines, with medium dry having a significant negative effect. The estimated coefficients for the gewürztraminer and sauvignon blanc grape varieties are negative respectively and significantly affect the price of white wine relative to chardonnay.

The results further indicate that only VQA (collective reputation signal) has a significant effect on the price of white wine, while individual winery reputation and other collective reputation measures (region) have no significant effect on the price of white wines. Vintage significantly

[72] The coefficient of multiple determination (R^2) for most hedonic models is usually below 50 percent. Some factors affect the magnitude of R^2 including: sample size, range of values of the independent variables and replicated values of the dependent and independent variables (Cornell and Berger, 1987). Most hedonic models use non-linear functional forms with low values of independent variables (product attributes). For this study, the prices and alcoholic content of some wines in the dataset are the same and some of the attributes are dummy variables. This potentially may have resulted in a low R^2.

affects the price of white wines. The coefficients for white wines produced after the year 2005 are negative and significant relative to white wines produced in or before 2005, suggesting that older white wines are at a premium relative to newer white wines.

Table 3.9: Parameter estimates for hedonic function - white wines

Variable	Level	Coef.(β)	$(e^{\beta i} -1)100\%$	Std. error	Pr(>|t|)
Intercept		2.6081**		0.8750	0.003
VQA		0.1094*	13.58	0.0548	0.017
Ln(alcohol)		0.2030***		0.5254	0.000
Sweetness	Dry	-0.0155	-1.54	0.0439	0.723
	Medium dry	-0.1254*	-11.79	0.12965	0.013
	Extra dry	base	base	base	base
Region	Niagara Peninsula	-0.0051	-0.51	0.0697	0.941
	Prince Edward county	0.1048	11.05	0.1010	0.300
	Other Ontario	0.0136	1.37	0.1193	0.909
	Lake Erie North Shore	-0.2228	-19.97	0.3506	0.526
	British Columbia (base)	base	base	base	base
Vol. supplied[a]	>1000 cases (large)	-0.1235	-11.62	0.1355	0.363
	$500 < X^1 \leq 1000$ (medium)	0.0635	6.56	0.0337	0.060
	$500 < X \leq 200$ (small)	0.0859	8.97	0.0470	0.069
	$0 < X \leq 200$ (very small)	base	base	base	base
Winery	Henry of Pelham	-0.5080	-39.83	0.3404	0.137
	Jackson-Triggs	-0.6470	-47.64	0.3954	0.103
	Cave Springs	-0.4593	-36.83	0.3983	0.250
	Peller Estate	0.1692	18.43	0.1860	0.364
	Pellee Island	0.2674	30.66	0.4275	0.532
	Inniskillin Wines	-0.0091	-0.91	0.2034	0.964
	Others (base)	base	base	base	base
Varietals	Chardonnay	base	base	base	base
	Gewürztraminer	-0.2179**	-19.58	0.0834	0.008
	Riesling	-0.0653	-6.32	0.0723	0.367
	Sauvignon blanc	-0.2759***	-24.11	0.0761	0.000
	Pinot grigio	-0.2454	-21.76	0.1766	0.166
	Pinot gris	-0.1311	-12.28	0.1049	0.212
	blend	-0.1023	-9.72	0.0962	0.281
	others	-0.1067	-10.12	0.0811	0.189
Vintage	≤ 2005	base	base	base	base
	2006	-0.7297***	-51.79	0.1712	0.000
	2007	-0.7795***	-54.13	0.1489	0.000
	2008	-0.7464***	-47.36	0.1435	0.000
	2009	-0.6417***	-49.55	0.1366	0.000
	2010	-0.6842***	-55.86	0.1370	0.000
	2011	-0.8179***	-55.86	0.1444	0.000
	2012	-0.8216***	-56.03	0.1447	0.000
R^{-2}	0.3201	n/a	n/a	n/a	0.000
F-statistics	12.16	n/a	n/a	n/a	n/a
N	291	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
n/a = Not applicable
[a]X = Number of cases

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Other wine types

The regression results for ice, rose and sparkling wines (see appendices 3.IV, 3.V and 3.VI) show that the estimated coefficient for VQA is positive but not significant for the three wine types respectively. There are very few observations in the rose and sparkling wine regressions, hence there was not enough degrees of freedom in these models which may be affecting the results. Thus, these results should be treated with caution. VQA certification on icewine cannot be said to have a premium since all the icewines in the sample have VQA certification and there is nothing to compare with it. When the attribute VQA certification was dropped for icewine, the regression result gave virtually the same result (level of significance, R^{-2}).

Testing interaction effects

Some interactions were included in the model. The idea is that the magnitude of the effect of an independent variable on the dependent variable may depend on another independent variable included in the model. To determine whether VQA is important for specific grape varieties, the variable *VQA* was interacted with red wine varietals and a null hypothesis that VQA coefficients are equal for all varietal was tested. The results are shown in Table 3.10.

H_0: VQA coefficients are equal for every red wine grape variety

H_1: VQA coefficients are not equal for every red wine grape variety

$F_{cal}^{0.05}(30, 286) = 15.71$

$F_{tab}^{0.05}(30, 286) = 1.46$

Table 3.10 shows that although the coefficients of all the interaction variables are positive, none of them are statistically significant. The coefficients for the interaction variables differ relative to the base case. In addition, the hypothesis testing shows that at the 5% significance level, F-cal. > F-tab. The null hypothesis is therefore rejected. Hence, VQA coefficients are not equal for individual red wine grape varieties. The significance of the VQA variable suggests that jointly (i.e. for a particular type/colour of wine) VQA is important but does not depend on individual grape varieties.

Table 3.10: Parameter estimates for hedonic function (red wines) - interaction of varietals with VQA

Variable	Level	Coef. (β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		-3.4531*		1.3382	0.010
VQA		0.1078*	11.38	0.0438	0.014
Ln(alcohol)		2.6958***		0.5075	0.000
Sweetness	Dry	-0.0511	-4.98	0.0541	0.345
	Medium dry	-0.3602***	-30.25	0.0951	0.000
	Extra dry (base category)	base	base	base	base
Region	Niagra Penninsula	-0.0787	-7.57	0.0827	0.342
	Prince Edward county	0.1724	18.82	0.1243	0.167
	Other Ontario	-0.0919	-8.78	0.1183	0.438
	Lake Erie North Shore	-0.0617	-5.98	0.1649	0.709
	British Columbia(base)	base	base	base	base
Vol. supplied[a]	>1000 cases (large)	-0.2489	-22.03	0.1554	0.111
	500 < X[1] ≤ 1000 (medium)	0.1669	18.16	0.4753	0.726
	500 < X ≤ 200 (small)	0.1421*	15.27	0.0566	0.013
	0 < X ≤ 200 (very small) base	base	base	base	base
Wineries	Henry of Pelham	-0.2558	-22.57	0.5185	0.622
	Jackson-Triggs	-0.3558	-29.94	0.4990	0.476
	Cave Springs	-0.3317	-28.23	0.4361	0.448
	Peller Estate	0.5793*	78.48	0.2339	0.014
	Pelee Island	0.0480	4.92	0.2709	0.859
	Inniskillin Wines	-0.0969	-9.24	0.2457	0.694
	Others (base)	base	base	base	base
Varietals	VQA*Cabernet franc	0.2289	25.72	0.1551	0.141
	VQA*Cabernet sauvignon	0.1494	16.11	0.1604	0.353
	VQA*Gamay noir	0.1793	19.64	0.2108	0.396
	VQA*Merlot	0.1266	13.50	0.1513	0.403
	VQA*Pinot noir (base)	base	base	base	base
	VQA*Syrah/shiraz	0.1018	10.72	0.1639	0.535
	VQA*blend	0.2149	23.97	0.1429	0.134
	VQA*others	0.2278	25.58	0.1879	0.226
Vintage	≤2005 (base)	base	base	base	base
	2006	-0.5471***	-42.14	0.1560	0.001
	2007	-0.2045	-18.49	0.1200	0.089
	2008	-0.4147***	-33.95	0.1244	0.001
	2009	-0.2974*	-25.73	0.1232	0.016
	2010	-0.3854**	-31.98	0.1217	0.002
	2011	-0.5929***	-44.73	0.1437	0.000
	2012	-0.2786	-24.32	0.2288	0.224
R^{-2}	0.3189	n/a	n/a	n/a	n/a
F-statistics	15.71	n/a	n/a	n/a	0.000
N	317	n/a	n/a	n/a	n/a

Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
n/a = Not applicable
[a]X = Number of cases
Data source: Liquor Control Board of Ontario (LCBO), 2013.

The regressions (e.g. Appendices 3.III (a), 3.III (b) and 3.III(c)) in which individual and collective reputation signals are included as separate variables isolate the effect of the VQA quality signal. Therefore, to test the extent to which VQA and region might be complementary quality signals, the attribute *VQA certification* was interacted with *region of origin* in the pooled regression. The results show that the coefficients for interaction variables, *VQA*Niagara-Peninsula* and *VQA*Other-Ontario,* are positive and statistically significant at the 5 percent level. This suggests that VQA and region could serve as complementary collective reputation signal in these regions. This also indicates that VQA could signal quality and origin. This is shown in Table 3.11.

Table 3.11: Interaction of VQA with winery region in the pooled regression

Variable	Level	Coef (β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		2.0047**		0.6692	0.003
VQA		0.1607**	17.43	0.1346	0.006
Ln(alcohol)		0.6764**		0.2132	0.002
Sweetness		0.0262		0.0232	0.259
Colour/type	Icewine	1.0089***	174.26	0.1433	0.000
	Red	0.4589***	58.23	0.1057	0.000
	Rose	base	base	base	base
	Sparkling	0.5389***	71.41	0.1468	0.000
	White	0.2649*	30.33	0.1031	0.010
Region	VQA*Niagara Peninsula	0.1178*	12.50	0.0499	0.019
	VQA*Prince Edward county	0.1168	13.39	0.0755	0.122
	VQA*Other Ontario	0.1534*	16.58	0.0779	0.049
	VQA*Lake Erie North Shore	-0.2091	-18.87	0.1360	0.125
	VQA*British Columbia	base	base	base	base
Vol. supplied[a]	>1000 cases (large)	-0.1433	-13.35	0.0915	0.118
	500 < X ≤ 1000 (medium)	0.0947	9.93	0.1225	0.440
	500< X ≤ 200 (small)	0.1130**	11.96	0.0357	0.002
	0< X ≤ 200 (very small)	base	base	base	base
Wineries	Henry of Pelham	-0.2234	-20.02	0.1829	0.222
	Jackson-Triggs	-0.2271	-20.31	0.1587	0.153
	Cave Springs	0.1995	22.08	0.1119	0.075
	Peller Estates	0.3619*	43.61	0.1413	0.011
	Pelee Island	-0.0073	-0.73	0.2005	0.971
	Inniskillin Wines	0.2115	23.55	0.1281	0.099
	Others	base	base	base	base
Vintage	≤ 2005	base	base	base	base
	2006	-0.5166***	-40.35	0.1016	0.000
	2007	-0.4095***	-33.60	0.0881	0.000
	2008	-0.5230***	-40.73	0.0853	0.000
	2009	-0.4265***	-34.72	0.0847	0.000
	2010	-0.4977***	-39.21	0.0849	0.000
	2011	-0.6723***	-48.95	0.0926	0.000
	2012	-0.6089***	-45.61	0.1240	0.000
R^{-2}	0.3211	n/a	n/a	n/a	n/a
F-statistics	16.82	n/a	n/a	n/a	0.000
N	662	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
n/a = Not applicable

[a]X = Number of cases
Data source: Liquor Control Board of Ontario (LCBO), 2013.

Generally, the results of the series of hedonic models show that there is a premium for VQA certification, and the magnitude of the premium varies depending on the type of wine. In addition, attributes such as percentage alcohol content, sweetness and vintage have significant effects on the price of wine. Collective reputation and only one individual winery reputation significantly influence the price of wine but the magnitude of the effects are different for different types (colours) of wine.[73] However, while VQA as a collective reputation signal has the largest effect on the price of wine relative to other collective reputation signals (e.g. region), results show that VQA and winery region can serve as complementary collective reputation signals. Presumably this is the case for only some regions.

Comparing the magnitude of the coefficient of the VQA variable across the different models, the results show that the size of the coefficient for VQA fluctuates relative to the size of the coefficients of other variables in the model. This suggests that the magnitude of the effect of VQA certification on the price of wine is not larger than that of other variables across the models. For example, considering the models for red (Table 3.8) wines, the size of coefficient for wineries variable (Peller Estate) is 72 percent higher than that of the VQA coefficient. The implication of this result (for example to a winery) is that although VQA certification significantly influences the price of wine, for some wines individual winery reputation has a higher influence on the wine price relative to VQA certification. The next section examines a winery's decision to seek VQA certification for a specific wine using a Probit model.

3.4.2 Probit Model

A Probit model is a type of regression analysis in which the dependent (response) variable is binomial, and is based on the assumption that the functional form follows a normal (cumulative) distribution (Kim, 2013). Probit models are used to evaluate the probability of an outcome given a change in an independent variable. In the context of this study, a winery's decision to use or not to use VQA certification is based on a vector of factors[74], X, including: price of VQA certified

[73] Only few wineries are used to represent individual reputation.

[74] These factors could be described as benefits or utility to the winery

wine relative to non-VQA base wine, quality (rating by wine experts), a winery's characteristics (volume of sales, region), wine type/colour, and the error term, which is normally distributed with zero mean.

Applying the concept of utility and following Adamowicz *et al.* (1998), Olynk *et al.* (2010) and Ida (n.d); assume that the i^{th} winery's utility is given by:

$U_{i1}(X) = \beta_1 X_i + \varepsilon_{i1}$, if it uses VQA; and

$U_{i0}(X) = \beta_0 X_i + \varepsilon_{i0}$, if it does not use VQA

Therefore, the decision by the i^{th} winery to apply for VQA certification for a specific wine is such that

$$Y_i = \begin{cases} 1 \; if \; U_{i1} > U_{i0} \\ 0 \; if \; U_{i1} \leq U_{i0} \end{cases}$$

Where Y_i = 1 if the winery uses VQA certification for a specific wine and Y_i = 0, otherwise. Therefore, the probability of using the VQA system for a specific wine is given by:

$$Pr(Y_i = 1) = Pr(U_{i1} > U_{i0}) = Pr(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0}) \qquad (3.6)$$

Considering the assumption of normal distribution of the error term in Probit analysis (Green, 2008, pp. 777), and following Gujarati and Porter (2009, p.566), equation (3.6) can be rewritten as

$$Pr(Y_i = 1) = Pr(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i) = Pr(\varepsilon_i < \beta X_i) \qquad (3.7)$$

$$Pr(Y_i = 1) = \Phi(\beta X_i) \qquad (3.8)$$

This implies that

$$\Pr(Y_i = 1) = \Phi(\sum_{k=1}^{K} \beta_i X_i)$$

and

$$\Pr(Y_i = 0) = 1 - \Phi(\sum_{i=1}^{I} \beta_i X_i)$$

Where,

Φ = Cumulative distribution function of the standard normal distribution

β_i = Parameters estimated using Maximum Likelihood

X' = Vector of independent variables influencing a winery's decision to use the VQA certification for a specific wine

Therefore, the probability of a winery to use VQA certification for a specific wine is given by

$$P(Y_i = 1 \vdots X) = \int_{-\infty}^{X'\beta} \frac{1}{\sqrt{2\pi}} e^{-\frac{Z^2}{2}} dz = \Phi(Z) \qquad (3.9)$$

Where,

$Z = \beta_0 + \beta_1 X_{1i} + \cdots + \beta_k X_{ki}$

Thus, the Probit model for the use of VQA by a winery is explicitly stated as follows:

$$E(Y_i) = \beta_0 + \beta_1 Price + \beta_2 Varietal + \sum_{k=1}^{K} \beta_k \, Region + \sum_{l=1}^{L} \beta_l Volume_l + \sum_{n=1}^{N} \beta_n Colour \qquad (3.10)$$

Where,

Y_i = Response (dependent) variable, VQA
β_0 = Constant
βs = Coefficients of explanatory variables

Following Green (2008, p.778), the likelihood function used to estimate the parameters is given by

$$L(\beta) = \prod_{i=1}^{N} P(Y_i) = \prod_{i=1}^{N} \Phi(\beta X_i)^{Y_i} \, \Phi(-\beta X_i)^{1-Y_i} \qquad (3.11)$$

The predicted probability of an independent variable is calculated using the relation:

$$P = \Phi(\beta_0 + \beta_i X_i)$$

Where P = predicted probability and other parameters are as defined above. Stata calculates this using the command, *.display normal* ($\beta_0 + \beta_i X_i$)

Many of the independent variables are qualitative in nature and therefore difficult to measure. These variables were quantified using dummy variables. According to Oczkowski (1994), dummy variables are preferred over single continuous variables in measuring some qualitative variables because they help to reduce the impact large measurement errors may have on the model.

The hedonic pricing model results show that there is a premium for VQA certification. Nevertheless, despite the existence of a premium, not every winery chooses VQA certification for every wine. In this sub-section, we analyze the determinants of a winery's decision to seek VQA certification for a specific wine. Table 3.12 shows summary statistics for wineries in the data set that used the VQA system for all their wines, some of their wines, and none of their wines.

Table 3.12: Classification of wineries based on use of VQA certification

Classification	Number of wineries	% frequency
Wineries with all wines certified by VQA	146	84.88
Only some wines certified by VQA	11	6.40
None of the wines certified by VQA	15	8.72
Total	172	100.00

Data source: Liquor Control Board of Ontario (LCBO), 2013.

The data in Table 3.12 show that of the 172 wineries in the data set, 146 (84.88 percent) have all their wines certified by the VQA. About 8.72 percent of the wineries do not use the VQA system, and therefore, sell their wines uncertified, while only 6.40 percent use the VQA for some (but not all) of their wines. Based on the volume of wine (number of cases) supplied by wineries to the Ontario retail market and distributed through the LCBO within the period under consideration, the 11 wineries that certify some of their wines comprise 1 large (Jackson-Triggs), 4 medium, 3 small, and 3 very small wineries.[75] Jackson-Triggs (J-T) supplied a total of 49 varieties of wine of which 33 received certification from the VQA and 16 were sold without certification. In addition, compared to other large wineries (Henry of Pelham, Cave spring) in the data set, wines supplied by J-T have the lowest average price of $19.22. Further, 3 out of the 15 wineries that did not certify any of their wines are small in size, while the remaining 12 are very small wineries.

To identify the factors that influence a winery's decision to apply for VQA certification for a specific wine, a Probit analysis was carried out. The results are shown in Table 3.13. The model has a good fit given the value of the McFadden's Pseudo R-squared. The analysis (dependent

[75] Large (≥ 1000 cases); medium (between 500 and 999 cases); small (between 300 and 499 cases) and very small (< 300 cases).

variable) is on the basis of a specific wine instead of at the winery level for two reasons. First, we do not have enough data on wineries to use the winery as the dependent variable. Second, there will be loss of degrees of freedom as only 6.40 percent (11 out of 172) of the wineries certify some of their wines, while 8.72 percent (15 out of 172) did not certify any of their wines.

Results in Table 3.13 show that the coefficients for price, red and white wines are positive but do not significantly influence the decision to seek VQA certification for a specific wine. The estimated coefficient for each independent variable relates the variable to the predicted probability of VQA certification, and shows the magnitude of change in the predicted probability of using VQA for a unit change in the independent variable. We can predict the probability of a winery seeking VQA certification for different values of the independent variables. The predicted probability for each variable is calculated based on the assumption that other variables are evaluated at zero.[76]

Table 3.13: Probit regression for the use of VQA certification by wineries

Variable	Coefficient	Std. error	z	P > |z|	Predicted Prob.[1]
Constant	0.2352	0.2690	0.87	0.382	0.5930
Price	0.0043	0.0028	1.53	0.125	0.5946
Varietal[2]	0.5272***	0.1022	5.16	0.000	0.7771
Winery region:					
Niagara Pen.	0.7843***	0.1418	5.53	0.000	0.8460
PEC	0.7368**	0.2489	2.96	0.003	0.8345
Lake Erie NS	0.9010***	0.2244	4.02	0.000	0.8721
Volume supplied					
Large	0.6799***	0.1600	4.25	0.000	0.8199
Medium	0.2312	0.1276	1.81	0.070	0.6795
small	-0.0788	0.1156	-0.68	0.495	0.5621
Wine type:					
Icewine	0.2979***	0.0922	3.23	0.001	0.7030
Red	0.4027	0.2372	1.70	0.089	0.7382
White	0.2141	0.2289	0.94	0.349	0.6734
Sparkling	-0.3559	0.2814	-1.26	0.206	0.4520
Log likelihood = -492.7894					
LR chi2(12) = 153.94					
Prob > chi2 = 0.000					
Pseudo R^2 = 0.1351					
Number of obs. = 1444					

P-values: *=0.05, **=0.01, ***=0.001

Data source: Liquor Control Board of Ontario (LCBO), 2013.

[76] Individual variables can also be evaluated at their means.

Note: [1]Predicted probability of seeking VQA certification when X (independent variables) increase by 1-unit
[2]Varietal indicates whether a wine is blended (produced using two or more grape varieties) or not (single variety). Blended wines = 1; 0 = otherwise
Base (omitted) dummy categories include: *other Ontario* for winery region, *very small* for winery size, and *rose* for wine colour/type.
[3]McFadden's Pseudo R-squared shows the level of improvement of the full model relative to the intercept model. A lower value is an indication that the full model has a better fit than the intercept model (http://www.ats.ucla.edu/stat/mult_pkg/faq/general/Psuedo_RSquareds.htm).
[4]Predicted probabilities were calculated and reported for the Probit regression instead of the marginal effects. This is because marginal effects for the Probit regression measure the likelihood of a winery to seek for VQA certification. In other words how the predicted probabilities will change as the binary independent variable changes from '0' to '1'. To show the magnitude of the likelihood, the predicted probability for each independent variable is calculated.

The result indicates that six explanatory variables including: varietal, Niagara Peninsula, Prince Edward County, Lake Erie North Shore, large wineries and icewine are positive and statistically significant. This indicates that volume of wine supplied (large), varietal (whether a wine is produced using single or blended grapes), winery region and icewine are key factors that significantly influence a winery's decision to seek VQA certification for a specific wine. Only wines produced using single Canadian grown grapes qualify for VQA certification. The significance of the coefficients of winery region is not surprising. As mentioned earlier, there are 172 wineries in Ontario as of March 2013 out of which 140 (81.4 percent) are registered with VQA. Therefore, the probability of a winery located in Ontario seeking VQA certification would be high.

British Columbia (BC) is excluded from the Probit regression because there are some wineries that supply a large volume of wines in BC (e.g. Mission Hill) that are under-represented in this data set[77] and therefore, may be erroneously regarded as small wineries. In addition, a variable, *quality*, measured as wine experts' (third-party) ranking or product score was not included in the Probit model as product score was only available for 19.6 percent (302) of the total observations (1537) in the data set. Of these 302 observations, 98.7 percent (298) are VQA wines, while the remaining 1.3 percent are non-VQA. These led to the decision to drop the attribute (product score) in hedonic regression, and in the Probit analysis where it was measured as quality.

[77] The data set contains primarily Ontario wines. Of the 1537 total observations, only 156 were from BC, with relative low volumes from the major BC winery, Mission Hill (see Table 3.5).

There are costs associated with VQA certification, including: monetary costs (testing and membership fees) and production restrictions (e.g. only 100 percent regionally grown grapes are used for VQA wines, which are monitored and harvested at a particular level of ripeness, no addition of artificial sugar). The membership fee is a flat rate irrespective of the volume of wine supplied by a winery. However, the value of some of these costs (e.g. cost of searching information about VQA) are difficult to ascertain. An attempt was made to control for fixed costs of seeking VQA certification (e.g. costs of learning about the VQA system, costs of documenting compliance with VQA certification). We defined this (dummy) variable as "experience with VQA." Wineries in the data set that have all or some of their wines certified by VQA take a value of '1' and wineries with no experience with VQA (have none of their wines certified) take a value of '0'. The variable was included in an earlier version of the Probit model (not the model presented in Table 3.13) as a check and the coefficient was insignificant.

Icewines in the dataset are all VQA presumably because it is a high priced wine and wineries potentially see VQA certification as being important to signal quality and earn collective reputation, both in the domestic and international markets. In addition, there is the possibility that some grape varieties used for blended Canadian wines might be cheap in terms of price and sourced from outside Canada (International Canadian Blends). Given VQA requirements, wines produced using such grapes do not meet one of the VQA requirements and, therefore, would not pass through the VQA system. Considering each independent variable at a time and evaluating other variables at zero, the results show that wineries located in Ontario, relative to BC (base category), have the highest predicted probability of seeking VQA status in order to signal authenticity and origin; and also earn collective reputation. This is followed by large wineries, wineries producing wines using single grapes potentially grown domestically and wineries producing icewine.

Although there is a premium for VQA, the probit results show that wine price is not a significant factor that drives a winery's decision to seek VQA for a specific wine. To resolve the issue of whether high priced wines seek VQA certification or whether VQA certification leads to higher wine prices, an attempt was made to estimate the model using an instrumental variable (IV) estimation approach. To use the IV approach, there has to be a valid *instrument (z)* for the endogenous independent variable (x) which must meet two conditions (Green, 2008, p.316), including:

a) *Instrument exogeneity*. This implies that the instrument must be uncorrelated with the error term. That is $Cov(z, \varepsilon) = 0$, and
b) *Instrument relevance*. This means that the instrument must be highly correlated with the endogenous independent variable. That is $Cov(z, x) \neq 0$

However, IV estimation was not feasible as none of the independent variables in the model were highly correlated with price to serve as a strong/valid instrument (See Appendix 3.VII for the correlation result). Based on the correlation analysis results, the included independent variables are weak instruments. A weak instrument often results in coefficients that are biased and thus may lead to misleading inferences (Stock, 2002).

To determine whether price and VQA are endogenous, a test of endogeneity (Hausman specification or *t*-test) was carried out following the method used by Gujarati and Porter (2009, p.703) and Pindyck and Rubinfeld (1990, p.304). Following equation (3.10), assume the following models:

$$V_{qa} = \beta_0 + \beta_1 P_i + \beta_2 V_{tal} + \beta_3 R_g + \beta_4 V_S + \beta_5 C_l + \varepsilon_i \qquad (3.12)$$

$$V_{qa} = \beta_0 + \beta_1 P_i + \varepsilon_{2i} \qquad (3.13)$$

Where,

P_i = wine price
V_{tal} = varietal (as defined in Table 3.12)
R_g = winery region
V_S = Volume of wine supplied by a winery to the Ontario retail market
C_l = wine colour/type
ε_i = error term

Assume P_i and V_{qa} are endogenous (i.e. P_i is correlated with ε_i) , and V_{tal} , R_g , V_s and C_l are exogenous (uncorrelated with ε_i)

To verify if there is endogeneity between *price* and *VQA*, a Two Stage Least Square (TSLS) regression was run and a Hausman's or *t*-test for endogeneity was carried out. First we rewrite equation (3.12) in a reduced form as follows:

$$P_i = \alpha_0 + \alpha_1 V_{tal} + \alpha_2 R_g + \alpha_3 V_S + \alpha_4 C_l + \mu_i \qquad (3.14)$$

Where μ_i is the reduced form of the error term. Equation (3.14) was estimated using Ordinary Least Square (OLS) and the regression residuals ($\widehat{\mu_\iota}$)and predicted values of price ($\widehat{P_\iota}$) calculated. The results of the OLS regression is shown in Table 3.14.

Table 3.14: OLS regression results of wine price against other independent variables

Variable		Coefficient	Std. error	P>|t|
Constant		2.6213***	0.0834	0.000
Varietal		-0.1241***	0.0286	0.000
Colour/type	Red	0.4060***	0.0679	0.000
	White	0.2247***	0.0667	0.001
	Icewine	0.9217***	0.0808	0.000
	Sparkling	0.3412***	0.0863	0.000
Vol. supplied	Large	-0.0763	0.0534	0.153
	Medium	0.1084**	0.0394	0.006
	Small	0.1861***	0.0387	0.000
Winery region	Niagara	-0.2754***	0.0412	0.000
	PEC	-0.1307*	0.0607	0.032
	LENS	-0.4639***	0.0670	0.000
R^{-2} = 0.6374	n/a	n/a	n/a	n/a
F-stat = 33.79	n/a	n/a	n/a	0.000
N = 1444	n/a	n/a	n/a	n/a

P-values: *=0.05, **=0.01, ***=0.001

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Note: Omitted (base) categories include: *rose* for wine colour/type, *very small* for volume supplied to the Ontario market and *other Ontario* for winery region.

$P_i = \widehat{P_\iota} + \widehat{\mu_\iota}$, where $\widehat{P_\iota}$ represents the estimated price and $\widehat{\mu_\iota}$ is the residual from the OLS regression. Substituting this for P_i in equation (3.13), we have:

$$V_{qa} = \beta_0 + \beta_1\widehat{P_\iota} + \beta_1\widehat{\mu_\iota} + \varepsilon_{2i} \qquad (3.15)$$

The second stage involves estimation of equation (3.15) using OLS and performing a test on the coefficient of $\widehat{\mu_\iota}$. The result of the estimation is shown in Table 3.15.

Table 3.15: Regression of VQA against estimated values of price and residuals of the error term

Variable	Coefficient	Standard Error	P-value
Constant	0.1125**	0.0435	0.010
Phat ($\widehat{P_i}$)	0.0528	0.0355	0.137
Residual ($\widehat{\mu_i}$)	0.0969	0.0591	0.073
R^{-2} = 0.5724	n/a	n/a	n/a
F-stat = 43.65	n/a	n/a	0.000
N = 1444	n/a	n/a	n/a

P-values: *=0.05, **=0.01, ***=0.001

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Test of hypothesis

H_0 = there is endogeneity between VQA and wine price
H_1 = there is no endogeneity between VQA and wine price

Table 3.15 shows that at 1, 5 and 10 percent levels, the coefficient of the residual $(\widehat{\mu_i})$ is not significant based on the p-value. We therefore reject the null hypothesis that there is endogeneity between VQA and the price of wine. This therefore suggests that VQA certification only leads to higher wine prices and not the other way round.

3.5 Implication of results

Food product authenticity and credible quality signals by producers in agri-food markets are important to reduce the negative externalities and/or spillovers arising from food fraud that affect other firms in the industry. The paper seeks to answer two key questions - does VQA certification bring a price premium and enhance the collective reputation of Canadian wines? What factors determine a winery's decision to seek VQA certification for a specific wine? The empirical results of the hedonic price analysis show that there exists a price premium for VQA certified Canadian wines, while the Probit regression results identify variables (factors) that shape a winery's decision to seek quality assurance certification. These results have some market and policy implications.

The results implicitly suggest that Vintners Quality Alliance (VQA) has established and signalled authenticity assurances and origin in the Canadian wine industry. VQA signals authenticity by verifying and certifying claims made on the wine labels by wineries. These appear to be valued by consumers, increasing their willingness to pay for quality, and earning a collective reputation for the Canadian wine industry. A premium for authenticity, quality and origin in the wine industry could serve as an incentive for other agri-food sectors in Canada to establish similar quality assurance system to gain or boost collective reputation.

Controlling for individual winery reputation with the winery variable, and controlling for other collective reputation signals (e.g. region, Province), the individual winery and region variables were included in the hedonic regression at different stages alongside the VQA variable. The idea is to separate VQA from other collective reputation signals. The results show that the estimated coefficient for VQA is positive and significant at every stage of the regression, suggesting that the VQA signal adds value beyond other signals of individual and collective reputation. This potentially shows the value of VQA as a collective reputation signal, and implies that VQA could be used as a shorthand for quality, which may enable consumers to make informed purchase decisions and may reduce their transaction (search) costs. Interacting the VQA variable with region to determine the extent to which the two can be used as complementary quality signals, the estimated coefficients are positive and significant for two sub-regions in Ontario, suggesting that VQA and region can be used as complementary collective reputation signal, at least for some regions. In addition, the results of the interaction of the VQA variable with red grape varieties suggest that the importance of VQA certification is independent of individual wine grape varieties. Comparing the magnitude of the effect of the VQA variable relative to the size of the coefficient of other variables included in the hedonic model, the results show that the size of the effect of the variable vary. Further, results of the Probit analysis indicate that large wineries (supplying more than one thousand cases to the Ontario retail market) located in Ontario, and producing icewine and single grape wines have a higher tendency of seeking VQA certification for a specific wine.

On the part of the wineries, the magnitude of the estimated premium for VQA wines could serve as a guide for wineries' investment decisions in quality assurance systems. New and non-participating VQA wineries could use the estimated premium in making a comparative analysis of the costs and benefits of getting their wines certified by VQA, and determine the expected return associated with investment in quality assurance. Information on attributes that significantly influence wine price could enable individual wineries to redirect resources in order to increase their marginal values, earn a higher price and protect their reputations.

3.6 Conclusions

Consumers' increasing demand for quality reassurance resulting from the recent spate of publicized cases of food fraud has spurred investments in quality, authenticity and reputation-enhancing programs by agri-food firms and industries. This paradigm shift is contingent on reputation externalities faced by food firms as a result of increased cases of food fraud in agricultural markets, resulting in the classic Akerlof's 'lemons' problem. The paper examines the mechanism of building and/or protecting industry-wide collective reputation using the Vintners Quality Alliance (VQA) certification system in the Canadian wine industry. Fundamentally, although it takes quite some time to build reputation, an industry can easily lose its reputation in a short time period. Reputation is therefore very important for a firm or an industry especially in competitive markets where producers strive to gain a first-mover advantage, market share and premiums.

A series of hedonic pricing models for Canadian wines and a Probit model are estimated to determine respectively whether there is a premium for VQA Canadian wines and to identify factors that determine a winery's decision to seek VQA certification for a specific wine. The results of the hedonic analysis show that there exists a premium for VQA red and white wines sold in Ontario, suggesting that authenticity assurances and origin signalled by the VQA system appear to be valued by consumers. Controlling for winery and regional characteristics (collective reputation attributes), the coefficient of VQA certification was positive and significant, indicating the value of VQA certification as a collective reputation building strategy. While the results of the hedonic analysis show that a number of attributes including: percentage alcohol content, sweetness, volume of wine supplied by a winery (large) and vintage have a significant influence on the price of wine; the Probit analysis results show that large wineries in Ontario that produce icewine and non-blended wines have a higher tendency of seeking VQA status.

Results of the analysis show that there is a premium for authenticity, and VQA adds a premium beyond the other signals of reputation (e.g. winery, region). A possible explanation of the uniqueness of VQA as a signal for quality and reputation is that, perhaps unlike other reputation signals (e.g. region), VQA is a third party certified quality signal. This potentially makes VQA a stronger assurance of quality and authenticity. Third party certification of quality seems to be a more reliable and transparent method of showing compliance and/or conformity with set standards, and could inspire consumer confidence in quality reassurance as the product has been evaluated and certified by an independent organization. It also has the potential of enhancing market access. Therefore, enforcing authenticity and credible quality signals in agri-food markets, complemented with verification of quality claims, could ease food fraud and quality uncertainty in agri-food markets, and ultimately boost industry-wide collective reputation.

3.7 Limitations of the study and suggestions for further research

Certain limitations were encountered in the course of this study. First is the timely availability of data. Although data were available from the Liquor Control Board of Ontario, important information such the aggregate quantity of wines sold annually and in various periods of the year by specific wineries could not be accessed. Such information is needed to control for seasonality effects in the analysis. In addition, product score (third party ranking of wines) was dropped from the analysis as only about 19.6 percent of the observations in the data set have product score, and about 98 percent of such observations are VQA wines. A data set with a fair balance of VQA and non-VQA wines with product scores would have enabled the researcher to interact VQA and product score, and use the result to tease apart the authenticity assurance from the quality assurance signalled by the VQA system in the analysis.

The hedonic model separates individual and collective reputation effects on wine price, while the results show that the magnitude of the effects are not the same for different types of wine. Although some consumers may have strong preferences for wine produced by specific wineries in different regions, it would be interesting to use another analytical technique (e.g. choice experiment) to compare consumers’ willingness to pay for wines based on individual and collective reputation, and other wine attributes. The results of such an experiment would give wineries and researchers a better understanding of the attributes that drive consumers’ wine purchase decisions. In addition, future studies should consider both Canadian and imported wines in order to examine how the VQA quality assurance system affects price competition for regional and imported wines.

Further, the researcher only had access to data from Ontario. It would be interesting to include sales from British Columbia (BC) as this may affect the type of BC wines that showed up in the dataset and provide more generalizable results and conclusions concerning the VQA system. For example, using data from Ontario and BC retail wine sales would give a better sense of whether price significantly influences a winery's decision to seek VQA. This potentially may provide the opportunity of applying the instrumental variable estimation approach, which was not feasible in the analysis.

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Appendix 3.I

A3.1: LCBO pricing formula for wines (750ml bottle)

		US imported wine	Other imported wine	100% Canadian Ontario wine	< 100% Canadian Ontario wine
Price Components					
Payment to supplier		3.5376	3.4867	4.3207	3.8557
Federal Excise Tax[1]	$0.62/litre	0.4650	0.4650	-	0.4650
Federal Import Duty	$0.0187/ litre	-	0.0140	-	-
Total Landed Cost		4.1695	4.1695	4.3207	4.3207
LCBO Mark-up[2]		2.9812	2.9812	2.8301	2.8301
LCBO Wine Levy	$1.62/litre	1.2150	1.2150	1.2150	1.2150
LCBO Bottle Levy	$0.29/ litre	0.2175	0.2175	0.2175	0.2175
LCBO Environment Fee[3]	$0.0893/ container	0.0893	0.0893	0.0893	0.0893
LCBO Rounding Revenue[4]		-	-	-	-
Basic Price		**8.67**	**8.67**	**8.67**	**8.67**
H.S.T	13% basic price	1.13	1.13	1.13	1.13
Container Deposit[5]		0.20	0.20	0.20	0.20
Consumer Price		**$10.00**	**$10.00**	**$10.00**	**$10.00**
Revenue Distribution					
Supplier (including freight)		3.70	3.69	4.32	3.86
Government of Ontario		5.20	5.20	5.05	5.05
Government of Canada		0.90	0.91	0.43	0.90
Container Deposit		0.20	0.20	0.20	0.20
Consumer Price		**$10.00**	**$10.00**	**$10.00**	**$10.00**

Notes:
1. There is no federal excise tax on domestic wine made from 100% Canadian-grown agricultural products.
2. LCBO mark-up as a share of landed cost is 71.5% for U.S. imports, 71.5% for other imports and 65.5% for Ontario wines.
3. Environmental fee applies to containers that cannot be returned for refilling by manufacturer.
4. Consumer price rounded up to the next nickel.
5. Container deposit rates are as follows: $0.10 for a container greater than 100 ml and less than or equal to 630 ml; $0.20 for a container greater than 630 ml; and $0.00 for a container less than or equal to 100 ml

Source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.II

A3.2: Correlation matrix for independent variables (hedonic regression)

	vqa	Alcohol	Sweetness	Niagara	PEC	Other Ont.	LENS	BC	Large	Medium	Small	Very small	HOP	JT	Cave spring	Peller	Pelee	Inniskillin
Vqa	1.0000																	
Alcohol	0.1583	1.0000																
Sweetness	0.0588	0.5618	1.0000															
Niagara	0.0263	-0.0194	0.0151	1.0000														
PEC	-0.0014	0.0217	-0.0045	-0.4172	1.0000													
Other Ont.	0.0097	-0.0107	-0.1124	0.0644	-0.0659	1.0000												
LENS	-0.0308	-0.0582	-0.0466	-0.3717	-0.0641	0.0669	1.0000											
BC	-0.0413	0.0755	0.0624	-0.5345	-0.0911	0.0483	-0.0814	1.0000										
Large	0.0096	-0.0320	0.0095	0.0373	0.0094	-0.0278	-0.0064	0.0131	1.0000									
Medium	0.0480	0.1596	0.1284	-0.0888	0.0366	-0.0761	0.0007	0.1145	-0.1550	1.0000								
Small	-0.0468	-0.1244	-0.1280	0.0529	-0.0390	0.0947	0.0026	-0.1094	-0.5039	-0.7711	1.0000							
Very small	-0.0206	-0.0986	-0.0843	-0.0282	-0.0280	-0.0419	0.0158	-0.0029	-0.0223	-0.3354	0.4371	1.0000						
HOP	0.0316	0.0653	0.0887	0.0167	0.0096	-0.0277	-0.0001	-0.0276	0.5347	-0.0828	-0.2695	-0.1187	1.0000					
J-T	-0.0338	-0.1171	-0.0851	0.0889	0.0018	-0.0368	-0.0023	-0.0727	0.6494	-0.0952	-0.3238	-0.1342	-0.0361	1.0000				
Cavespring	0.0374	0.0239	0.0091	-0.0853	0.0026	0.0177	-0.0119	0.1562	0.4635	-0.0718	-0.2336	-0.1029	-0.0248	-0.0313	1.0000			
Peller	-0.0220	0.0343	0.0154	-0.0788	0.1018	-0.0354	-0.0254	0.0889	-0.0735	0.4743	-0.3697	-0.1629	-0.0393	-0.0393	-0.0496	1.0000		
Pelee	0.0620	0.0935	0.0794	-0.0328	0.0264	-0.0259	0.0101	0.0534	-0.0700	0.4518	-0.3522	-0.1552	-0.0374	-0.0472	-0.0324	-0.0513	1.0000	
Inniskillin	-0.0612	0.0571	0.0140	-0.0886	0.0110	-0.0394	-0.0399	0.1863	-0.0528	0.3408	-0.2657	-0.1171	-0.0282	-0.0356	-0.0245	-0.0387	-0.0369	1.0000
Others	-0.0038	-0.0651	-0.0576	0.0715	-0.0784	0.0644	0.0209	-0.1563	-0.6017	-0.5102	0.8334	0.3690	-0.3218	-0.3883	-0.2789	-0.4415	-0.4206	-0.3173
Icewine	0.0434	-0.4138	-0.6183	-0.0283	-0.0342	-0.0179	0.0968	-0.0445	-0.0729	-0.0953	0.1446	0.1015	-0.0390	-0.0155	-0.0338	-0.0535	-0.0509	-0.0384
Red	0.0045	0.3365	0.2899	-0.0828	-0.0005	0.0498	0.0148	0.0397	0.0702	0.0271	-0.0713	-0.0899	0.1956	-0.1772	0.1696	-0.2007	-0.1912	0.1180
Rose	-0.0360	-0.1210	-0.1263	0.0362	-0.0121	-0.0046	0.0150	0.0010	0.5139	-0.0095	-0.3123	-0.1327	-0.0358	0.7910	-0.0310	-0.0491	-0.0468	0.1706
Sparkling	-0.0039	-0.0294	0.0145	0.0209	0.0468	0.0970	-0.0109	-0.0490	0.1584	-0.0704	-0.0399	0.0690	-0.0244	0.2564	-0.0211	-0.0334	-0.0318	-0.0240
White	-0.0037	-0.1048	-0.0072	0.0573	0.0031	-0.0672	-0.0570	-0.0016	-0.2960	0.0427	0.1515	0.0909	-0.1581	-0.1922	-0.1370	0.2484	0.2366	-0.1559
≤ 2005	0.0621	-0.0031	-0.0893	0.0527	-0.0440	-0.0018	0.0022	-0.0405	0.0133	-0.0448	0.0302	-0.0155	-0.0278	0.0569	-0.0241	-0.0382	-0.0364	0.0305
2006	0.0372	-0.0718	-0.1326	0.0245	-0.0119	-0.0208	-0.0032	0.0123	0.0208	-0.0750	0.0519	0.0355	0.0237	0.0271	-0.0258	-0.0409	-0.0389	-0.0022
2007	0.0769	0.0976	0.0621	0.0031	0.0210	0.0883	0.0386	-0.0546	0.0362	-0.0296	0.0085	0.0144	0.0612	0.0136	-0.0197	-0.0369	-0.0187	-0.0094
2008	0.0376	0.0451	0.0016	0.0117	-0.0162	-0.1002	0.0351	-0.0499	0.0358	-0.0250	-0.0020	0.0059	0.1133	0.0015	-0.0445	-0.0335	0.0357	-0.0172
2009	0.0414	0.0812	0.0431	0.0437	-0.0374	-0.0862	-0.0322	0.0150	0.0230	-0.0111	-0.0060	-0.0245	-0.0290	0.0844	-0.0439	-0.0371	0.0606	0.0269
2010	0.0769	0.1305	0.0615	0.0001	0.0166	0.0948	-0.0134	-0.0145	-0.0650	0.0742	-0.0248	-0.0526	-0.0610	-0.0193	-0.0365	0.0768	0.0544	-0.0311
2011	0.0613	0.0008	-0.0195	-0.0438	0.0006	-0.0173	0.0289	0.0572	-0.0084	0.0474	-0.0297	-0.0169	-0.0211	-0.0036	0.0101	0.1373	-0.0537	0.0202

Note:
PEI = Prince Edward County (Prince Edward Island)
LENS = Lake Erie Northshore
BC = British Columbia
HOP = Henry of Pelham
J-T = Jackson-Triggs

Correlation Matrix for Independent Variables Cont’d

	Others	icewine	Red	Rose	Sparkling	White	≤ 2005	2006	2007	2008	2009	2010	2011
Others	1.0000												
Icewine	0.1211	1.0000											
Red	0.1115	-0.1783	1.0000										
Rose	-0.3845	-0.0148	-0.1755	1.0000									
Sparkling	-0.0667	0.0156	-0.0245	-0.0305	1.0000								
White	0.0156	-0.2014	-0.8080	-0.1903	-0.1345	1.0000							
≤ 2005	0.0180	0.1769	-0.0377	0.0812	0.0429	-0.0877	1.0000						
2006	0.0284	0.2010	-0.0277	0.0497	0.0683	-0.0763	0.0536	1.0000					
2007	0.0081	0.0312	0.1264	0.0002	-0.0186	-0.1380	-0.0082	-0.0310	1.0000				
2008	-0.0181	0.0911	0.0333	-0.0508	0.0715	-0.0717	-0.0499	-0.0534	0.0725	1.0000			
2009	-0.0373	-0.0364	-0.0500	0.1038	-0.0178	0.0239	-0.0492	0.0621	-0.0821	-0.0908	1.000		
2010	-0.0107	-0.0399	0.0359	-0.0298	-0.0185	-0.0015	-0.0446	-0.0359	-0.0896	-0.1093	-0.1079	1.000	
2011	-0.0476	-0.0109	-0.1038	0.0620	-0.0349	0.0954	-0.0339	-0.0427	-0.0537	-0.0736	-0.0649	-0.0875	1.0000

A correlation coefficient indicates the degree and direction of linear relationship between two variables (Rumsey, 2011, p.116). A high correlation between independent variable results in multicollinearity. The results on the correlation matrix table suggest that there is no multicollinearity among the independent variables in the hedonic model. Many of the variables in the model are dummies derived from categorical variables. Inclusion of all the dummy variables in a category in the regression would result in the dummy variable trap (perfect linear relationship between the set of dummies within a category (Andren, 2007, p.121). To avoid this problem, a reference (base) category is dropped for each set of dummy variables in the same category.

Appendix 3.III (a)

A3.3: Hedonic pricing result (pooled regression) with VQA and province

Variable	Level	Coef.(β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		2.0412**		0.6743	0.003
VQA		0.1038***	10.94	0.0317	0.001
Ln(alcohol)		0.6608**		0.2140	0.002
Sweetness		0.0321	3.26	0.0235	0.173
Colour/type	Icewine	0.9844***	167.62	0.1453	0.000
	Red	0.4232***	52.68	0.1067	0.000
	Rose	base	base	base	base
	Sparkling	0.5326***	70.34	0.1483	0.000
	White	0.2397*	27.09	0.1042	0.022
Province	Ontario	-0.1029*	-9.78	0.0496	0.039
	British Columbia	base	base	base	base
Vol. supplied	>1000 cases (large)	-0.0762	-7.34	0.0756	0.314
	500 < X ≤ 1000 (medium)	-0.0346	-3.40	0.0604	0.567
	500< X ≤ 200 (small)	0.1073**	11.33	0.0359	0.003
	0< X ≤ 200 (very small)	base	base	base	base
Vintage	≤ 2005 (base)	base	base	base	base
	2006	-0.5264***	40.93	0.1024	0.000
	2007	-0.3908***	-32.35	0.0889	0.000
	2008	-0.5221***	-40.67	0.0859	0.000
	2009	-0.4155***	-33.99	0.0853	0.000
	2010	-0.4976***	-39.20	0.0854	0.000
	2011	-0.6685***	-48.75	0.0926	0.000
	2012	-0.6217**	-46.30	0.1254	0.002
R^{-2}	0.2707	n/a	n/a	n/a	n/a
F-statistics	14.63	n/a	n/a	n/a	0.000
N	662	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
Data source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.III (b)

A3.4: Hedonic pricing result (pooled regression) with VQA and region

Variable	Level	Coef.(β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		1.8779**		0.6675	0.005
VQA		0.1630***	17.70	0.0425	0.000
Ln(alcohol)		0.7328***		0.2122	0.001
Sweetness		0.0257	2.60	0.0233	0.270
Colour/type	Icewine	0.9946***	170.36	0.1437	0.000
	Red	0.1436***	15.44	0.1056	0.000
	Rose	base	base	base	base
	Sparkling	0.5381***	71.27	0.1470	0.000
	White	0.2511*	28.54	0.1030	0.015
Region	Niagara Peninsula	-0.1122*	-10.61	0.0499	0.025
	Prince Edward county	0.1222	12.99	0.0757	0.107
	Other Ontario	-0.1456	-13.55	0.0780	0.063
	Lake Erie North Shore	-0.3151**	-27.03	0.1110	0.005
	British Columbia	base	base	base	base
Vol. supplied	>1000 cases (large)	-0.0596	-5.79	0.0752	0.428
	500 < X ≤ 1000 (medium)	0.0159	1.60	0.0624	0.799
	500< X ≤ 200 (small)	0.1108**	11.71	0.0357	0.002
	0< X ≤ 200 (very small)	base	base	base	base
Vintage	≤ 2005 (base)	base	base	base	base
	2006	-0.5249***	-40.84	0.1014	0.000
	2007	-0.4068***	-33.42	0.0880	0.000
	2008	-0.5235***	-40.76	0.0852	0.000
	2009	-0.4287***	-33.86	0.0846	0.000
	2010	-0.5012***	-39.42	0.0845	0.000
	2011	-0.6615***	-48.39	0.0920	0.000
	2012	-0.6256***	-46.51	0.1241	0.000
R^{-2}	0.2980	n/a	n/a	n/a	n/a
F-statistics	15.73	n/a	n/a	n/a	0.000
N	662	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
Data source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.III (c)

A3.5: Hedonic pricing result (pooled regression) with VQA and winery

Variable	Level	Coef (β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		1.9147**		0.6652	0.004
VQA		0.1487***	16.03	0.0345	0.000
Ln(alcohol)		0.7147***		0.2083	0.001
Sweetness		0.0300	3.05	0.0235	0.201
Colour/type	Icewine	0.9762***	165.44	0.1446	0.000
	Red	0.4330***	54.19	0.1067	0.000
	Rose	base	base	base	base
	Sparkling	0.5078***	66.16	0.1475	0.001
	White	0.2384*	26.92	0.1039	0.022
Vol. supplied	>1000 cases (large)	-0.2018*	-18.27	0.0892	0.024
	500 < X ≤ 1000 (medium)	0.0408	4.16	0.1229	0.740
	500< X ≤ 200 (small)	0.0844*	8.81	0.0343	0.014
	0< X ≤ 200 (very small)	base	base	base	base
Wineries	Henry of Pelham	-0.2141	-19.27	0.1850	0.248
	Jackson-Triggs	-0.2233	-20.01	0.1605	0.165
	Cave Springs	0.1311	14.01	0.2123	0.537
	Peller Estates	0.3704**	44.83	0.1404	0.009
	Pelee Island	-0.0903	-8.63	0.1725	0.601
	Inniskillin Wines	0.2509*	28.52	0.1277	0.050
	Others	base	base	base	base
***V**intage*	≤ 2005	base	base	base	base
	2006	-0.5157***	-40.29	0.1025	0.000
	2007	-0.4103***	-33.65	0.0887	0.000
	2008	-0.5122***	-40.08	0.0860	0.000
	2009	-0.4110***	-33.70	0.0854	0.000
	2010	-0.4998***	-39.33	0.0856	0.000
	2011	-0.6743***	-49.05	0.0932	0.000
	2012	-0.6150***	-45.94	0.1252	0.000
R^{-2}	0.3017	n/a	n/a	n/a	n/a
F-statistics	15.46	n/a	n/a	n/a	0.000
N	662	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
Data source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.IV

A3.6: Hedonic pricing result for icewine

Variable	Level	Coef.(β)	$(e^{\beta i}$ -1)100%	Std. error	Pr(>|t|)
Intercept		5.0302***		1.3006	0.001
VQA		0.1635	17.76	0.3537	0.648
Ln(alcohol)		-0.3208		0.5588	0.571
Sweetness		0.1432		0.2113	0.504
Region	Niagara Peninsula	-0.6219	-46.30	0.4111	0.143
	Prince Edward County	-0.6871	-49.70	0.5899	0.256
	Other Ontario	-0.3420	-28.97	0.5293	0.524
	Lake Erie North Shore	-0.0904	-8.64	0.5495	0.871
	British Columbia	base	base	base	base
Vol. supplied	>1000 cases (large)	-0.0281	-2.77	0.3732	0.941
	500 < X[1] ≤ 1000 (medium)	0.0008	0.08	0.1385	0.996
	500 < X ≤ 200 (small)	0.0075	0.75	0.6720	0.991
	0 < X ≤ 200 (very small)	base	base	base	base
Winery	Henry of Pelham	-0.2834	-24.68	0.3099	0.370
	Jackson-Triggs	-0.2488	-22.03	0.5068	0.628
	Cavespring	0.6786	97.11	0.5723	0.247
	Peller Estate	-0.3794	-31.57	0.4991	0.457
	Inniskillin Wines	0.6095	83.95	0.3916	0.133
	Others (base category)	base	base	base	base
Varietal	Cabernet franc	0.0216	2.18	0.1178	0.855
	Riesling	0.0859	8.97	0.1296	0.511
	Vidal	-0.2455*	-21.77	0.1190	0.045
	Others	base	base	base	base
Vintage	≤ 2005	base	base	base	base
	2006	-0.0939	-8.96	0.2113	0.627
	2007	-0.3547	-29.86	0.2103	0.108
	2008	-0.1883	-17.16	0.1636	0.261
	2009	-0.4204	-34.32	0.2710	0.134
	2011	-0.2594	-22.85	0.2364	0.283
	2012	-0.3564	-29.98	0.2677	0.196
R^{-2}	0.2735	n/a	n/a	n/a	n/a
F-statistics	1.62	n/a	n/a	n/a	0.128
N	46	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.V

A3.7: Hedonic pricing result for rose wine

Variable	Level	Coef.(β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		1.8399		1.6034	0.281
VQA		0.0993	10.44	0.1182	0.423
Ln(alcohol)		0.3872		0.6204	0.548
Sweetness	Dry	-0.0790	-7.60	0.0851	0.378
	Extra dry	base	base	base	base
Region	Niagara Peninsula	-0.1209	-11.39	0.0990	0.253
	Prince Edward County	-0.3046	-26.26	0.1839	0.132
	British Columbia	base	base	base	base
Winery	Inniskillin Wines	0.0501	5.14	0.1389	0.727
	Others	base	base	base	base
Vintage	2008	base	base	base	base
	2010	-0.0664	-6.42	0.1155	0.579
	2011	0.0981**	10.31	0.2510	0.004
	2012	-0.0585	-5.68	0.1191	0.635
R^{-2}	0.1623	n/a	n/a	n/a	n/a
F-statistics	3.80	n/a	n/a	n/a	0.0273
N	21	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001
Data source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.VI

A3.8: Hedonic pricing result for sparkling wine

Variable	Level	Coef.(β)	$(e^{\beta i}-1)100\%$	Std. error	Pr(>|t|)
Intercept		4.5111		11.1868	0.699
VQA		0.0969	10.17	1.3340	0.949
Ln(alcohol)		-1.2697		4.1985	0.771
Sweetness	Dry	0.3879	47.39	0.6342	0.603
	Extra dry	base	base	base	base
Region	Niagara Peninsula	-0.5706	-43.48	1.0583	0.644
	Prince Edward County	-0.5134	-40.15	1.0160	0.664
	Other Ontario	base	base	base	base
Vol. supplied	>1000 cases (large)	-0.3850	-31.95	1.4386	0.814
	500 < X ≤ 200 (small)	-0.8059	-55.33	1.0937	0.538
	0 < X ≤ 200 (very small)	base	base	base	base
Winery	Cave Springs	0.4285	53.50	0.4708	0.774
	Others	base	base	base	base
Vintage	≤ 2005	base	base	base	base
	2006	-0.2382	-21.20	0.6869	0.752
	2007	0.0664	6.87	0.9142	0.467
	2008	0.2103	23.40	0.6698	0.774
	2009	-0.3509	-29.59	0.6735	0.638
	2011	-0.3751	-31.28	0.8469	0.688
	2012	-0.4104	-33.66	0.9461	0.699
R^{-2}	0.0304	n/a	n/a	n/a	n/a
F-statistics	1.02	n/a	n/a	n/a	0.509
N	17	n/a	n/a	n/a	n/a

Notes: Significance level and codes of p-values: *=0.05, **=0.01, ***=0.001

Data source: Liquor Control Board of Ontario (LCBO), 2013.

Appendix 3.VII

A3.9: Correlation matrix for independent variables (Probit regression)

	Price	Varietal	Red	White	Icewine	Sparkling	Large	Medium	Small	Niagara	PEC	LENS
Price	1.0000											
Varietal	-0.0846	1.0000										
Red	0.0783	0.3010	1.0000									
White	-0.1664	-0.1550	-0.0760	1.0000								
Icewine	0.2614	-0.1153	-0.2078	-0.2308	1.0000							
Sparkling	-0.0113	-0.1278	-0.1740	-0.1933	-0.0528	1.0000						
Large	-0.0397	-0.0658	-0.0049	0.0080	-0.0233	0.0333	1.0000					
Medium	-0.1211	0.0426	-0.0066	-0.0136	0.0011	0.0374	-0.1311	1.0000				
Small	0.0510	-0.0157	-0.0084	0.0270	-0.0372	-0.0255	-0.2479	-0.3731	1.0000			
Niagara	-0.0388	-0.0370	-0.1141	0.0422	0.1133	0.0156	0.1571	-0.0520	0.0928	1.000		
PEC	0.0783	-0.0450	0.0210	0.0052	-0.0411	-0.0132	-0.0754	-0.0476	0.0227	-0.0410	1.0000	
LENS	-0.1113	0.0170	0.0419	-0.0123	-0.0112	-0.0112	-0.0737	0.0405	-0.2040	-0.0407	-0.0637	1.0000

Data source: LCBO (2013)

Note: PEC = Prince Edward County

LENS = Lake Erie North Shore

CHAPTER 4

Private Incentives to Adopt the International Barcode of Life Technology for Fish Species Authentication

4.1 Introduction

The paper examines an emerging authenticity technology, the International Barcode of Life (IBOL) and the incentives for its adoption in fish (seafood) supply chains in Canada by the private sector. The focus on fish is a strategic choice. Fish is an important source of protein and consumed in large quantities globally. Results of some studies (e.g. Pepe *et al.*, 2007; Schwartz, 2008; Bertoja *et al.*, 2009; Miller and Mariani, 2010), in different countries show that mislabelling and substitution in fish supply chains have been on the increase relative to other products, therefore leading to calls for assurances of authenticity and quality verification. In Canada and other developed economies, seafood fraud has become a significant problem (Hanner *et al.*, 2011). According to the Canadian Centre for DNA Barcoding (n.d),[78] Canada has about a $3.9 billion seafood export market while Canadian fisheries contributed about $1.7 billion to Canadian GDP in 2009.

According to DFO (2011), Canada is the 8th largest exporter of fish and seafood products in the world, and it exports about 85 percent of its fish and seafood production to more than 130 countries (AAFC, 2011). In the last three years, Canada imported on average 517.1 million kilograms of fish products worth about $2.79 billion (DFO, 2013). Canada therefore makes a significant contribution to global fish and seafood markets, and with the increase in Canadian seafood imports and domestic consumption, there is the potential for increased fraud for economic gain.

The economic gains accruing to sellers of genuine products have given some producers and other members of agri-food supply chains an economic incentive to cheat consumers by misrepresenting their own products and substituting substandard products for legitimate items. Producers and sellers of legitimate (quality) products incur losses while consumers pay a premium for low quality

[78] www.ccdb.ca

products as they cannot ascertain quality e*x ante* to purchases or presumably even *ex post* in some cases (e.g. fish species). Alternatively, they incur transaction (search) costs in the process of seeking information about a product's true quality.

The increasing spate of publicized cases of substitution and mislabelling in fish markets implicitly suggests that the existing testing system has not been credible. For example, survey results from Wong and Hanner (2008) show that 25 percent (23 out of 91) of fish species sampled domestically in Canada and U.S. were mislabelled. In addition, a CBC market place report (2010) indicated that 23 percent of 153 fish species sampled across Canada were mislabelled.[79] These problems have prompted firms to invest in developing traceability and authenticity technologies to create and exploit market niches for verifiable authenticity assurances (Kemp, 1994) as well as protect their reputations, while some consumers and the organizations that represent them are seeking some form of authenticity assurances for products traded in local markets, including those that arrive as a result of international trade.

Authenticity in the context of this paper relates to the capacity to verify and certify the genuineness of a food product and all the claims made by the producer and/or seller concerning the product. In other words, verifying the authenticity of a food product involves uncovering fraudulent activities, including: substitution, mislabelling, adulteration, etc. Food fraud according to Spink and Moyer (2011, p. 158) refers to "*the deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging; or false or misleading statements made about a product, for economic gain.*" These illicit activities introduce a market failure and create a lemons problem but sometimes the cost of regulatory intervention to address the problem may outweigh the benefits, especially when it does not result in any food safety concern.

Although it is not always the case, substitution and mislabelling in fish markets can create a food safety risk. An example is the consumption of toxic "puffer fish" mislabelled as "monk fish" in the United States in which many people became sick after consuming the product in 2007 (Leschin-Hoar, 2011). A consumer who is allergic to salmon and eats a fish labelled as trout when

[79] http://www.cbc.ca/news/mislabelling-means-rare-fish-sold-marketplace-1.919822

it is actually salmon will potentially have health problems. In seafood markets, a species may be correctly labelled but the seller may intentionally fail to provide information on the credence attribute (wild or farmed). Fish authentication processes may assist in reducing market failures, fraud, health risks and unfair market competition between genuine and fraudulent producer/sellers. These challenges, therefore, may motivate the uptake of authenticity technologies, such as the International Barcode of Life (IBOL) by some retailers, firms or an industry to authenticate their fish supplies in order to gain consumers' confidence and protect their individual and collective reputations; or alternatively by a third party such as an environmental or consumer group as a means to verify quality claims and authenticity at either the point of sale (e.g. retail level) or at other stages along fish supply chains. Third party verification of quality claims using the technology potentially would affect the retailer's incentive to adopt the technology to avoid being caught, and also could serve as a disincentive to cheat and mislabel. This potentially would address any lemons problems that exist and which would result in low quality products chasing out quality products from the market (adverse selection).

IBOL technology is an emerging molecular-based authenticity technology that uses genetic markers to identify plants and animal species through DNA sequencing (Hebert *et al.* 2003). In the IBOL system, DNA is extracted from the standard part of the genome of a tissue sample taken from a specimen to be identified. The barcode region of the DNA is amplified to generate a barcode, which is used to match and/or compare with sequenced reference barcodes in the database for correct identification (Floyd *et al.* 2010).

The key research questions examined in this paper are as follows: *what are the potential incentives for private sector firms (e.g. retailers) or third parties to adopt IBOL technology for fish authentication in Canada? Is IBOL technology feasible for a typical fish retail store?* IBOL could be a more effective alternative in fish species authentication than simple visual (morphological) inspection, and could potentially help in protecting the reputation and integrity of fish supply chains while leading to market prices being a closer reflection of a product's quality attributes with respect to origin or species. Some key players along the fish supply chain (suppliers, processors and retailers) have an incentive to cheat through mislabelling of fish species if price premiums exist. In this situation some third parties and "honest" retailers may have an incentive to adopt the technology for supply chain monitoring and for the protection of their individual reputation, respectively. The paper therefore, models fraud in fish markets within a domestic supply chain context and focuses on adoption of the technology by a third party and potentially by some fish retailers.

The paper is structured as follows: Section 2 examines the existing systems of food product authentication with examples of authenticity issues in Canada. Sections 3 looks at the incidence of fish species substitution in fish markets and examines the potential incentives for IBOL technology adoption along the fish supply chain using a vertical market structure model. Incentives to adopt IBOL technology are modelled formally in section 4. Section 5 discusses the potential for the IBOL technology to be commercialized, while section 6 concludes.

4.2 Existing Systems of Authentication and Problems Arising from Authenticity Issues in Canada

Ensuring the authenticity and safety of food in Canada is the shared responsibility of Agriculture and Agri-Food Canada and Health Canada. The department of Fisheries and Oceans (DFO) is responsible for fisheries management. While the establishment of policies and standards for food safety and quality is the responsibility of Health Canada, the Canadian Food Inspection Agency (CFIA) implements federal legislation concerning food inspection. The legislation covering fish products includes: the Fish Inspection Act, Fish Inspection Regulations, and the Consumer Packaging and Labelling Act.[80] In Canada, only licensed importers are allowed to import fish and fish products, which must meet the set national standards and requirements.

A portion of the fish consumed in Canada is imported by wholesalers while the remainder comes from domestic supplies (both wild caught and farmed). The CFIA grants fish importers the opportunity of taking part in the inspection of their imported products through a programme known as "Quality Management Programme for Importers (QMPI)". An importer operating under this programme is allowed to establish his quality management system with a well-functioning

[80]http://inspection.gc.ca/about-the-cfia/acts-and-regulations/eng/1299846777345/1299847442232

laboratory, which must be inspected and accredited by the CFIA to ensure that all microbiological and chemical analyses conducted by the CFIA can be done in the laboratory. At the point of entry, the CFIA takes samples of fish products for inspection from different consignments. The inspection rate varies from 2 to 100 percent, and this depends on a number of factors, including: perceived risk associated with the product, existence of prior inspection and control for the product in the exporting country, compliance history of the product and the exporter,[81] and the existence of a quality management system used by the importer (Ababouch *et al.* 2005).

Aside from other tests, specific authenticity tests carried out on randomly sampled fish products include: bacteriological tests, species identification, composition and chemical analyses. However, as of a decade ago, the results of a study carried out by the Fisheries and Aquaculture Department of the Food and Agriculture Organization (FAO) (Ababouch *et al.* 2005) suggest that potentially proper identification of substituted fish species at the Canadian borders (based on table 4.1) has not been achieved using the existing system. Presumably, this may be the case for fish fillets and fish products without the head as the public testing system for identification was mainly done using physical morphological features.

Table 4.1 shows the number of rejections for all fish imports (shipments) at the Canadian border between 1999 and 2002. It also shows the tests carried out for fish products imported from different countries at the border. Of the entire tests, authenticity issues in the context of this study are mainly concerned with "safety parameters" and "species identification". Comparing this data (Table 4.1) with the total volume of fish imported to Canada from different countries within the period, the total border rejection rate was about 0.06% (430 out of 745,383 number of shipments[82]) of total fish imports.

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[81]Exporters and/or processors with a good history of compliance receive less inspection. Products that do not meet the Canadian requirements will be refused and in some cases destroyed. Acceptance of inspection and control carried out in the exporting country by the CFIA depends on whether the control authority is recognized by CFIA under a special agreement (CFIA, 2009).

[82]Total fish imports was calculated using data on page 46 (table 43) in Ababouch *et al.* (2005).

Table 4.1: Border cases involving fish in Canada from exporting regions (1999 - 2002)

Risk/Test	Africa	Asia	EU[1]	Europe (Non EU)	North America	C and S[2] America	Oceania
Sensory evaluation[83]	16	74	12	35	3	53	7
Net weight	7	48	33	11	2	14	4
Can integrity	13	11	25	24	2	5	3
Moisture	0	3	1	0	4	4	0
Safety parameters	0	8	2	0	0	0	0
Missing Canadian code	1	1	1	1	0	0	0
Commercial sterility	0	1	0	0	0	0	0
Species identification	0	0	0	0	0	1	0

Source: Ababouch, Gandini and Ryder (2005).
[1]European Union
[2]Central and South

The data shows that some consignments from Asia failed the safety parameters test while only a single case was identified for specie substitution and mislabelling in a consignment from central and South America. This leaves an open question: is species substitution in fish imports relatively rare or were testing and inspection protocols insufficient to detect most cases during the time period presented in table 4.1?

In Canada, a study shows that out of 450 border rejections involving fish and seafood products between 1999 and 2002, 298 or 66.2 percent of cases involve fish (Ababouch *et al.* 2005). The distribution of those border cases by species is shown in figure 4.1. Comparing the number of border cases and total annual imports for each specie group, data (Ababouch *et al.* 2005, p.51) show that about 0.03 percent (i.e. 69 out 243,415; 61 out of 245,765; and 66 out of 256,203 for 1999, 2000 and 2001 respectively) of total number of shipments had border cases related to authenticity issues.

[83] This involves determining the freshness of the fish. This is usually carried out on the whole fish.

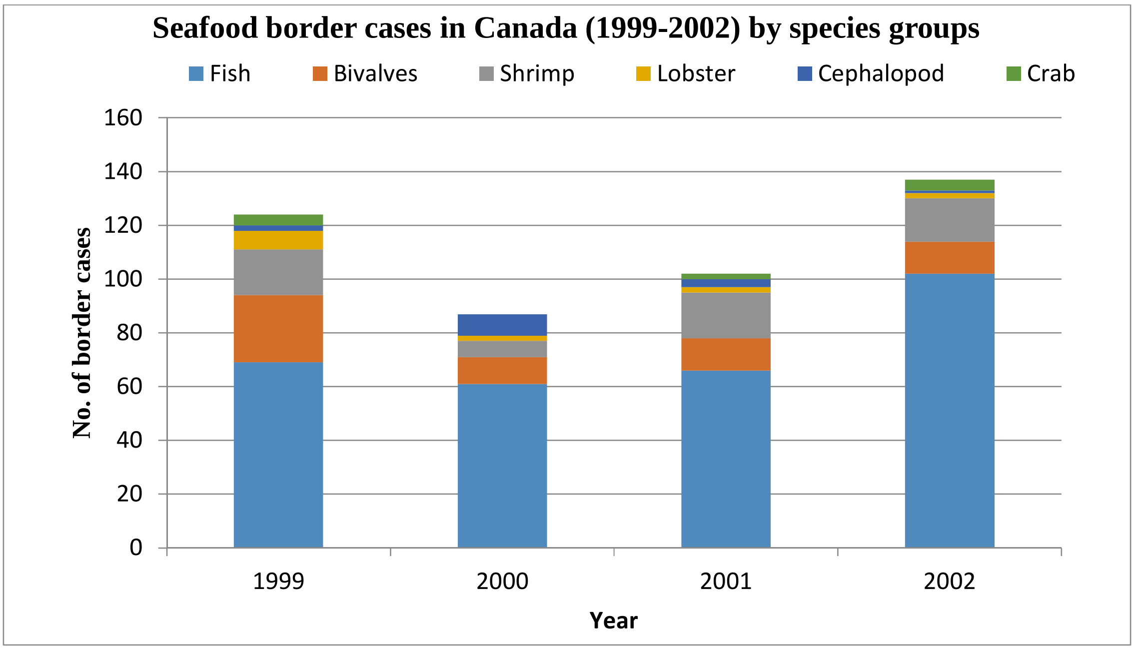


Figure 4.1: Border cases in Canada by seafood species groups

Source: Data from CFIA in Ababouch *et al.* (2005, p.49)

For shrimp, 0.03, 0.009 and 0.02 percent of total imports for each of the years had border rejections related to authenticity; while 0.13, 0.06, and 0.06 percent of total bivalves imports had issues at the border. Other specie groups, on average, had about 0.02 percent of total annual imports withheld at the border. The result further shows that border rejections for seafood products during the period are relatively small, suggesting that most imports are presumably good. Potentially, it could be that the tests fail to catch or identify incidences of substitutions and mislabelling.

Looking at authenticity within the domestic fish supply chain in Canada, apparently there is no official data presently showing the number of cases of authenticity issues in fish markets. Domestically, authenticity issues concerning fish products are detected mainly at the borders, particularly for imported fish. However, fish sourced locally are not free from substitution and mislabelling. Hence, detection of fraudulent activities requires proper monitoring of both imported and locally sourced fish products.

The inability to detect fraudulent activities at the Canadian borders in previous years could be as a result of the use of the "traditional morphology-based identification" method (Wong and Hanner, 2008; p. 1) by the regulatory agencies, such as CFIA. This identification method cannot be used for processed fish products or different species with similar morphological features. However, recent application of emerging technologies in fish product authentication within domestic markets has helped to uncover some unethical activities (species substitution and mislabelling) as evidenced in several survey results (e.g. Wong and Hanner, 2008; Hanner *et al*. 2011). For example, the survey results of Wong and Hanner (2008) show that of the 91 fish and seafood muscle tissue samples obtained from "commercial markets and restaurants" in Canada and the U.S. and sequenced, 25 percent (23) were mislabelled. In addition, the results of a survey by Hanner *et al.* (2011) indicate that 41 percent (97) of the 236 seafood samples procured by five media establishments from retail stores in "five metropolitan areas" in Canada were mislabelled. These tests were carried out at the IBOL laboratory of the University of Guelph.

Further discussion of incidence analysis of fish species substation is provided in the next section. Complementing the traditional physical identification method with technological techniques would make fish species identification easier, both within the domestic supply chain and at the borders. The occurrence of these illegitimate activities in fish markets is shown in the next section.

4.3. Incidence Analysis and Incentives to Adopt IBOL Technology

In this section, incidence (fraud) analysis in fish markets is examined using insights from Akerlof's Market for Lemons contribution, and the potential private incentives to adopt IBOL technology are modelled. The Akerlof lemons problem is described in figure 4.3 in the context of fish substitution and mislabelling.

There is no comprehensive assessment study for all fish species so far in the literature that examines the levels of fish species substitution and mislabelling in the market. Most studies (e.g. Wong and Hanner, 2008; Hanner *et al.* 2011) involve sampling of species in retail outlets. With the increasing complexity of seafood supply chains globally, it has been difficult to precisely identify the stage along the supply chain where mislabelling and substitution occurs (Warner *et al.* 2013). One of the surveys involving fish species substitution and mislabelling with wide coverage is that of Warner *et al.* (2013). In this study, 1247 seafood samples were purchased by staff and supporters of OCEANA[84] between 2010 and 2012 from 674 retail outlets comprising "restaurants, Sushi venues, grocery stores and seafood markets" (p.4) in selected cities of 21 states in the United States. Fish samples purchased include mostly species that have been found to be mislabelled in previous studies by different scholars, as well of species with a high market value. The DNA test results show that snapper and tuna are frequently mislabelled (see Figure 4.2) (Warner *et al.* 2013).

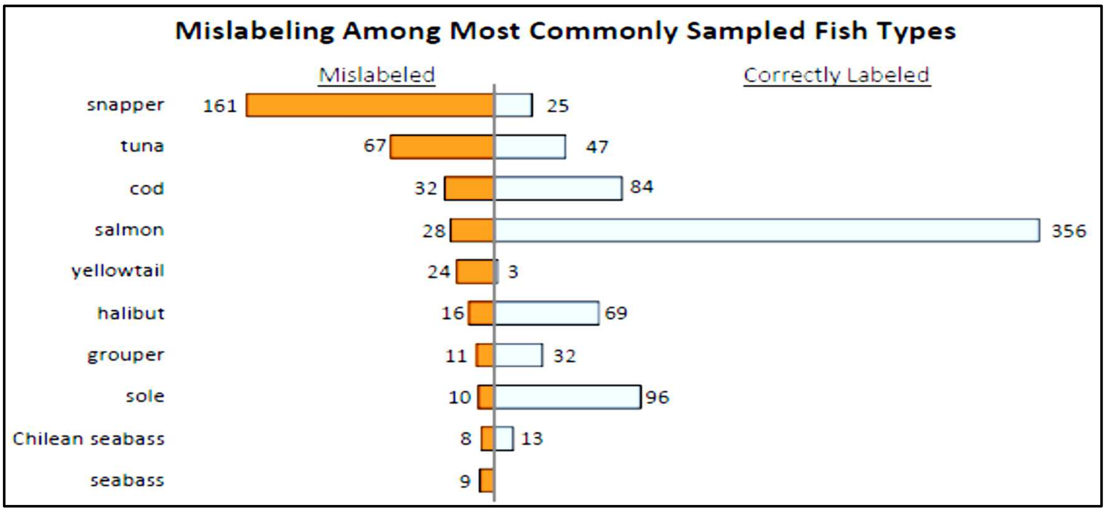


Figure 4. 2: Mislabelling of fish species in the United States

Source: Warner *et al.* (2013, p.7)

The result of the study by Warner *et al.* (2013) shows that out of 120 samples of "red snapper" collected and tested, about 93 percent were mislabelled. Different species of snapper were substituted for higher valued red-snapper for economic reasons. The results of Warner *et al.* (2013) further show that about 20 percent of mislabelled cases involve substitution of different species of snapper for red snapper, while more than 75 percent involve other species outside the snapper family, especially tilapia and rocket fish.

For tuna, 53 percent (67 out of 114 samples) of the samples were mislabelled. The highest number of mislabelling cases was found in samples purchased from Sushi restaurants while those from grocery stores were somewhat lower (Warner *et al.* 2013).

[84] Oceana is an international organization engaged in ocean conservation with offices in the U.S., Europe, Chile and Belize (http://oceana.org/en/canada/about-us/what-we-do)

Cline (2012), in a recent study on marketplace fish species substitution in Washington State, found that farmed Atlantic salmon are being mislabelled as wild Pacific salmon. The result of the study shows that out of 99 samples of salmon collected at retail outlets (grocery stores and restaurants) in Western Washington of United States, 11 percent were Atlantic salmon mislabelled and sold as Pacific salmon, which have a higher market value. Atlantic and Pacific salmon are two different species. However, there are six closely related species of wild Pacific salmon including: coho, Chinook, pink, sockeye, chum and Japanese cherry (Cline, 2012). According to FAO (2004), more than 90 percent of Atlantic salmon is farmed while only two species of Pacific salmon (coho and chinook) are farmed, usually on a small scale (Cline, 2012).

Canada is the 4^{th} largest producer of farmed salmon and contributes 8.2% in global production (CAIA, 2012). Figure 4.3 illustrates the effect of mislabelled farmed salmon entering the market for wild salmon. This creates a market failure due to Akerlof's lemons problem, which could motivate the adoption of authenticity technologies.

Salmon could be wild-caught or farm-raised. As mentioned earlier, most farmed salmon are *Atlantic* while wild-caught is mainly *Pacific*. These are two different species with similar morphological features but which differ in quality. Quality in this context is reflected in a difference in market prices for wild-caught Pacific and farm-raised Atlantic salmon. The wild-caught salmon is assumed to be of high quality and commands a higher price due to the following reasons: some consumers prefer the taste of wild-caught salmon, it is relatively scarce (fresh caught is usually available between the months of May and September after which all supplies are frozen); while farm-raised salmon are readily available and some consumers are concerned about the issues of chemical contaminants and antibiotics (Beattie and Barnes, n.d).

Assume there are two suppliers of wild-caught Pacific salmon in a fish market, one supplies correctly labelled wild-caught Pacific salmon and the other supplies farm-raised Atlantic salmon mislabelled as wild-caught Pacific salmon. Also assume that consumers cannot differentiate between wild-caught and farm-raised salmon prior to purchase. Two scenarios from a supply and demand perspective could be used to illustrate what is going on in this market and are presented in Figure 4.3.

S^H and S^{LM} show supply curves for wild-caught and farm-raised but mislabelled Atlantic salmon products respectively, while S_M and D_M are the total market supply (horizontal summation of S^H and S^{LM}) and demand curves. Implicit in this model is the assumption that wild-caught Pacific salmon is superior to farm-raised salmon.

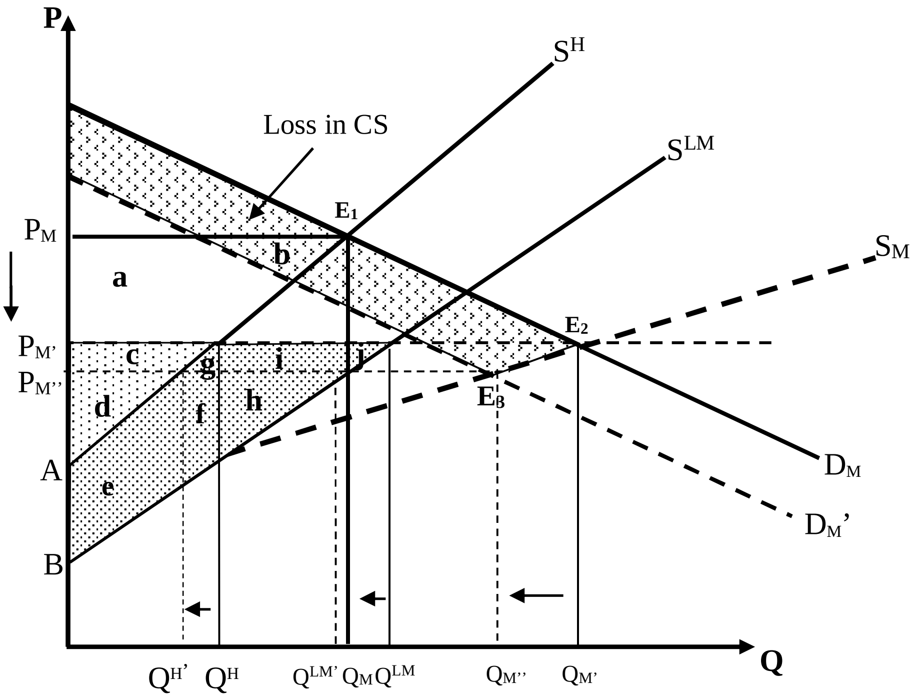


Figure 4.3: Effect of mislabelled farmed salmon entering the market for wild salmon

At price (P_M), there is no form of substitution or mislabelling and therefore, only wild-caught Pacific salmon is supplied and sold in the market. The intersection of the market supply (S^H) and demand (D_M) curves at 'E$_1$' gives the market equilibrium price (P_M) and quantity (Q_M). At this price, the supplier's surplus is area *'a+b+c+d'*. The high price for wild-caught Pacific salmon serves as an economic incentive to introduce mislabelled farmed Atlantic salmon by a supplier in order to make more profit. This increases total market supply of wild and farmed salmon to $Q_{M'}$ at the intersection of the total market supply and demand curves, S_M, D_M, and all other things being equal reduces the market price to $P_{M'}$. At this price ($P_{M'}$) it is assumed that consumers cannot differentiate both products and hence pay the same price for wild and farm-raised salmon respectively. With the decrease in price, the wild salmon supplier loses area *'a+b'* while his counterpart gains area *'c+d+e+f+g+h+i+j'* given their different cost structures.

If for any reason consumers are being alerted (possibly through the media) about the existence of farm-raised Atlantic salmon in the market, which are sold at the same price per kilogram as wild Pacific salmon, market demand by consumers would potentially reduce from D_M to $D_{M'}$ and quantity falls from $Q_{M'}$ to $Q_{M''}$ as quality is no longer guaranteed. This, all other things being equal, would further lower market price to $P_{M''}$ and, thereby, reduce quantities sold and profits for both sellers. In addition, this creates a loss in consumer surplus (CS) due to an "adverse quality effect", as shown in Figure 4.3, and the suppliers' surpluses reduce to areas *'d'* and *'d+e+f+h'* respectively. If demand continues to decline and market price drops to point *'A'*, the honest wild Pacific salmon supplier would exit the market leaving only the lemons. These price effects demonstrate Akerlof's lemons problem and shows the incidence of cost on wild salmon suppliers. The cost effect serves as an incentive for the wild salmon supplier to pay for third party certification of authenticity, for example through the use of a fish species identification technology. The amount to spend in adopting the technology would depend on the net effects of market fraud on the entire supply chain and gains from the technology.

The increasing reports of fraud in fish supply chains have posed several challenges to genuine fish sellers including: reputation building and protection, gain in consumers' confidence, and trust. Fear of reputation loss, avoidance of downward (leftward) shift in a product's demand curve (Ropicki *et al.* 2010) and loss in consumers' confidence are potential incentives for some retailers, firms or industries to adopt authenticity technologies. For example, the 2013 incidents involving substitution of horse, pork, donkey, water buffalo and goat meat for beef in Europe and South Africa have prompted many retailers to engage in the use of DNA-based techniques to ascertain the authenticity of meat products supplied to them by distributors. Some food distributors (e.g. Findus and Comigel in France, and H.J. Schypke based in Germany) whose products tested positive for horse meat, and retail outlets supplied with these products, suffered damaged reputations as a result of a loss in consumers' confidence and reduced trust for their products, at least in the short run (Durden, 2013).

In principle, a retailer's decision (e.g. in Canada) to adopt a fish authentication technology such as IBOL (explained below) would lie mainly on private (internal to the retailer) market-based incentives (e.g. price premium, bolstered consumer confidence and reputation), while a third party's adoption decision may be driven by broader public (including regulatory) motivations. For the retailer, according to Jayasinghe-Mudalige and Henson (2007), the potential impacts these incentives would have on an adopting retailer will depend on the retailer's scale of operation. Therefore, it is hypothesized that a retailer would voluntarily adopt an authenticity technology for fish authentication under the following conditions:

- if the retailer would use the technology to check the authenticity of fish supplied by upstream suppliers and therefore as a deterrent against cheating by suppliers (Segerson, 1999);
- the difference between the perceived market benefits (e.g. premium, market share) and the associated costs of adopting the technology is high enough to warrant such investment (Henson and Heasman, 1998). For example, if the cost of adopting the technology is very high, retailers (especially small scale retailers) might not go for the technology;
- if it is easy to trace the origin/source of the fraud and the defaulting retailer is strictly responsible for any costs imposed (spillover) on other retailers in the fish industry for damaging their reputation (Segerson, 1999). In this case, individual retailers would consider adopting the technology to protect their reputations and that of the industry; and
- compliance with existing government regulation to access international markets. For example, a large Canadian fish distributing firm that supplies fish to a processing firm in the U.S. where DNA barcoding technology is already in use for fish authentication. If the supply contract strictly indicates that every fish supplied must undergo an authenticity test, this could be an incentive for the distributor to adopt the technology and use it to test the fish supplied to him by fishermen or wholesalers in Canada.

A description of the IBOL technology and the trend in the cost of DNA sequencing are presented in the next section.

4.3.1 The IBOL technology

The application of DNA barcoding in species identification started in 2003 by a group of scientists led by Paul Hebert of the Biodiversity Institute of Ontario, University of Guelph.[85] The specimens of the first set of species identified by the research group were collected from the zoo, museums, field, seed banks, among others.[86] The project has expanded and involves many scientists across the world.

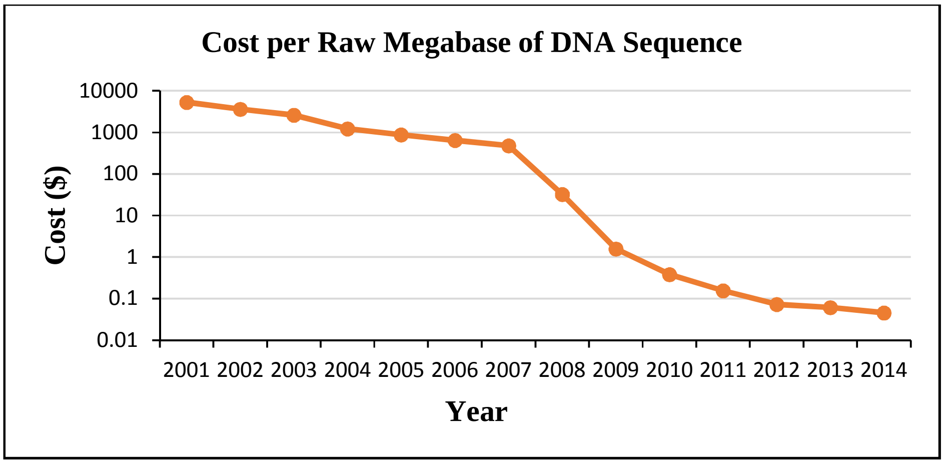
The IBOL technology uses DNA sequencing and barcode in species identification. DNA barcode is "*a short gene sequence used to identify species taken from a standard position in the genome*" (Yancy, 2007, slide no.4). The first step in the IBOL process involves extraction of a tissue sample from the specimen of a specie to be identified. A high resolution photograph of the specimen is taken for record keeping in the reference library (database) followed by recording of the specimen's taxonomy information. The DNA is extracted from the gene region of the tissue sample and the barcode region (COI) amplified using the Polymerase Chain Reaction (PCR). The DNA sequencer is then used to generate a barcode, which is used to compare the barcodes of species already identified and stored in the reference library for appropriate identification (Floyd *et al.* 2010).

As mentioned earlier, the cost of DNA-based technologies relative to existing methods of establishing authenticity is an important factor that affects adoption of the IBOL technology. However, statistics have shown that the cost of DNA sequencing is rapidly reducing overtime. Figures 4.4 (a) and (b) show the trend in the cost of DNA sequencing from 2001 to 2014 (see appendix 4.I for a summary table).

[85] http://ibol.org/about-us/what-is-dna-barcoding/

[86] ibid

(a)



(b)

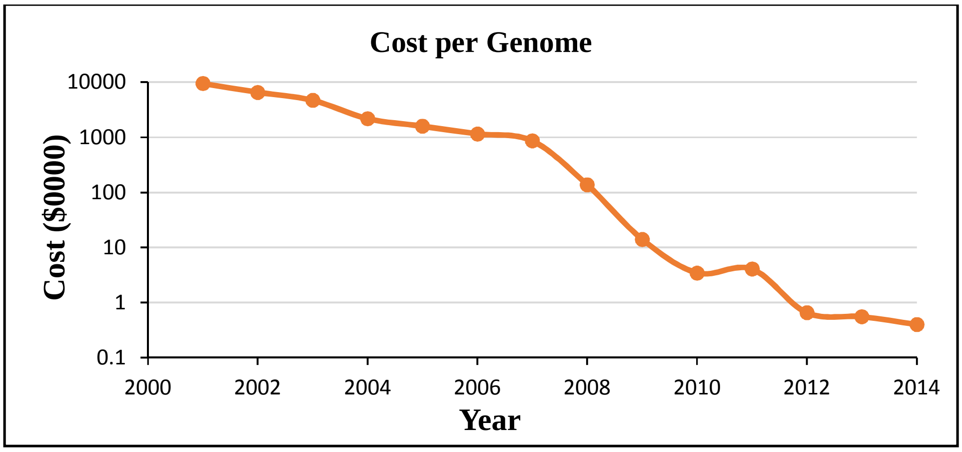


Figure 4.4: Trend in the cost of DNA sequencing

Data Source: Wetterstrand (2014)

The "cost per megabase" (million base pairs) shows all costs that are associated with generating one megabase of quality raw DNA sequence, while "cost per genome" is the cost of sequencing a "human-sized genome" (Wetterstrand, 2014). Figures 4.4 (a) and (b) show a sharp decline in the cost of DNA sequencing starting in 2007 with the inception of second generation sequencing technologies (i.e. from $800 per raw megabase in 2007 to about 4 cents in January 2014, and from $10m per genome to about $4,008 during the same period). The trend suggests that the cost of DNA sequencing would continually decrease as years go by. According to Wetterstrand (2014), these technologies are faster, automated, more precise with a high degree of accuracy, and can concurrently undertake thousands/millions of genes sequencing.

In the case of fish products, usually samples for authentication can be selected from commercial markets (e.g. retail stores) or from consignments at the borders for imports. The trends in figures 4.4 (a) and (b) show that costs of testing are relatively low. If for example, a retailer who wants to protect his reputation adopts the technology along the fish supply chain, how would the benefits from the technology be distributed given the cost of adoption? Obviously, participants that benefit from the status quo would lose. This is shown in the next section.

4.3.2 Distribution of Potential Welfare Benefits from Adoption of International Barcode of Life (IBOL) Technology in Fish and Seafood Authentication

Consumers' increasing demand for authenticity implicitly suggests an increased willingness to pay for genuine quality products. Some studies have shown that consumers are willing to pay a premium for wild-caught fish (e.g. O'Dierno *et al.*, 2006; Kelly *et al.*, 2012).

A fish supply chain refers to a network of interdependent fish producers (suppliers), processors, distributors, transporters, wholesalers, retailers and food services who are involved in the production, processing and delivering of fish products to consumers (UNEP, 2009). For the purposes of this analysis, in Canada the domestic fish supply chain comprises fishermen/fish farmers (producers), processors, wholesalers and retailers. Fishermen supply their captured fish to processors who sell their processed fish products to wholesalers (distributors). The wholesalers store and transport the fish and sell to retailers, food service establishments and restaurants. The retailers through their outlets (supermarkets) finally sell to consumers, as do restaurants. Sometimes, the processors sell directly to retailers, restaurants and food service establishments.

In this section, the potential stage along the fish supply chain at which the IBOL technology could be adopted and the incentives to adopt the technology are modelled under an autarky situation. Assume that Canada is in autarky for fish products. Here, we look at the vertical fish supply chain comprised of the fish producers/sellers/suppliers, the processors and the retailers.

The idea is to examine the incentives for technology adoption and determine at what point along the fish supply chain in Canada the IBOL technology may be adopted and how the potential welfare benefits are distributed. To determine the size and distribution of potential social benefits associated with IBOL technology adoption, the following assumptions are made:

a) IBOL technology provides benefits to consumers by verifying the authenticity of the food products they consume;
b) Since the functional forms are not known, we assume linear supply and demand curves and a parallel shift (upwards due to increased cost) in a Canadian retailer's supply curve resulting from technology adoption;[87]
c) The price change at each level of the supply chain reflects costs of technology adoption and other associated costs; and
d) The nature of the stylized fish supply chain examined potentially determines the level of transparency within the supply chain. For example, it is assumed that a supply chain that has a short distance between the fish producers and consumers presumably would be more transparent or easier to monitor by a third party (UNEP, 2009)

Looking at the incidence analysis from the perspective of substitution and mislabelling, the costs of these fraudulent activities are not equally distributed among the key players along the fish supply chain. While some fish producers/suppliers may benefit from the status quo (e.g. substitution of low for high valued species, particularly when fish are supplied without the head, (which is the major part of the body used for physical identification), the processors and particularly retailers may lose through damage to their reputation, loss of consumers' trust and/or confidence if such activities are identified by enforcement authorities or third parties.

On the other hand, mislabelling may also occur at the processor and retailer levels, although there may be some honest processors and retailers who would be willing to adopt authenticity

[87] Alston and Wohlgenant (1990) show that when there is a parallel shift in a supply curve due to technology adoption, the choice of functional form basically has little or no effect on the magnitude and distribution of social welfare benefits. In addition, studies (e.g. Voon and Edwards, 1991; Mills, 1998) contend that when the functional forms of demand and supply are not known, linear functions can be used as approximations.

technologies to prove that their fish are not mislabelled, protect their reputations against cheating elsewhere in the supply chain by other retailers (causing damage to collective reputation).

Drawing from the horse meat scandal in Europe that led to questions concerning the integrity and credibility of meat supply chains, the incentive to adopt authenticity technologies along the fish supply chain presumably would be high at the retail level. This is because retailers deal directly with consumers and most retailers would want to protect their reputations, and gain consumers' trust and confidence by ensuring that the quality claims of all the products supplied to them are verified.

Third parties (e.g. consumer or environmental associations or the regulator) may also have an incentive to adopt IBOL technology for monitoring to guard against cheating at various stages within the supply chain (including at the retail level). It is usually difficult to physically distinguish fish products in processed (e.g. fillets) forms. Therefore, who gains and/or loses would inform who might have an interest in seeing IBOL technology adopted.

Figure 4.5 shows the model for IBOL technology adoption in the stylized fish supply chain in an autarky condition in Canada. At every stage of the supply chain, *D* and *S* (without IBOL) represent the demand and supply curves prior to technology adoption; while *D'* and *S'* (with IBOL) respectively represent post technology adoption demand and supply curves. Although species substitution is a possibility at all stages of the supply chain, the probability of its occurrence would be highest at the producer/supplier level. This would particularly be the case for beheaded fish species with the same morphological structure. Therefore, the size and direction of the demand shift at each level is contingent on the probability of detecting cheating (use of authenticity technology).

Given the increasing spate of widely publicized cases of fraud in fish markets and other food supply chains; and the challenge of reputation building, protection, and gaining consumers' trust, a fish retailer potentially would adopt the IBOL technology to test the authenticity of fish provided by the fish supplier and/or distributor in order to ensure quality and protect his reputation. If the test result shows a high level of misrepresentation or species substitution, the retailer may cease sourcing products from the fish supplier. Thus, the fish supplier will lose market share and incur costs, especially if there exist penalties for cheating, such as withdrawal of licenses; high storage and inventory costs, and search and negotiation costs to establish a new business relationship with another retailer.

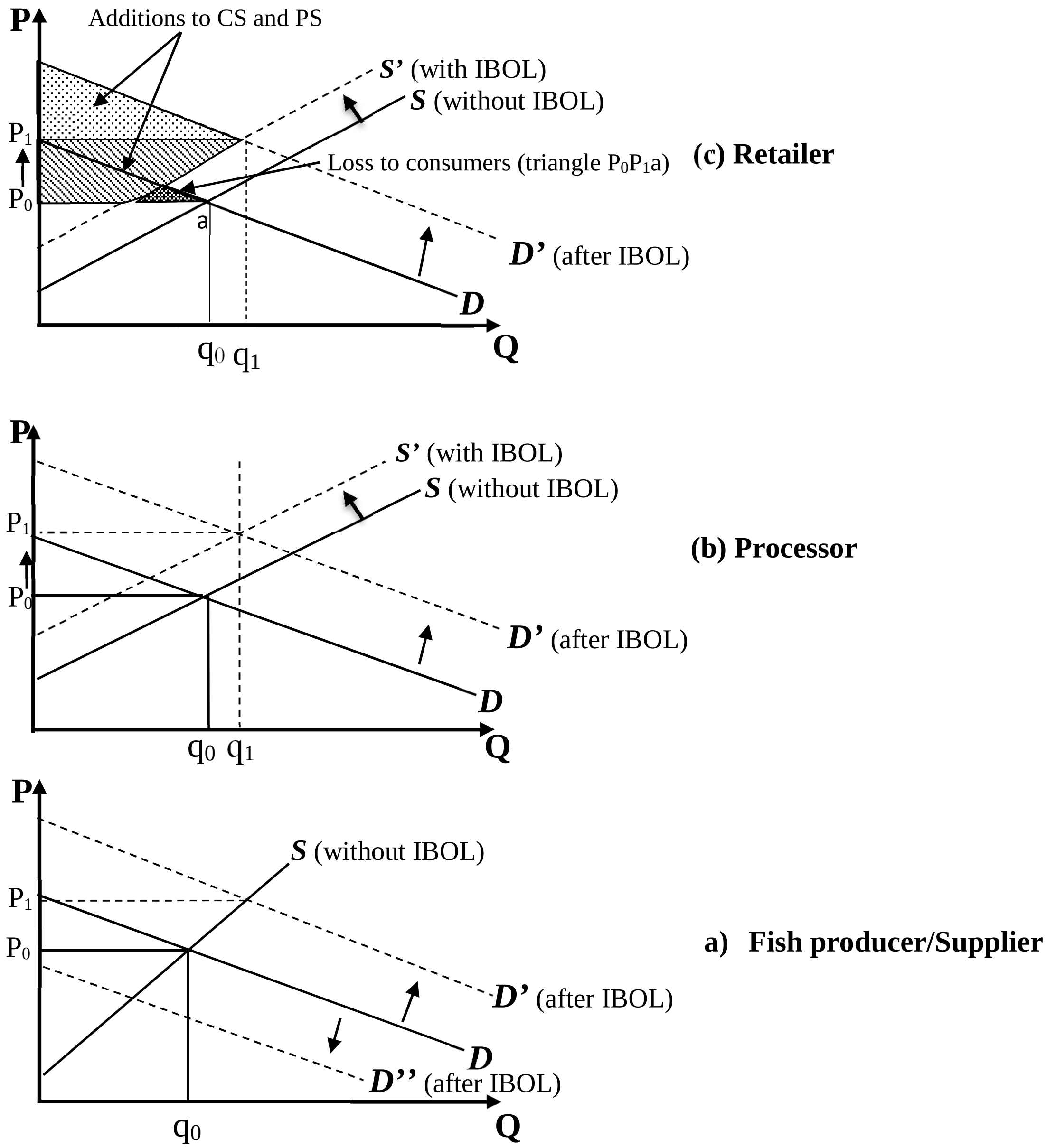


Figure 4.5: Fish supply chain in Canada

As mentioned earlier, it is assumed that there is potential for cheating at every stage along the fish supply chain. At the processor and retailer levels, the market equilibrium price and quantity are q_0

and P_0 respectively resulting from the intersection of demand and supply curves in the absence of IBOL.[88] Adoption of IBOL would raise retailer's costs and increases consumers' confidence, reduce quality uncertainty and will potentially increase demand for fish and therefore, revenues. The increase in demand, combined with the increase in costs, all other things being equal, will lead to a price increase (from P_0 to P_1). The intersection of the new demand and supply curves results in new equilibrium price (P_1) and quantity (q_1). Holding other factors constant, an increase in price would result in a loss in consumer surplus and a gain to fish processors and retailers. The size of the gains and losses depend on the sizes of the demand and supply shifts and the elasticities. However, it is assumed that the retailer would have the incentive to adopt the technology only if the size of the demand shift is bigger than the change in marginal costs. It would be a disincentive to adopt the technology by a retailer if the change in marginal costs driven by technology adoption outweighs the change in demand resulting from fish authentication. The adoption cost at the retail level would be built into the retail price.

Considering the processor level, the retailer would adopt an authenticity technology to test the fish supplied by the processor as cheating could occur at both the processor and supplier levels of the supply chain. Thus, adoption of an authenticity technology by the retailer to test the fish supplied by the processor would serve as an incentive for the processor to avoid cheating (substitution and mislabelling), and possibly drive his decision to pay for the technology and use it to test fish supplied by the producer in order to protect his reputation, gain confidence and maintain a good business relationship with the retailer. In addition, if the processor, through testing, discovers some form of misrepresentation (species substitution) by the fish producer/supplier, the processor would lose confidence in the supplier and may cease sourcing fish from him.

At the producer level, *D* and *S* respectively represents demand and supply curves prior to technology adoption. While *D'* shows an increase in demand for fish by the processor when fish supplied by the producer are truthfully declared, *D''* represents a fall in demand for fish by the processor if he discovers that fish (or some) supplied by the producer are misrepresented, assuming

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[88]The demand curve *D* shows the demand for non-tested (unauthenticated) fish while *D'* (after IBOL)" is the demand curve for confirmed (authenticated) fish.

the technology is effective in detecting cheating. Authenticity technology adoption may not be feasible at the fish producer level, and therefore, the fish producer will not incur any adoption costs. This is because the fish supplier is at the upstream of the supply chain. However, at every level of the supply chain, the key player's individual reputation is considered very important. Hence, every player is always careful in order not to lose his reputation and consumer confidence.

Overall, a threat of third party testing/monitoring of the fish supply chain with the IBOL technology would be an additional motivation for retailers and processors to adopt the technology. Potentially, this would enhance the credibility and integrity of the fish supply chain.

It is assumed that authentication creates confidence and quality assurance and, therefore, potentially increases demand and market price. Although an increase in price reduces consumer surplus, quality assurance from authenticity would potentially increase demand for fish. However, a gain in consumer surplus would depend on which effect is larger, the loss in surplus from the price increase or the gain in surplus from the quality effect. In other words, it introduces an adverse price effect but at the gain of reducing/eliminating the adverse quality effect. If the size of the demand shift outweighs adoption costs, the retailers would benefit. However, the actual size of the net benefits (consumer and producer surpluses) depend on the relative sizes of supply and demand shifts as well as elasticities. Thus, it is more of a computable problem than a theoretically derived result. The fish supply chain model (figure 4.5) will be used in developing a framework for modelling private incentives to adopt the technology in the next section if IBOL can easily detect fraud with a high level of accuracy.

4.4 Modelling Incentives to Adopt IBOL Technology for Fish Authentication

At every stage of the fish supply chain, participants are assumed to strive to maximize economic profits. As mentioned earlier, a processor or retailer would be incentivized to adopt the IBOL authentication technology if the private market benefits are greater than the associated costs, and also to protect their reputations given the expectation of illegitimate activities going on in fish markets. This implies that a retailer would be willing to adopt the technology if it will generate higher profits (i.e. the cost of adoption has to be compensated by a higher price and revenue). Alternatively, the expected net payoff has to be larger than the alternative of not adopting the technology. It is therefore expected that the retailer would set a price mark-up which reflects the cost of adoption. Fish authentication could be seen as a form of value addition and product differentiation, which is expected to yield economic rent, at least in the short run.

Assume the retailer is in a competitive market; his total revenue (TR) after selling a particular quantity (q) of fish at a market price (P) is given by

$$TR_{(q)} = P_{(q)}.Q \tag{4.1}$$

Assume also that the total economic cost incurred by the retailer is represented by TC, and is comprised of variable (C) and fixed costs (F). i.e.

$$TC = C + F \tag{4.2}$$

We look at the adoption decision from two perspectives, with and without IBOL.

The profit maximizing functions of the fish retailer, with and without IBOL are specified as follows:

$$\max_{Q} \pi_{WI} = P.Q - CQ - F \tag{4.3}$$

$$\max_{Q,\theta} \pi_{I} = [P + k(\theta)]Q - [C + j(\theta)]Q - F - Z\theta \tag{4.4}$$

Where superscripts *WI* and *I* represent *without* and *with* IBOL respectively.

$$\left.\begin{array}{l} \theta = 1, if\ IBOL \\ \theta = 0, if\ no\ IBOL \end{array}\right\} \textit{Parameter indicating adoption or non-adoption cases}$$

k = Price premium for IBOL authenticated fish

$j =$ Variable costs associated with IBOL

$P, Q =$Market price and quantity of fish sold

$F =$Fixed costs[89] without the IBOL system

$C =$Variable costs without IBOL system

$Z =$Fixed costs of IBOL independent of the number of fish tested. That is the investment required to switch to the IBOL system (e.g. equipment procurement, staff training, advertisement for the use of the technology to consumers, etc.)

[89] This does not enter the decision whether to adopt.

The change in profit resulting from technology adoption is given by (4.4) – (4.3). That is

$$\Delta\pi = (k - j)Q - Z \qquad (4.5)$$

Two important assumptions are made. First, the retailer will objectively adopt the technology based on its expected market benefits relative to the costs of adoption and operation without any regulatory control from the government. Second, the expected benefits (e.g. revenue) exceed the cost of technology adoption. There is need for a certain level of profit to justify investment in the authenticity technology. Thus, the incentive to adopt the technology would potentially occur when

$$\Delta\pi = (k - j)Q - Z \geq 0 \qquad (4.6)$$

However, Q is the market size (quantity of fish). If the size of Q is too small relative to Z, this may affect the decision to adopt for small, medium and large scale fish retailers. This implies that IBOL technology adoption may be affected by the market size of the firm.

The incentive to adopt IBOL technology is modelled under two scenarios. The first (section 4.4.1) is adoption by a retailer (honest) to test the fish supplied by upstream suppliers and protect his reputation against cheating elsewhere in the supply chain or cheating by other retailers that could cause damage to collective reputation. The second scenario (section 4.4.2) is adoption by a third party to monitor the supply chain and guard against cheating by retailers and other participants along the fish supply chain.

4.4.1 IBOL Technology adoption by a retailer

The decision to adopt the technology by the retailer could be examined in three stages of technology development or evolution.

Stage 1:

This is assumed to be the stage when the technology is newly developed and relatively costly, there will be no adoption due to the high cost of the technology. By assumption, the price of IBOL authenticated fish would be less than the average total cost (ATC) of adoption. This is shown in figure 4.6 for different market structures of perfect competition and monopoly. In both markets, the firm will not cover the cost of adoption at market price P*.

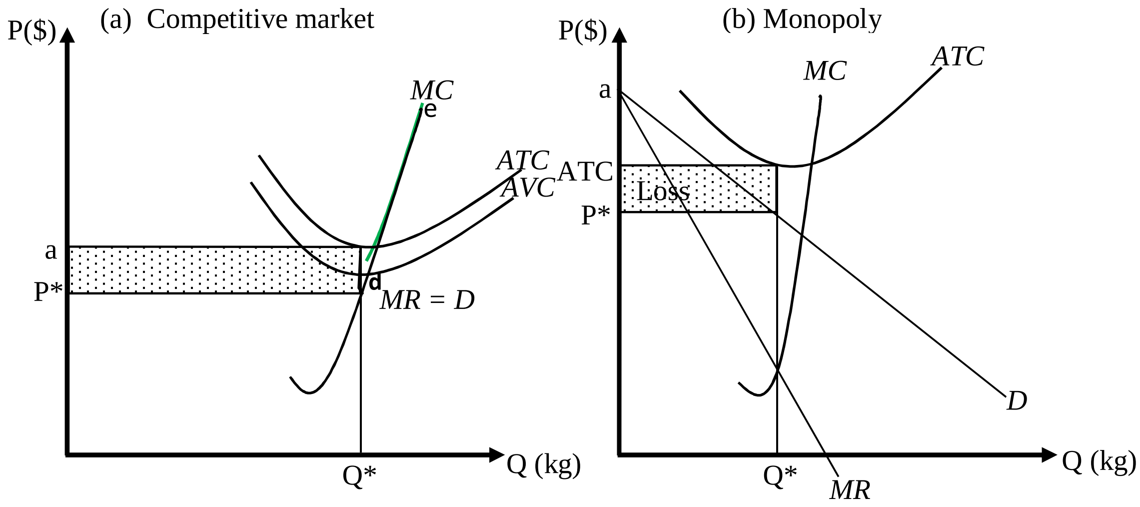

Figure 4.6: Disincentive to adopt IBOL technology due to initial costs

In panel (a), the firm's short-run supply curve is the portion of the marginal cost curve labelled '*de'* that lies above the average variable cost curve. In panel (a) market, *MR* = *D* (i.e. demand is perfectly elastic at price *P**).

Stage 2:

This is the second stage of the technology development where costs start to fall, as shown in figure 4.4 of section 4.3.1 above. At this stage, although costs start to fall, the private market incentive to adopt the technology is insufficient. However, if the technology is deemed to have broader social benefits, potentially the public sector might adopt it or subsidize its adoption. Thus, adoption of the technology yields zero economic profit at point *b* in figure 4.7. The slope of the ATC curve is equal to the slope of the demand curve at point '*b'*. This is shown in figure 4.7.

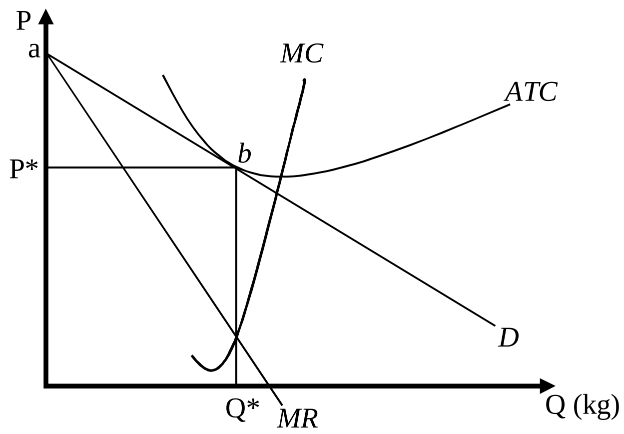

Figure 4.7: Technology adoption when profit is zero

Stage 3:

Studies in the technology adoption literature have shown that adoption costs typically decrease overtime (Smith and Ulu, 2012). At this stage, it is assumed that fish consumers are willing to pay premium *k** for IBOL authenticated fish (see figure 4.8). The short-run profit (price effect) equivalent to area '*k*abATC'* would serve as an economic incentive for a (large) fish retailer to pay for the technology and enjoy the first-mover advantage. That is the private market incentive is sufficient to adopt the technology by an early adopter (retailer) who could set his price above marginal cost and make economic profit before adoption by other retailers. The profit would attract other retailers and incentivize them to adopt the technology. Increased adoption of the technology could be a way of gaining consumer trust and assist in collective reputation building for the industry as a whole. However, as other retailers adopt the technology, the premium declines and will eventually disappear when every retailer adopts the technology.

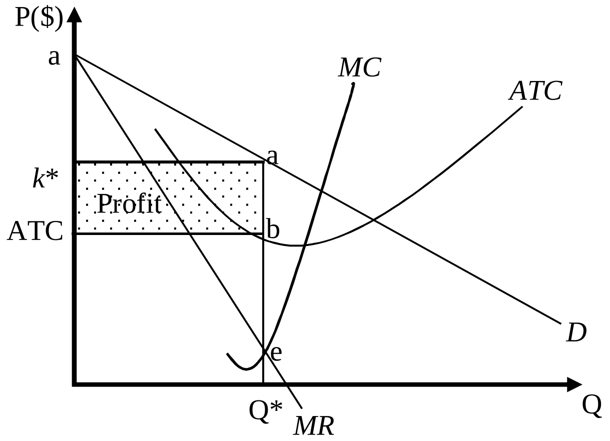

Figure 4.8: IBOL technology adoption by a retailer when profit is positive

In modelling the first scenario (adoption of IBOL technology by a retailer), an important factor considered here that could shape a retailer's adoption decision for the technology is *the number of retailers that adopt the technology and the size of their market shares*.

In examining this factor, the following assumptions are made:

a. Linear demand function;
b. Retailers sell a homogenous product (salmon) and engage in static Cournot competition;
c. No barriers to entry and exit from the retail fish market. This implies that a retailer adopts the technology when the expected profit is positive and exits when profit is negative;
d. Market demand for salmon is constant;
e. Economies of scale for use of the IBOL technology (average cost is greater than the marginal cost); and
f. Retailers have identical cost functions

Assume the market demand function for authenticated salmon is given by:

$$k(Q_f) = a - bQ_f \tag{4.7}$$

where,

k = price premium for IBOL authenticated fish

a = the highest amount of premium obtainable in the salmon fish market (choke price)

Q_f = quantity (kg) of salmon sold in the market[90]

Figure 4.9 shows how the price premium (k) is derived. In figure 4.9, D_0 and S_0 represent market demand and supply curves prior to technology adoption. Q is the quantity of authenticated fish sold in the market. The intersection of D_0 and S_0 gives the equilibrium price (P_e) and quantity (Q_e). Adoption of the technology involves some costs and this causes an upward shift in the supply curve. On the other hand, the demand curve shifts to the right as a result of an increase in demand for the authenticated fish. Intersection of the new demand and supply curves results in a higher equilibrium price and quantity. The difference in price is the premium for authenticated fish.

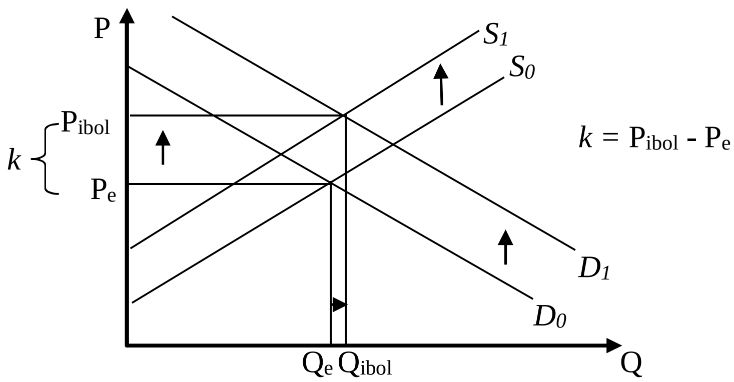

Figure 4.9: Derivation of premium for IBOL authenticated fish

First, we determine the number of retailers that could earn non-negative profits from the adoption and use of IBOL technology in fish authentication using Cournot competition. The idea is that the technology might support a certain number of retailers beyond which the expected profit from the technology would be negative. Assume also that there are N salmon retailers in the market, each having the same cost function given as:

$$C_i(q_i) = mq_i + F \tag{4.8}$$

where,
q_i = the quantity of salmon supplied to the market by the i^{th} retailer
m = marginal cost

[90] This gives an idea of the market size for salmon.

F = fixed cost of switching to the IBOL system[91]

The market demand is given by equation (4.7) where total quantity of fish supplied in the market is $Q_f = \sum_{i=1}^{N} q_i$. The retail fish market is modelled as a free entry Cournot oligopoly (Cournot, 1960) to determine the number of retailers the technology could support. The Cournot model is chosen because in a Cournot equilibrium, a retailer that first adopts the technology would have the incentive (market power) to set his price above marginal cost. This power decreases as other retailers switch to the IBOL system with their demand curves shifting inwards (Church and Ware, 1999, p.239).

Following Cournot (1960), assume retailer *i* wants to adopt the technology. At equilibrium his best response function is determined by equating his marginal revenue to marginal cost.

$$a - b\sum_{j \neq i} q_j - 2bq_i = m \tag{4.9}$$

By selling a homogenous product, the retailers' Cournot equilibrium quantity of authenticated fish sold, denoted by q_f^c , will be symmetric. Therefore, equation (4.9) could be written as

$$a - b\sum_{i=1}^{N} q_f^c - 2bq_f^c = m \qquad (4.9a)$$

This implies that:

$$a - b(N-1)q_f^c - 2bq_f^c = m \qquad (4.9b)$$

Solving for the equilibrium quantity of authenticated fish sold by each retailer, market quantity, price and profit, we have;

$$q_f^c = \frac{a-m}{b(N-1)} \tag{4.10}$$

$$Q_f^c = N * q_f^c = \frac{(a-m)N}{b(N+1)} \tag{4.11}$$

$$P_f^c = \frac{a+Nm}{N+1} \tag{4.12}$$

$$\pi_f^c = \frac{(a-m)^2}{b(N+1)^2} - F_{ibol} \tag{4.13}$$

[91] The fixed costs associated with IBOL technology adoption will not affect the equilibrium quantity of authenticated fish sold in the market. It will only affect market equilibrium profit.

Equations (4.10) and (4.11) respectively show that an increase in the number of retailers adopting the IBOL technology will reduce the market share for each retailer and increases total market supply. Consequently, market price and profit will decline. Equation (4.13) indicates that a retailer would have an economic incentive to adopt the technology if his market profit is greater or at least equal to the fixed costs of technology adoption. Therefore, to determine the number of retailers, N_f^*, that would potentially adopt and benefit from technology, we have to equate the Cournot equilibrium profit to the fixed cost associated with the IBOL system. That is:

$$\left[\frac{(a-m)^2}{b(N+1)^2}\right] = [F_{ibol}] \Rightarrow \pi = 0 \ (equilibrium)$$

Solving, we have;

$$N_f^* = \frac{a-m}{\sqrt{bF_{ibol}}} - 1 \tag{4.14}$$

Profit can be positive or negative. The sign (value) is contingent on the number of retailers (*N*), the magnitude of the fixed costs (*F*) and elasticity (*b*) respectively. However, equation (4.14) shows that the bigger the slope parameter, b (elasticity), the lower will be the mark-up and, the smaller the number of retailers that will earn positive profits from using the technology. That is:

$$\frac{\partial N_f^*}{\partial b} = -\frac{a-m}{2b^{\frac{3}{2}}\sqrt{F_{ibol}}} < 0 \tag{4.14a}$$

$$\frac{\partial N_f^*}{\partial F_{ibol}} = -\frac{a-m}{2\sqrt{b}F_{ibol}^{\frac{3}{2}}} < 0 \tag{4.14b}$$

$$\frac{\partial N_f^*}{\partial a} = \frac{1}{\sqrt{bF_{ibol}}} > 0 \tag{4.14c}$$

The technology would yield positive profits up to $N_f^* th$ (equilibrium) number of retailers that adopt the technology. Therefore, $(N_f^* + 1)th$ retailer adopts the technology, all the retailers that adopt the technology would earn negative profits. This is based on the assumption that the model is static and not sequential.

To show these outcomes empirically and following the method in Church and Ware (1999, p.249) using arbitrary numbers and considering equations (4.7) and (4.8), assume the highest premium obtainable from a kilogram of IBOL authenticated fish, *a = $8*, *b = 0.7*, *m = $1.5* and *F = $5;* table 4.2 shows how an increase in the number of retailers who adopt IBOL technology would affect market share and profits (see Appendix 4.III for a detailed calculation).

Table 4.2: Retail profit for IBOL technology adoption as a function of number of retailers

No. of fish retailers (*N*)	Market share per retailer (q_f^c)	Market quantity (Q_f^c)	Price per fish (P_f^c)	Average costs (AC)	Profits ($)
1	4.64	4.64	4.75	2.58	10.08
2	3.10	6.2	3.67	3.11	1.73
3	2.32	6.96	3.13	3.66	-1.22

Source: Non-Market data (results based on author's calculations using arbitrary values)

Results of table 4.2 and figures 4.10, 4.11 and 4.12 respectively show that the first two retailers that adopt the technology would earn positive profits in the context of this model. When the third retailer adopts the technology, however, all the three retailers would earn negative profit, which would serve as a disincentive to adopt the technology. Substituting the values of *a, b*, *m* and *f* in equation (4.14), we determine the optimal number of retailers that would earn positive profits from the technology as follows:

$$N_f^* = \frac{8 - 1.5}{\sqrt{0.7 * 5}} - 1 = 2.46 \approx 2$$

The equilibrium number of retailers in this case is 2. What happens as retailers adopt the technology is graphically shown in figures 4.10, 4.11 and 4.12 respectively. The retailer is assumed to be profit maximizing. Assume the first retailer that adopts the technology in the market supplies $0q_1$ quantity of authenticated fish and earns a premium equal to k_1. The second retailer adopts the technology and supplies $0q_2$ quantity of fish with an increased average costs. The total quantity of authenticated fish supplied and sold in the market by retailers 1 and 2 is '$0q_1 + 0q_2$'.

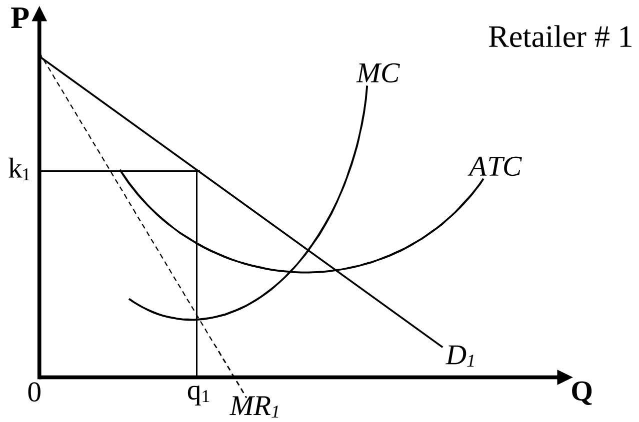

Figure 4.10: Technology adoption by the first retailer

The increase in market supply, assuming market demand and all other factors remain constant, reduces the premium from k_1 to k_2 when the second retailer adopts the technology. The decrease in revenue as a result of the lower price would be $(k_1 - k_2)q_2$. Despite the decrease in revenue, the retailers would still make a positive profit.

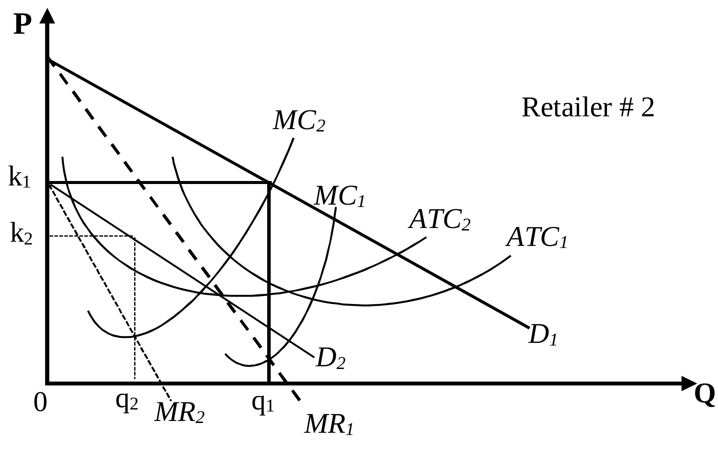

Figure 4.11: Technology adoption by the second retailer

The third retailer would supply only q_3 quantity of authenticated fish thereby increasing the total market quantity to '$0q_1 + 0q_2 + 0q_3$' while premium decreases to k_3, which would be negative. This amount of premium and market share could be a disincentive for switching to the IBOL system. The premium will eventually diminish when all the retailers adopt the technology.

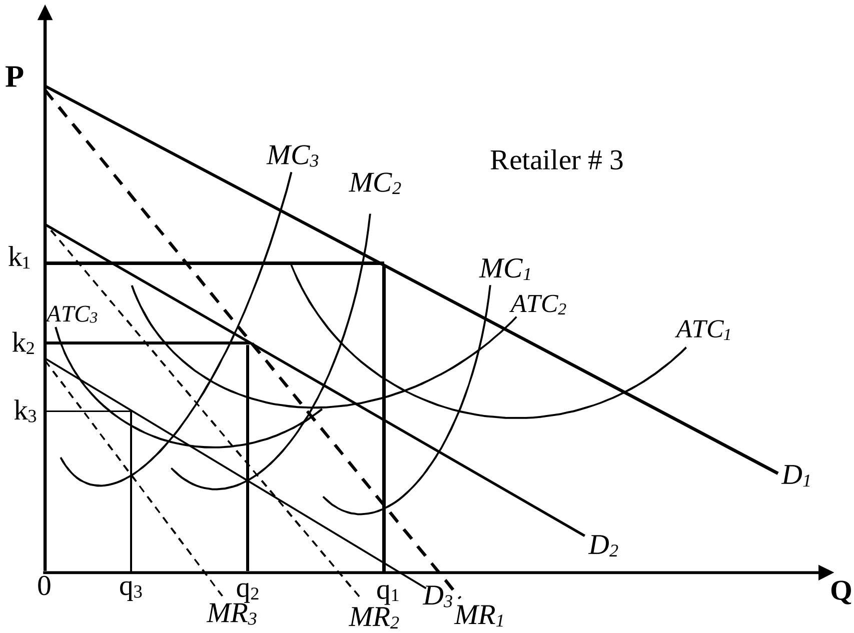

Figure 4.12: Technology adoption by the third retailer

Results of the analysis in this sub-section suggest that as the number of retailers selling authenticated fish increases, the market share for each retailer decreases as well as the premium for the authenticated fish.

4.4.2 Outcomes of third Party adoption of IBOL technology for supply chain monitoring

In this section, the outcomes of a third party (e.g. CFIA or an environmental/consumer group) incentive to adopt IBOL technology for fish supply chain monitoring are modelled. The fish supply chain comprises suppliers/producers, processors/distributors and retailers who (most times) sell directly to consumers. A major assumption here is that fish suppliers, processors and retailers have an incentive to cheat through substitution and/or mislabelling of species, particularly if price premiums exist. This could be an incentive for a third party to adopt the technology for supply chain monitoring to catch cheaters given the accuracy of the technology in detecting fraud, and possibly impose penalties for fraudulent misrepresentation of products.

The methodological framework used here is drawn from the fish supply chain model (figure 4.5, p.138). The analysis is done at the retail level for several reasons. First, the analysis provides a starting point to model incentives to adopt an authenticity technology by a third party for supply chain monitoring. Second, the retailer sells directly to the consumers, and following the incidence of substitution of horse meat for beef in processed meat products in Europe, the illegitimate market activity was uncovered at the retail level. Hence comparatively the retailer would potentially have more incentive to adopt an authenticity technology to protect its reputation against any illicit market activity that may occur upstream along the supply chain. Third, focusing on the fish producer might entail a different method of analysis and, therefore, could be a potential area to consider for future studies. Nevertheless, the results of the analysis at the retail level potentially would apply also to processors.

Although different in focus, the analytical approach follows that of Malik (1990), Lear and Maxwell (1996) and Popkova (2013). Malik (1990) examines how existing government enforcement policy shapes a firm's compliance with pollution control, while Lear and Maxwell (1996) examine a firm's incentive to comply with environmental regulation. Popkova (2013) examines government's willingness to combat corruption (i.e. how government handles anti-corruption policies). In this sub-section, we model the potential outcomes of a third party adoption of the IBOL technology for supply chain monitoring to catch cheaters, which can be retailers, processors or suppliers.

The stylized analytical framework drawn from figure 4.5 (fish supply chain in Canada) is shown in figure 4.13. As mentioned earlier, while recognizing that cheating (substitution or mislabelling) may occur at any point in the fish supply chain (i.e. by fish suppliers, processors/distributors or retailers), it is assumed that the processor or distributor sources fish from a known supplier.

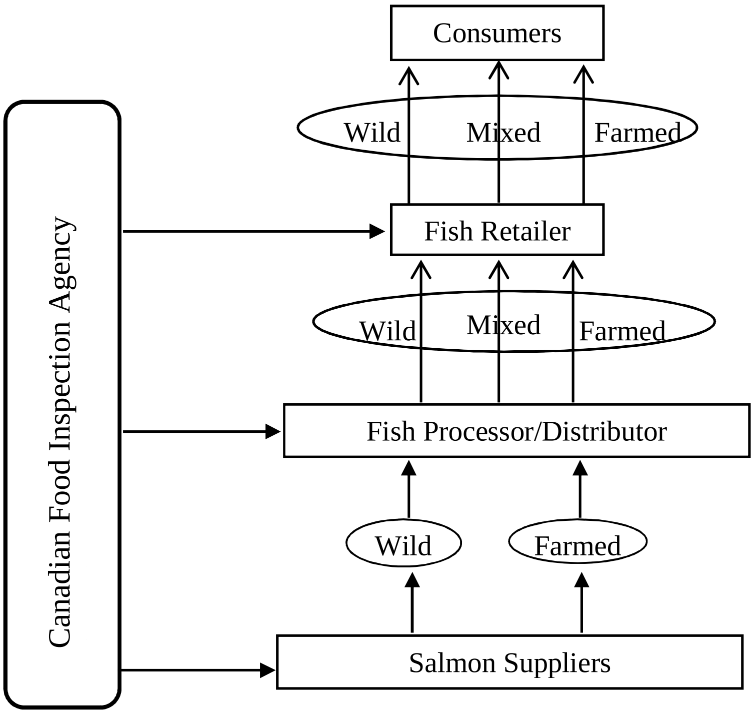

Figure 4.13: Analytical framework for modelling third party adoption of IBOL technology for supply chain monitoring

Assume a regulator (e.g. CFIA) or a consumer/environmental group carries out periodic random tests of retailers', processors' and suppliers' fish stock using the IBOL technology. Following figure 4.13, assume a fish processor and/or distributor buys *wild* and *farmed* salmon from known suppliers. The processor supplies both wild and farmed salmon to the retailer who finally sells to the consumers. At every stage along the supply chain, it is assumed that the player has more information about the product than the next player, hence, there is an incentive to cheat for economic gain.

The retailer who sells directly to consumers is assumed to have two choices. First, an honest retailer can truthfully sell wild and farmed salmon separately to the consumers without deception and makes different levels of profit. In this case, he may still pay for the IBOL testing to avoid inadvertent misrepresentation of his product, which may affect his reputation, as IBOL has up to

99.84 percent accuracy in identification without false negatives (Ko *et al.* 2013).[92] Second, a dishonest retailer (who wants to make more gains through cheating) would have an incentive of knowingly diverting some farmed salmon, mislabel and sell them as wild-caught at a higher price. Under such a situation, the retailer's profit would be a weighted average of profits from wild salmon (labelled as "wild and tested"), and farmed salmon (mislabelled as "wild and tested" or bypassing the testing procedure).

Following Malik (1990), the retailer's objective is to maximize expected profit given by

$$\underset{q_W, q_F}{\text{Max}}\ E(\pi)|_{\alpha} = \alpha\pi_F^F + (1-\alpha)\pi_W^F \ \ , \alpha\epsilon[0,1] \qquad (4.15)$$

Where α is the detection parameter, superscript F and subscript W respectively represent *fish type* (wild or farmed) and *label* (wild or farmed), while q_w and q_F represent quantities of wild-caught and farmed salmon. Without loss of generality, we assume q=1. In the first part of equation (4.15), it is assumed that the retailer may not be falsely accused when tested by a third party as the type of fish is truthfully declared and sold. This potentially is the case for an honest retailer. For the second part of equation 4.15, the retailer could successfully misrepresent and sell farmed salmon as wild-caught without being caught or he may be caught if tested. That is:

$$\underset{q_W, q_F}{\text{Max}}\ E(\pi)|_{\alpha} = \alpha\pi_F^F + (1-\alpha)[\rho\pi_{nc}^F + (1-\rho)\pi_c^F] \qquad (4.16)$$

Where subscripts '*nc*' and '*c*' respectively refers to *not caught* and *caught,* and ρ is the probability of being caught cheating. The retailer's profit will depend on whether the firm is caught cheating

[92] Accuracy in species identification depends on whether or not the sample is contaminated. It is easy to distinguish existing old fish species, such as salmon using their barcodes. However, barcoding discriminates 99% of marine species and ~95% of fresh water (Communication with Dr. Robert Hanner of IBOL laboratory, University of Guelph, Ontario). Therefore, false detection is possible and can go either way (i.e. detecting wild salmon when it is in fact farmed or vice versa). However, following Ko *et al*. (2013) and communication with Dr. Robert Hanner, the error rate is insignificant and, therefore, ignored for a retailer that truthfully sells either wild or farmed to consumers.

and pays a penalty. If not caught, the retailer will enjoy the premium associated with wild salmon. Let the retailer's expected profit be given as:

$$E(\pi_{nc}^{F}) = (P + k)\tilde{q} - C\tilde{q} - \bar{F} \qquad (4.17)$$

Where $\bar{F}$ and C are the fixed and variable production costs incurred by the retailer, $\tilde{q}$ is the quantity of fish sold, k is the premium and P is the selling price. Assume the probability of being caught cheating (substitution or mislabelling) ρ is a function of increase in accuracy of the IBOL system Φ, the sampling frequency (percentage of q tested) δ, and leakage, $\frac{1}{2\psi}$ following Popkova (2013).[93] This is given by

$$\rho = \left[\Phi\delta\ \frac{1}{2\psi}\right]\ ;\ \Phi, \delta, \frac{1}{2\psi} \in (0,1) \qquad (4.18)$$

Equation (4.18) implies that the probability of being caught cheating will be high the more accurate is IBOL in detection and the larger the sampling frequency and leakage. Since the testing rate is exogenous to the retailer; assuming the testing rate is constant, the degree of leakage (substituting farmed for wild) would be independent of the retailer's scale of operation. Instead, large scale retailers would make higher profits.

Assume the fish industry has the objective of ameliorating externalities and/or spillover effects (e.g. reputation loss) arising from fish fraud and, therefore, encourages the regulator to establish a legal punishment in the form of a monetary fine given by β and other indirect costs ω (e.g. product recall, withdrawal of license to operate); drawing from Popkova (2013), if caught cheating, the expected penalty cost of cheating would be

$$\rho = \left[\frac{\Phi\delta}{2\psi}\right]\beta\omega \qquad (4.19)$$

While the expected profit when caught (assume he has not sold any fish) would be

$$E(\pi_{c}^{F}) = P\tilde{q} - C\tilde{q} - F - \left[\frac{\Phi\delta}{2\psi}\right]\beta\omega \qquad (4.20)$$

93 Leakage in this context refers to the quantity of *farmed* fish that are misrepresented and sold as *wild*. It also shows the inability of the existing system (use of morphological features) to detect substitution as the consumer cannot differentiate between the two by physical examination.

Therefore, the expected net profit from cheating will be (4.20) minus (4.17). That is;

$$\Delta E(\pi) = E(\pi_c^F) - E(\pi_{nc}^F)$$

$$\Delta E(\pi) = \left[P\tilde{q} - C\tilde{q} - F - \left(\frac{\Phi\delta}{2\psi}\right)\beta\omega\right] - \left[(P+k)\tilde{q} - C\tilde{q} - \bar{F}\right]$$

$$\Delta E(\pi) = P\tilde{q} - \frac{\beta\delta\Phi\omega}{2\psi} - \tilde{q}(k+P) \qquad (4.21)$$

Taking the derivative of equation (4.21) with respect to the legal penalty β, and other indirect costs ω incurred by the retailer when caught cheating, we have;

$$\frac{\partial \Delta E(\pi)}{\partial \beta} = -\frac{1}{2\psi}\delta\Phi\omega < 0 \qquad (4.22)$$

Also

$$\frac{\partial \Delta E(\pi)}{\partial \omega} = -\frac{1}{2\psi}\beta\delta\Phi < 0 \qquad (4.23)$$

Equations (4.22) and (4.23) show that a legal penalty and other associated (indirect) costs would negatively affect a retailer's profit if caught cheating by a third party using the IBOL technology. This would serve as an incentive to reduce fish market fraud and encourage truthful declaration of product origin or identity.

Further, equation (4.18) shows that the probability of being caught cheating is a direct function of sampling frequency (testing rate), which is exogenous to the retailer and determined by the third party carrying out the test. This could also have an influence on the quantity of leakage and a firm's profit. Potentially the higher the testing rate or frequency and accuracy of the technology in detecting fish market fraud, the higher the chances of catching cheaters by the third party. Similar outcomes could occur for cheating at other stages of the fish supply chain (e.g. cheating by processors). In this case, retailers would be vulnerable to unintentionally selling mislabelled fish to consumers.

4.4.3 Feasibility of IBOL technology for a typical retail store in Canada

The threat of third party monitoring of the fish supply chain (e.g. by a regulator or a consumer or environmental group) could incentivize a retailer to adopt the IBOL technology and use it to test fish supplied by upstream suppliers in order to protect its reputation. Determining the testing rate above which a retailer would make a negative profit, and therefore not use the technology, would give an indication of the feasibility of the technology for a typical retail store. The retailer may face a decision of whether he can afford the fixed cost of acquiring the IBOL technology in-house or to outsource testing to an external laboratory for authentication.

To determine the feasibility of IBOL technology adoption, a simulation analysis is carried out using data on the estimated fixed and variable costs of fish authentication collected from the IBOL laboratory of the Biodiversity Institute of Ontario (BIO), University of Guelph as well as a fish market survey data gathered from retail stores in Canada. Table 4.3 shows the actual fees for authenticating fish samples based on information provided by the Biodiversity Institute of Ontario. The data is used to derive the cost function of a prospective retailer who would adopt the technology. The idea is to determine if the average cost of testing a fish sample decreases with a higher number of fish samples. The data in table 4.3 could be used to approximate a cost function for authenticating fish.

Table 4.3: Fees for authenticating fish samples

No. of samples (X)	Actual fees (CAD$)
1	200
15	125
1000	25
Above 1000	Negotiable but below 25

Source: Biodiversity Institute of Ontario (2013)

Assume the retailer's cost function for authenticating fish is of the Cobb Douglas form and specified as follows:

$$C = AX^{b}, b \in (0,1) \qquad (4.24)$$

where,

A = constant

X = number of fish samples authenticated

Taking the first derivative of (4.24) with respect to X will yield the marginal cost. That is:

$$\frac{\partial C}{\partial X} = MC = bAX^{b-1} \qquad (4.25)$$

Estimating the values of *b* and *A* by considering two points (X = 1; MC = $200 and X = 1000; MC = $25) in table 4.3 and substituting them into equation (4.25), we have:

$$200 = bA \qquad (4.25a)$$

When *X = 1000* and *MC = 25,*

$$25 = bA1000^{b-1} \qquad (4.25b)$$

From (4.25a), $= \frac{200}{A}$, and substituting this in (4.25b), we have;

$b = 0.7$, and *A = 285.71*

Therefore, the retailer's cost function is given by:

$$\boldsymbol{C = 285.71X^{0.7}} \qquad (4.26)$$

and

$$MC = \frac{\partial C}{\partial X} = 1999.997X^{-0.3} \qquad (4.27)$$

Using a range of samples (1-50,000), the estimated average total costs (ATC) of fish authentication (testing) are shown in figure 4.14. See appendix 4.II for the table.

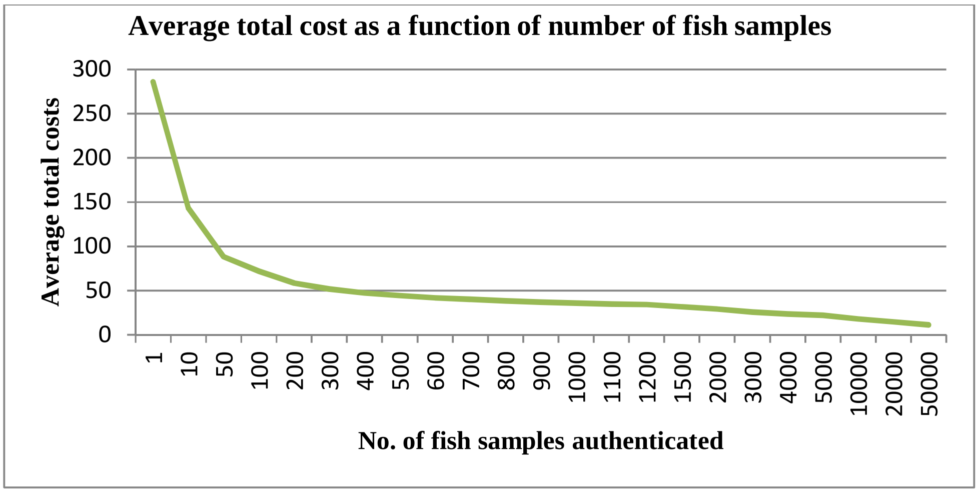

Figure 4.14: Average total costs of testing a fish sample
Source: Calculated from data on marginal costs (table 3) of fish authentication obtained from Biodiversity Institute of Ontario (2013)

Figure 4.14 shows that the average total costs of authenticating a fish sample decreases as the number of samples increases. This suggests that large scale retailers are likely to enjoy economies of scale, while small scale retailers will incur higher costs to authenticate a fish sample.

Results of some market studies in Canada (e.g. Hanner *et al.*, 2011; ICES, 2012) show that salmon is the most widely substituted and mislabelled fish specie because of its high market value, followed by red snapper. A market survey of three food retail stores (A, B and C) in Saskatoon was carried out in May 2014 to inform the simulation analysis. Information on the average standard weight (1.098kg) of Atlantic salmon sold in the stores, number of kilograms sold daily and average price per fish were collected through observation at the stores and discussion with the store managers. The information is used to compute other variables such as the number of fish sold per day (month) and total revenue per month from fish sales.[94] The results are shown in table 4.4 for a single retail store in Saskatoon. The analysis is based on one month of sales.

Table 4.4: Market (store-level) data analysis for Atlantic salmon fish

Retail store	Fish type	Std weight /fish (Kg) (A)	No. of Kg sold/day (B)	No. of fish sold/day (Kg) (C)	No. of fish sold/month (D)	Ave. price/ kg sale($) (E)	Ave. price/ Fish ($/Kg) (F)	TR/month without testing ($) (G)	Price premium ($/fish)	ATC of testing /fish sample ($)
Store A	wild	1.098	30	27	820	30.99	34.03	27891.00	6.00	38.32
	farmed	1.098	30	27	820	24.99	27.44	22491.00	6.00	38.32
	total		60	55	1640			50382.00		31.01
Store B	wild	1.098	15	14	410	31.99	35.13	14395.50	6.00	46.66
	farmed	1.098	15	14	410	26.99	29.64	12145.50	6.00	46.66
	total		30	27	820			26541.00		38.18

C = B/A; D = C*30; F = A*E; G = F*D

Source: Market survey data, 2014

Note: 1. ATC for testing a fish sample is derived using data on table 3(see appendix)
2. Premium of $6 for authenticated fish is assumed by the author
3. Revenue (column G) is for the total number of fish sold in a month
4. Store B recently acquired store C and therefore, their prices were the same when the market survey was carried out

[94] The footnote at the base of table 4.4 shows how other variables in different columns are calculated.

In this analysis, it is assumed that the testing (authentication) is done at an external laboratory (e.g. IBOL laboratory in Guelph) once a month. Therefore the fixed cost of adopting the IBOL system and other associated costs (e.g. inputs, transportation) are not considered.[95]

The idea is to see whether use of the technology would be feasible for a typical retailer who may not afford the fixed costs associated with the technology, and therefore, has the alternative of accessing an external laboratory for authentication. In the absence of an external laboratory testing service, the retailer would incur additional fixed costs of acquiring testing equipment and facilities (not shown in table 4.4).[96] Column 'G' of table 4.4 shows the estimated monthly revenue for a retail store that sells fish without authentication. This implies that the magnitude of the net revenue is contingent on the retailer's scale of operation and the number of samples tested at a particular time.

Assume a price premium of $6 per 1.098kg for authenticated fish. The key question is: *Why should a retailer authenticate his fish and consumers pay a premium for authenticated fish?* Potentially, a consumer will be willing to pay a premium for authenticated fish if the authenticating body is credible and trusted. Comparing stores 'A' and 'B', store 'A' sells an estimated 820 wild and farmed Atlantic salmon respectively in a month and makes an assumed revenue of $50,382 without authentication and related premium; while store 'B' sells 410 wild and farmed salmon respectively with total projected revenue of $26,541. Considering scale effects, and using the simulated cost functions in equations 4.26 and 4.27, it would cost stores 'A' and 'B' an average of $38.32 and $46.66 respectively to test a fish sample.[97]

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[95] Inputs and transportation costs are not available at the time when data were collected.

[96] Estimates of the fixed costs of establishing a DNA barcoding laboratory are provided in appendix 4.IV and range from $130,000 to $350,000 (year 2000).

[97] Data on retail price is for a whole fish while testing (authentication) is done with a piece of a whole fish (specimen). Costs of testing (authentication) per sample were calculated using the cost function (equation 4.26). See Appendix 4.II for the table. Total mark-up for wild salmon in store 'A' is calculated by multiplying the total number of fish sold in a month by the assumed premium. The product of the average total cost of testing a fish sample, number of fish sold in a month and the testing rate (δ/100) gives the variable cost of authentication for store 'A'.

Given an assumed premium of $6 per whole fish, the total number of fish sold in a month and the costs of authenticating a fish sample, what testing rate (δ) would yield the same net revenue obtained without authentication? This would give an idea of the optimum testing rate beyond which a retailer may not use the technology and would prefer to sell his fish without authentication given that consumers cannot distinguish between farmed and wild salmon. Calculating the testing rates for stores 'A' and 'B', we have:

Store A:

Net revenue from authentication = total mark-up – variable costs of authentication

$$[820 * 6] - \left[38.22 * \frac{\delta}{100} * 820\right]$$

Equating to zero and solving for δ we have

$$3134.40\delta = 492000$$

Therefore,

$$\delta = 16\%$$

Store B:

$$[410 * 6] - \left[46.66 * \frac{\delta}{100} * 410\right]$$

$$246000 = 19130.60\delta$$

$$\delta = 12.8\% \sim 13\%$$

This shows that, under the assumptions used in this illustrative example, a large company (retail level) such as store 'A' comprised of 'X' number of stores would spend less on authentication using IBOL technology and generate higher revenue at a testing rate of 16 percent or less. On the other hand, small retail stores (e.g. store B) would pay more for every fish sample authenticated, and potentially may not use the IBOL technology for a testing rate above 13 percent.[98] The simulation results for estimated contribution margin at different testing rates for a large retail store (store A above) is shown in figure 4.15.

[98] The testing rates of 16 and 13 percent calculated above for stores 'A' and 'B' do not represent exact figures as these are derived based on the assumptions of the simulation. They are for illustrative purposes.

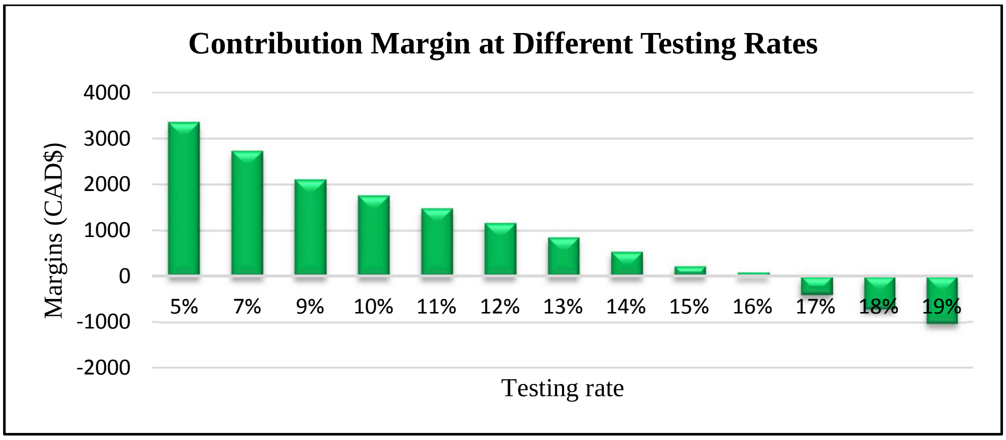

Figure 4.15: Estimated contribution margin from technology adoption at different testing rates for a large retail store

Source: Author's calculations

Results in figure 4.15 suggest that a large retail store in Canada potentially would use the technology if the testing rate does not exceed 16 percent. A testing rate above 16 percent will result in a loss and could be a disincentive for technology adoption.

Considering the fixed costs (see appendix 4.IV) and other variable costs (e.g. staff salaries) associated with establishing a testing laboratory given the assumed premium of $6 for authenticated fish, it becomes clear that paying for IBOL technology would not likely be feasible for a typical retail store at this time. The payback period would be high and could serve as a disincentive for adoption. Although the analysis is based on the level of an individual retail store, a large-scale food retailer (e.g major supermarkets) with multiple retail stores, however, would be in a position to spread the fixed costs of establishing a DNA barcoding/testing facility over a larger number of retail stores or outlets. Given the magnitude of the fixed costs for the IBOL technology and the low food safety risk associated with fish species substitution in Canada presently, a potential way to afford the technology at this time, particularly for small scale retailers, may be to go into strategic alliance and pool resources together. In addition, reducing the size of technology into hand-held tools would make it more affordable and easy to use within the domestic supply chain (e.g. food restaurants) and at the border.

4.5 Commercialization of IBOL technology

Commercialization in this context is the process of introducing the technology into the market. Successful commercialization of IBOL technology for fish species authentication would require strategic involvement and collaboration of market actors (key stakeholder groups) in the food control system (e.g. regulatory agencies, industry associations). The different actors have diverse interests and expectations. For example, the interest of regulatory agencies (e.g. Canadian Food Inspection Agency) is in enforcing quality and safety in the food system, while industry associations (e.g. National Fisheries Institute in the U.S.) would be interested in preserving the reputation and integrity of the food supply chains. In addition, the interest of other third parties, such as consumer and environmental groups, are to protect consumers or provide them with useful information that enables more informed purchase decisions, and the protection of endangered or threatened species, respectively.

Consumers' valuation (potential benefits) and trust in the technology would influence their demand for authenticated fish, and consequently drive retailers' adoption of the technology. This implies that the commercialization strategy has to be consumer focused (building consumers' trust for the technology). A potential way to gain consumers' confidence for fish authenticated using IBOL technology is for retailers to cooperate with groups such as the Marine Stewardship Council (MSC). Consumers may be more confident and willing to pay premium for fish authenticated using the technology and bearing the logo of a trusted body, such as MSC, whose credibility can more easily be ascertained by consumers.

Although not directly derived from the analysis, comparing the relative strengths of different incentives to adopt the IBOL technology by different agents (retailers, third parties, regulators), it is possible that retailers are more likely to adopt the technology in order to protect their collective reputation. For example, drawing from the horsemeat scandal in Europe, the retailers may not be the ones that substituted horsemeat for beef, but sold the final product (processed meat products) to consumers. Thus, an increased demand for IBOL authenticated fish would potentially increase the use of the technology in fraud mitigation in the market place.

4.6 Conclusions

IBOL technology offers a potential improvement over the existing DNA-based techniques (e.g. Polymerase Chain Reaction) in detecting food fraud, particularly in fish markets. The paper uses a theoretical approach to examine the incidence of species substitution and mislabelling in fish markets using welfare analysis to determine who gains and loses relative to a status quo and models private (retailer and third party) incentives to adopt IBOL technology to protect their reputation from fraudulent activities carried out by upstream suppliers, and for monitoring the supply chain as an incentive to encourage truthful labelling. It also employs an empirical approach to determine the feasibility of the IBOL technology for a typical retail store in Canada through a simulation analysis using estimated fixed and variable costs of fish authentication and market survey data gathered from retail stores in Saskatoon.

The analyses in this paper provide some key results. First, factors including post adoption market profit relative to costs of technology adoption, number of fish retailers in the market already using the IBOL system and their market shares influence a retailer's decision to adopt the IBOL technology. Retailers who adopt the technology early (i.e. early adopters) are likely to earn a premium from fish authentication, and the premium would diminish as more retailers adopt the technology. The implication of this result is that only the first few early adopters (retailers) would potentially enjoy economic benefit (price premium) from using the technology, hence, the distribution of the market benefits are not equal. Second, the likelihood or probability of catching a retailer, or other key players along the supply chain, cheating (substitution or mislabelling) by a third party is dependent on the accuracy of the IBOL technology in detecting fraud, the sampling rate or frequency, and the rate of species substitution. This suggests that increased accuracy of the IBOL technology and testing rate would mean that cheaters could more easily be caught. This, however, has implications for monitoring. Setting the testing rate by a third party or regulator (perhaps using the IBOL) would affect the incentives of retailers to adopt IBOL technology to detect cheating by upstream suppliers and/or mislabel or label honestly themselves. Leakage would be an important issue of concern even with IBOL technology adoption. This is because retailers may find a way of bypassing testing (authentication) and claim to be tested. Therefore, third parties monitoring the fish supply chain can effectively reduce leakage by indicating the sampling rate and frequency, pay unscheduled visits without prior notice, and randomly self-selects samples to be tested.

Third, enforcement of legal penalties and other indirect costs (e.g. product recall) would negatively affect expected profit if a retailer is caught cheating by a third party. This would serve as a disincentive for cheating in fish markets. Fourth, based on the assumptions used in the empirical analysis, testing rates above 13 and 16 percent (which are purely illustrative) for small and large retail stores would yield negative net revenue and would be a disincentive to adopt the technology by retailers. Fifth, results also suggest that currently it appears that IBOL technology could be feasible for a typical retail store if testing is done in an external testing facility, while it may not be feasible if fixed and other associated costs of switching to the IBOL system are considered. Although not directly derived from the analysis, large food retail stores with multiple outlets potentially could spread the fixed costs associated with establishing a testing laboratory over the numerous retail stores.

Presently in Canada, IBOL technology adoption is voluntary and little food safety risk has been identified to be associated with illegitimate market activities in the Canadian fish markets. Reducing the size of the technology, government subsidization and coordination of small scale retailers are potential ways the private sector could pay for the technology and set up their own laboratories, particularly in the absence of any food safety risk associated with market fraud in the Canadian fish markets. Availability of hand-held IBOL technology would make on-site testing at retail locations more affordable. Strategic involvement of the key stakeholder groups in the food control system and credible third party certification would ensure successful commercialization of the technology.

In sum, quality verification at all levels of the fish supply chain and credible disclosure of product attributes are essential ingredients in building trust and reducing market opportunistic behaviour. This would also guide consumers' purchase decisions and protect the integrity and reputation of the fish industry.

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Appendix 4.I

A4.1: Trend in the cost of DNA barcoding

Date	Cost per Mb ($)	Cost per Genome ($)		Date	Cost per Mb ($)	Cost per Genome ($)
Sep-01	5292.392885	95263072		Jul-08	8.356443	752079.9
Mar-02	3898.635412	70175437		Oct-08	3.805578	342502.1
Sep-02	3413.801195	61448422		Jan-09	2.585949	232735.4
Mar-03	2986.204671	53751684		Apr-09	1.71904	154713.6
Oct-03	2230.975235	40157554		Jul-09	1.200724	108065.1
Jan-04	1598.909789	28780376		Oct-09	0.781481	70333.33
Apr-04	1135.698674	20442576		Jan-10	0.519714	46774.27
Jul-04	1107.463652	19934346		Apr-10	0.350134	31512.04
Oct-04	1028.850676	18519312		Jul-10	0.345833	31124.96
Jan-05	974.1649757	17534970		Oct-10	0.323241	29091.73
Apr-05	897.7610799	16159699		Jan-11	0.23292	20962.78
Jul-05	898.9013391	16180224		Apr-11	0.185689	16712.01
Oct-05	766.7291219	13801124		Jul-11	0.116633	10496.93
Jan-06	699.2032723	12585659		Oct-11	0.086038	7743.438
Apr-06	651.8074733	11732535		Jan-12	0.08518	7666.219
Jul-06	636.4064012	11455315		Apr-12	0.06557	5901.293
Oct-06	581.9197978	10474556		Jul-12	0.066497	5984.721
Jan-07	522.7077172	9408739		Oct-12	0.073537	6618.349
Apr-07	502.6112761	9047003		Jan-13	0.063015	5671.346
Jul-07	495.9634524	8927342		Apr-13	0.063641	5826.262
Oct-07	397.0872994	7147571		Jul-13	0.06167	5550
Jan-08	102.127333	3063820		Oct-13	0.056623	5096
Apr-08	15.03313588	1352982		Jan-14	0.044535	4008.107

Source: Wetterstrand (2014)

Appendix 4.II

A4.2: Costs of testing and authenticating fish samples using IBOL technology

x	MC	ATC	TC
1	199.997	285.71	285.71
10	100.2359	143.1942	1431.942
50	61.84897	88.35567	4417.784
100	50.23698	71.76711	7176.711
200	40.8051	58.293	11658.6
300	36.13159	51.61656	15484.97
400	33.14404	47.34863	18939.45
420	32.66245	46.66064	19597.47
500	30.99791	44.28274	22141.37
600	29.34797	41.92568	25155.41
700	28.02167	40.03096	28021.67
800	26.92133	38.45904	30767.23
820	26.72264	38.1752	31303.66
840	26.53015	37.90021	31836.18
900	25.98668	37.12382	33411.44
1000	25.17813	35.96876	35968.76
1100	24.46841	34.95487	38450.35
1200	23.83796	34.05423	40865.08
1500	22.29442	31.84917	47773.75
1640	21.70553	31.0079	50852.95
2000	20.451	29.21571	58431.42
3000	18.10869	25.86956	77608.68
4000	16.61137	23.73053	94922.12
5000	15.53576	22.19394	110969.7
10000	12.61896	18.02708	180270.8
20000	10.24978	14.64254	292850.8
50000	7.786324	11.12332	556166

Source: Calculated from data on actual fees (table 4.3) of fish authentication obtained from Biodiversity Institute of Ontario (2013)

Appendix 4.III

Calculation of Retailers' Post Technology Adoption Market Shares, Prices and Profits

N = 1: $q_f^c = \frac{a-m}{(N+1)b} = \frac{8-1.5}{2*0.7} = \frac{6.5}{1.4} = 4.64$

$Q_f^c = N * q_f^c = 1 * 4.64 = 4.64$

$P_f^c = \frac{a+Nm}{N+1} = \frac{8+1*1.5}{2} = \$4.75$

$TC = mq_f^c + F = 1.5 * 4.64 + 5 = 11.96$

$AC_{(q_f^c)} = \frac{TC}{q_f^c} = \frac{11.96}{4.64} = 2.58$

$\pi_{N=1} = P_f^c * q_f^c - \left(mq_f^c + F\right) = 4.75 * 4.64 - 1.5 * 4.64 + 5 = \$10.08$

N = 2: $q_f^c = \frac{6.5}{2.1} = 3.10$

Q_f^c = 2*3.10 = 6.2

$P_f^c = \frac{8+2*1.5}{3} = 3.67$

$TC = mq_f^c + F = 1.5 * 3.10 + 5 = 9.65$

$AC_{(q_f^c)} = \frac{TC}{q_f^c} = \frac{9.65}{3.10} = 3.11$

$\pi_{N=2} = 3.67 * 3.10 - 1.5 * 3.10 + 5 = \$1.73$

N = 3: $q_f^c = \frac{6.5}{2.8} = 2.32$

$Q_f^c = 3 * 2.32 = 6.96$

$P_f^c = \frac{8+3*1.5}{4} = 3.13$

$TC = mq_f^c + F = 1.5 * 2.32 + 5 = 8.48$

$AC_{(q_f^c)} = \frac{TC}{q_f^c} = \frac{8.48}{2.32} = 3.66$

$\pi_{N=3} = 3.13 * 2.32 - 1.5 * 2.32 + 5 = -\$1.22$

Appendix 4.IV

A4.3: Costs of establishing a DNA Barcoding laboratory

Large Scale

S/N	Item	Description	Quantity	Unit Cost ($)	Total ($)
1	DNA Sequencer	3500xL Genetic Analyzer, 24 capillaries (Applied Biosystems)	1	214,500.00	214,500.00
2	Eppendorf Thermocylers	Mastercycler EP Gradient S Thermal Cycler with Manual Lid	2	12,853.75	25,707.50
3	Centrifuge for DNA-extraction room	Beckman-Coulter Allegra 25R Centrifuge with S5700 Swinging Backet Rotor (Beckman-Coulter)	1	10,918.00	10,918.00
4	Centrifuge for sequencing room	Thermo IEC CL40 Centrifuge with swing rotor for microplates	1	7,502.51	7,502.51
5	Agarose gel documentation system	AlphaImager Gel Documentation System with MultiImage II (DE-500) Light Cabinet, Standard Computer and 17" LCD Monitor; Alpha Innotech DTP-2001 Large Format Digital Thermal Grayscale Printer	1	21,471.52	21,471.52
6	Fisher Isotemp 5.0Cu Ft Standard Microprocessor Control Incubator	New Brunswick Innova Model 2000 Gyratory Platform Shaker (120V, 60Hz) to fit inside of lysis incubator **(**one for lysis, one for DNA extraction**)**	2	3,912.98	7,825.96
7	Small table-top centrifuges	Brinkmann Eppendorf Minispin Centrifuge, 115V (one for DNA extraction room, other for sequencing room)	2	1,590.75	3,181.50
8	Small autoclave for sequencing plates	Harvey® MC8 Hydroclave, with non-recirculating feature	1	7,924.52	7,924.52
9	*Pipettors:*				

a	Single channel	Eppendorf Research Single Channel Pipettor Pack Includes: one 2-20µl, 20-200µl and one 100-1000µl pipette packs (one for reagents in DNA extraction room, second one for reagents in sequencing room)	2 packs	920.94	1,841.88
b	8-channel Matrix	Matrix Impact2 pipettor, 15µl-1250µl	2	1,385.00	2,770.00
c	12-channel pipettors for DNA and PCR transfer	Biohit mLINE 12-channel Mechanical Pipettors (0.5-10 µl) - for PCR setup, for sequencing setup and for E-gels)	3	1,251.34	3,754.02
10	PCR Product Check	Invitrogen™ E-Base™ electrophoresis station (Mother E-Base™ device EB-M03)	1	512.00	512.00
11	Spectrophotometer	ND-1000 Nanodrop® ND-1000 Spectrophotometer	1	11,244.00	11,244.00
12	*Reagent preparation equipment:*				
a	Analytical Balance	Denver Summit Series Model SI-124 Analytical Balance 120g x 0.1mg	1	2,919.72	2,919.72
b	Top-loading Balance	Denver Summit Series Model SI-4002 Top-loading Balance 4000g x 0.01g	1	1,997.84	1,997.84
c	PH Meter	Orion 3-Star Benchtop pH Meter with Probe	1	1,298.88	1,298.88
d	Stirring Hotplate	Corning Model PC420D Digital Display Stirring Hotplate 5x7"	1	542.60	542.60
13	*Fridges/Freezers:*				
a	+4°C fridge	One for DNA extracts; one (small) for reagent stocks; one for PCR products and sequencing plates	3	500.00	1,500.00
b	-20°C freezer	One for PCR reagents; one for sequencing reagents). *Note: regular freezers (avoid no-frost system)*	2	183.00	366.00
c	-80°C freezer	Forma 900 -86C Ultra low Freezers (9 cu ft, 255 litres)	1	5,495.00 (5,095 for 5 cu)	5,495.00
14	AirClean System	AirClean 600 PCR workstation, AirClean Systems (Fisher Scientific)	1	4,134.38	4,134.38
15	UV Ultrpure water system	Millipore Simplicity UV Personal Ultrapure Water System, 115V 60Hz	1	4,260.00	4,260.00

				Total	**341,668.00**

Small Scale

S/N	Item	Description	Quantity	Unit Cost ($)	Total ($)
1	Eppendorf Thermocylers	Mastercycler EP Gradient S Thermal Cycler with Manual Lid	2	12,853.75	25,707.5
2	Centrifuge for DNA-extraction room	Beckman-Coulter Allegra 25R Centrifuge with S5700 Swinging Backet Rotor (Beckman-Coulter)	1	10,918.00	10,918.00
3	Centrifuge for sequencing room	Thermo IEC CL40 Centrifuge with swing rotor for microplates	1	7,502.51	7,502.51
4	Agarose gel documentation system	AlphaImager Gel Documentation System with MultiImage II (DE-500) Light Cabinet, Standard Computer and 17” LCD Monitor; Alpha Innotech DTP-2001 Large Format Digital Thermal Grayscale Printer	1	21,471.52	21,471.52
5	Fisher Isotemp 5.0Cu Ft Standard Microprocessor Control Incubator	New Brunswick Innova Model 2000 Gyratory Platform Shaker (120V, 60Hz) to fit inside of lysis incubator **(**one for lysis, one for DNA extraction)	2	3,912.98	7,825.96
6	Small table-top centrifuges	Brinkmann Eppendorf Minispin Centrifuge, 115V (one for DNA extraction room, other for sequencing room)	2	1,590.75	3,181.50
7	Small autoclave for sequencing plates	Harvey® MC8 Hydroclave, with non-recirculating feature	1	7,924.52	7,924.52
8	*Pipettors:*				
a	Single channel	Eppendorf Research Single Channel Pipettor Pack Includes: one 2-20µl, 20-200µl and one 100-1000µl pipette packs (one for reagents in DNA extraction room, second one for reagents in sequencing room)	2 packs	920.94	1,841.88
b	8-channel Matrix	Matrix Impact2 pipettor, 15µl-1250µl	2	1,385.00	2,770.00

c	12-channel pipettors for DNA and PCR transfer	Biohit mLINE 12-channel Mechanical Pipettors (0.5-10 µl) - for PCR setup, for sequencing setup and for E-gels)	3	1,251.34	3,754.02
9	PCR Product Check	Invitrogen™ E-Base™ electrophoresis station (Mother E-Base™ device EB-M03)	1	512.00	512.00
10	Spectrophotometer	ND-1000 Nanodrop® ND-1000 Spectrophotometer	1	11,244.00	11,244.00
11	*Reagent preparation equipment:*				
a	Analytical Balance	Denver Summit Series Model SI-124 Analytical Balance 120g x 0.1mg	1	2,919.72	2,919.72
b	Top-loading Balance	Denver Summit Series Model SI-4002 Top-loading Balance 4000g x 0.01g	1	1,997.84	1,997.84
c	PH Meter	Orion 3-Star Benchtop pH Meter with Probe	1	1,298.88	1,298.88
d	Stirring Hotplate	Corning Model PC420D Digital Display Stirring Hotplate 5x7"	1	542.60	542.60
12	*Fridges/Freezers:*				
a	+4°C fridge	One for DNA extracts; one (small) for reagent stocks; one for PCR products and sequencing plates	3	500.00	1,500.00
b	-20°C freezer	One for PCR reagents; one for sequencing reagents). *Note: regular freezers (avoid no-frost system)*	2	183.00	366.00
c	-80°C freezer	Forma 900 -86C Ultra low Freezers (9 cu ft, 255 litres)	1	5,495.00 (5,095 for 5 cu)	5,495.00
13	AirClean System	AirClean 600 PCR workstation, AirClean Systems (Fisher Scientific)	1	4,134.38	4,134.38
14	UV Ultrpure water system	Millipore Simplicity UV Personal Ultrapure Water System, 115V 60Hz	1	4,260.00	4,260.00
				Total	**127,168.00**

Notes:

* Equipment costs are for the year 2000

Data source: Personal communication with E. Zakharov of the Canadian Centre for DNA Barcoding, Biodiversity Institute of Ontario, University of Guelph, 2013.

Note: Appendix 4.IV shows the equipment that would be needed to establish a standard large and small scale laboratory. The only difference between a large and small scale testing laboratory is that large scale laboratory uses a DNA Sequencer, which constitute about 63% of the total cost of equipment. The cost of the DNA Sequencer is the difference in cost of establishing a small and large scale laboratory. Various steps involved in fish authentication (from specimen collection to amplification of the barcode region) can be done in a small scale laboratory, while the final stage, sequencing and barcode generation, is done in a large scale laboratory.

CHAPTER 5

Summary, Conclusions and Recommendations for Further Research

5.1 Summary

Truthful declaration and signalling of quality attributes to consumers has become a critical issue to policy makers and industries given the increasing spate of market fraud that has attracted recent media attention. This study represents an initial attempt to examine technological (International Barcode of Life) and industry-led certification (Vintners Quality Alliance) solutions to authenticity and information asymmetry issues in agri-food and natural resource markets. The dissertation explores the adoption of authenticity technologies and quality verification systems in the Canadian agri-food sector and in international markets. It comprises three stand-alone papers, each examining independent but related issues of authenticity, quality verification and signalling in agricultural and natural resource markets, and the implications for collective reputation. This research contributes to the literature by providing more insights and understanding of authenticity issues, and the role of emerging authenticity technologies (IBOL) and industry-led quality assurance systems in delivering authenticity signals in agri-food and natural resource markets.

Chapter two (paper 1) takes a look at the role of technologies in verifying authenticity, and enhancing the implementation of CITES trade restrictions for endangered tree species. A review of literature shows that the technology has a potential role in enhancing authenticity, safety and sustainability; and has been used in species identification including: seafood, invasive and/or endangered species, natural health products, vectors of zoonotic diseases, among others. An important feature of this technology is that it has high speed and accuracy in measurement (detection) and can identify credence attributes in food products; thereby enabling consumers to make more informed purchase decisions.

To examine how technological solutions (IBOL technology) could enhance restrictions for international trade in endangered species, the paper uses a case of an endangered species of tree, Brazilian rosewood (*Dalbergia nigra*). Three scenarios are analyzed using a graphical partial equilibrium trade model to adapt a base case including: adoption and use of IBOL technology to test imported rosewood by a single large importing country (the U.S.); multilateral adoption of IBOL technology for imported rosewood timber testing; and upstream adoption of the authenticity technology and a certification system within the domestic supply chain of the exporting country (Brazil) in response to a threat of multilateral testing by importing countries.

Results of the analyses suggest the following: first, the use of an authenticity technology by one country to test imports of rosewood may not be effective in reducing commercial trade in *Dalbergia nigra* as exports of the endangered species could be diverted to a third market where there is no testing for authenticity. Second, while multilateral implementation of regulations requiring authenticity testing for imported rosewood may not completely eliminate the harvesting of the endangered species it could eliminate cross border trade in *Dalbergia nigra,* thereby reducing the equilibrium domestic price and quantity (due to demand/supply factors of illegal rosewood), which would discourage its harvesting. Third, product differentiation (separating rosewood timber from the endangered species from those not threatened with extinction) through credible upstream testing and certification of authenticity in the exporting country (Brazil) may increase the confidence level of importers and their demand for Brazilian legally harvested rosewood exports. Overall, the results suggest that technological solutions to authenticity and information asymmetry issues in international markets could serve as a complement to, rather than a substitute for, existing regulatory enforcement.

This paper makes a new contribution to the literature. Previous studies tended to focus on the use of IBOL technology in the identification of different plant and animal species. This paper, in addition to contributing in understanding of authenticity issues in agri-food and natural resource markets, illustrates the potential role of the authenticity technology in providing a solution to problems of authenticity and information asymmetry in the context of international trade. The paper develops partial equilibrium trade models and uses them to illustrate how IBOL technology can be used to enhance effective implementation of the CITES trade restriction on cross border commercial trade in *Dalbergia* nigra, an endangered species of Brazilian rosewood. Although the analysis focuses on a case study, the potential outcomes of the analysis extend more broadly to other at-risk species listed by CITES including invasive species for which sustainability or eradication is relevant.

Chapter three (paper 2) examines the VQA certification system for Canadian wines to determine empirically whether VQA certification elicits a price premium and enhances the individual and collective reputation of Canadian wines. Hedonic pricing and Probit models are estimated. This paper is different from existing wine studies. In addition to empirical estimation of the marginal contributions of wine attributes to the price of wine as done in previous studies, the paper incorporates Probit analysis to ascertain what could drive a winery's decision to seek quality assurance (VQA certification). The paper also incorporates winery characteristics (winery, region) in the hedonic model to separate the effect of individual and collective reputations on the price of wine. Unlike other wine studies that examine the marginal contribution of VQA to the price of wines (e.g. Rabkin and Beatty, 2007), the paper examines whether there is endogeneity between VQA and the price of wine. The results suggest that in the data set VQA certification leads to high wine prices and not the other way around.

Results of the hedonic model show that there exists a premium for VQA wines. On average, the price of VQA wines is 16.72% higher than non-VQA wines in Ontario, the price of VQA red and white wines are 21.42% and 13.58% respectively higher than the non-VQA base red and white wines. This suggests that the VQA quality assurance program established by the Canadian wine industry has been a successful quality signalling strategy, valued by consumers and generates a premium for authenticity that it represents. This may be a valuable lesson as well as an incentive for other Canadian agri-food industries to establish similar industry-led quality assurance systems. The paper separates the effects of two different dimensions of reputation, including individual (winery) and collective (region, VQA) reputation on the price of wine. The results show that while individual (firm-level) reputation is important, collective (industry-wide) reputation signals have the potential to add additional price premiums when consumers perceive them as being credible and reliable, and therefore, can act as a shorthand for quality and reduce their search costs. Further, results of the hedonic model indicate that attributes such as percentage alcohol content, sweetness (sugar content), volume of wine delivered by wineries to retail outlets in Ontario (small) and vintage (year of production) significantly affect the price of wine; while the prices of wines delivered by small and medium wineries are higher than the price of wines delivered by large wineries potentially due to volume of sales.

In addition, the hedonic results of the interactions of the VQA variable with grape varieties and region suggest that VQA certification does not depend on grape variety, and VQA and region can serve as complementary collective reputation signals. While controlling for individual winery and collective reputation signals, the results suggest that the VQA signal adds value beyond other collective reputation signals. Presumably this is because VQA is a third party certified quality signal, which may be perceived to be more reliable and transparent by consumers, and this potentially makes VQA a stronger assurance of quality and authenticity. The Probit analysis results identify significant factors that could influence a winery's decision to seek quality assurance (VQA certification) for a specific wine. Such factors could serve as a guide for wineries who want to enjoy premium for their wines.

In chapter four (paper 3), incidence (substitution and mislabelling) analysis in fish markets and the incentives for the private sector (retailers) or a third party to adopt IBOL technology for fish species authentication are presented. Understanding the factors that could influence private sector adoption of authenticity technologies would be an important element to technology developers and policy makers. In the context of this study, while development of authenticity technologies could be seen as an advancement in the agri-food sector, adoption of the technologies is critical to feel the impacts of the technologies in the markets. This paper contributes to the economics of information asymmetry literature by providing insights on the economic incentives for species substitution and mislabelling in fish markets and the negative outcomes associated with such illicit market activities. The paper also adds to the literature by identifying key economic parameters that are likely to influence adoption of authenticity technologies by fish retailers.

IBOL technology is new and yet to be commercialized. Results of the analyses suggest that the costs (fixed) associated with the technology, number of retailers already using the technology and their market shares, and the use of the technology by a third party in monitoring fraud along the fish supply chain are the factors that could influence IBOL technology adoption by the private sector. Further, in modelling the use of IBOL technology for fish supply chain monitoring by a third party, the results suggest that the likelihood (probability) of catching a retailer (or other key players along the fish supply chain) cheating is contingent on the accuracy of the technology in detecting substitution and mislabelling, the sampling rate (frequency) and rate of species substitution. The results of the theoretical model also show that enforcement of legal penalties and other indirect costs would negatively affect a retailer's expected profit if caught cheating by a third party. This could serve as a disincentive for cheating.

To determine whether the technology would be feasible for a typical retailer at this stage of its development, an empirical analysis is carried out using fish market survey and testing cost data from the IBOL laboratory in Guelph Ontario. Presently it appears that IBOL technology would be feasible for a typical retail store if testing is done in a third party laboratory (external testing facility), while it may not be feasible if fixed and other associated costs of switching to the IBOL system are considered. Feasibility of the technology for a typical retail store would mean that the testing (sampling) rate potentially should not exceed 16% for large retailers and 13% for small and/or medium retailers. While it is anticipated that the cost of the technology would decline overtime, reducing the size of the technology to a hand-held tool would make it more affordable and could expand its use for identification and authentication.

The three papers in this dissertation focus on authenticity and collective reputation, and show different motivations by different actors (firm, industry and regulator) used in the analyses. For example, while firms (in paper 3) are motivated to adopt the IBOL authenticity technology to protect their individual firm reputation, an industry's (e.g. wine industry in paper 2) motivation for the uptake of a quality assurance system is to preserve the collective reputation and integrity of the industry. On the other hand, the regulator (government) may have a role to play when there is a market failure, such as the imposition of a testing regulation as modelled in paper 3.

Public policy has a role to play in the development and adoption of technological innovations such as IBOL. Publicizing offending producers or firms and establishment of severe legal penalties may reduce fraud. This reputational threat would encourage due diligence and investment in quality and authenticity. Richard Macrory in his study, *"making sanctions effective"* contends that:

> "When thinking about how to motivate firms to change their behavior, reputational sanctions can have more of an impact than even the largest financial penalties. […]. The consequences of damaging a firm's reputation can potentially exceed the effect of a maximum fine that a court could impose (Macrory, 2006, p.129)."

Therefore, when the expected cost of cheating outweighs the potential benefits, producers would be more likely to play by the rules.

5.2 Limitations of the study and suggestions for further research

There were certain limitations in the course of this study. The first is timely and availability of data. In chapter two (paper 1), non-availability of data (e.g. volume of trade in endangered species and the economic costs) limits the study to only a theoretical analysis. Such data would have been used to quantify the outcomes as well as test the reliability of the theoretical results.

In chapter three (paper 2), empirical analysis is carried out to determine the attributes that influence wine prices and the factors that drive a winery's decision to seek VQA status. Information on the aggregate quantity of wines sold annually and quarterly could not be accessed from the Liquor Control Board of Ontario. This information is important to control for possible seasonality effects on the price of wine. In addition, only Canadian wines data in Ontario Liquor Control Board stores were accessible, which under represents sales of other non-Canadian wines. Data on sales of imported wines were not available to the researcher. Such data would have enabled the researcher to examine the role of VQA as a signal of Canadian origin. In chapter three (paper 3), data on border rejections in seafood (fish) trade in Canada (before 1999 and after 2002) arising from authenticity issues could not be assessed. Such data could be useful in making an objective comparison of fish species identification before and after the emergence of the IBOL technology.

The issue of food authenticity in agri-food markets has not been widely explored in the literature. This leaves room for further research and improvements on this study. In chapter one (paper 1) for example, data on the volume of trade and the economic costs of cross border trade in endangered species, if available in future studies, could be used to examine the costs/benefits trade off in using IBOL technology to implement international trade restrictions on endangered species. In chapter two, further work could be done to identify the attributes that drive consumers' willingness to pay for wines. More so, future studies could use data on both Canadian and imported wines to examine how the VQA quality assurance system affects price competition for regional and imported wines. Inclusion of data on wine sales from other provinces in Canada (e.g. British Columbia) in the dataset would give more generalizable results and conclusions about the VQA system. Such a dataset may provide the opportunity of applying the instrumental variable estimation approach to get a better sense of whether price significantly influences a winery's decision to seek VQA for a specific wine. In chapter four (paper 3), the analysis of the incentive to adopt IBOL technology by a third party focuses on the retail level. This gives room for extension of the analysis to other (processor and producer) levels of the supply chain in future studies. In addition, it would be interesting to examine the potential of embedding IBOL technology as a protocol for fish species identification within the international regulatory system. This would further strengthen its institutionalization as a common protocol in the current food system.

Overall, this study aims to provide insights on the causes, impacts and solutions to authenticity issues in agri-food and natural resource markets. Specifically, the analysis centers on the role of industry-led quality assurance systems (certification) versus technological solutions to verifying authenticity and reducing quality uncertainty in the markets. Essentially, identifying mechanisms that will address authenticity and information asymmetry issues in the markets potentially will help gain consumers' confidence, reduce negative spillovers or externalities arising from market fraud, enhance industry-wide collective reputation and the integrity of supply chains.

References

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