Effectiveness of COOL in the U.S. Seafood Industry

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"Unscrupulous importers and some foreign producers are now 'gaming the system' to move seafood products into the commercial food industry that might not withstand 'grocery store scrutiny' where nearly all items are now labeled for country of origin". The Catfish Institute

Introduction

The spate of incidents in the last couple of months regarding imports has turned the heat back on the issue of mandatory country-of-origin labeling (MCOOL). Prominent among the incidents are recalls of a number of Chinese-made products: farm-raised shrimp and catfish, pet food laced with contaminated wheat gluten, toothpaste containing diethylene glycol- a poison used in antifreeze, children's necklaces and earrings, toy trains and popular preschool toys containing high levels of lead. These presumptions are supported by Barboza (2007), who outlines the degrading conditions in which seafood for export to United States is farmed in China. The media also reports that at-risk Chinese seafood shipments that are supposed to be tested for safety are going unchecked and FDA personnel "inspect less than 1 percent of all imported food and conduct laboratory analysis on only a tiny fraction of those" (LA times, 2007). At the same time, a food labeling poll conducted by *Consumer Reports* shows that consumers want to know where their food comes from and expect higher label standards. According to the poll, 92 percent of consumers agree that imported foods should be labeled by their country of origin.

COOL was introduced in April 2005 and implemented in September 2006 on fish and shellfish by the U.S. Congress. The objective was to communicate to consumers the national origin and method(s) of production (wild and/or farm-raised) via mandatory labels. The labels are however restricted to fresh and frozen seafood at the retail level.

Foodservice establishments, small retailers and ingredients in processed seafood products are exempt. The resulting partial coverage creates a gaping hole possibly undermining the effectiveness of COOL law.

Organizations like The Catfish Institute (TCI) of the United States are spearheading a drive to require that country of origin labels for imported seafood be displayed on restaurant menus. TCI believes that consumers should be informed of the origin of catfish served in restaurants as a result of recent media reports that revealed imported catfish contained harmful pollutants such as malachite green, illegal antibiotics and salmonella bacteria.

There are a number of seafood guides available on the Internet, magazines, and newspapers which help consumers make proper and informed choices. Table 1 describes a healthy seafood guide for consumers and provides information about seafood, their origin, and method of production. Considering that most of the fish in the "avoid" category pertain to imported fish, it becomes imperative for foodservice establishments to disclose origin information. Restaurant materials that can be distributed to foodservice operators to convey origin include brochures on food safety, logo stickers for menus and certificates that can be framed and hung.

The growth of cheaper imports of seafood, increase in consumption away-from-home, and partial implementation of COOL imply that a large part of the market is not covered by the law. Over the past five years there has been an increase in demand for fish and seafood products, primarily due to the steady growth in eating away-from-home. According to Hale (2005), restaurants are the key source of seafood, with 60 percent of consumers reporting they eat more seafood away from home. The trend in per capita away-from-home and at-home food expenditures is shown in figure 1. Away-from-home food expenditure increased from 44.9 percent of total food expenditures in 1991 to 47 percent in 1999, and 48.9 percent in 2006 (figure 2). Reasons for this trend include smaller household size, more affordable and convenient fast foodservices, a growing number of women working outside the home, and higher household incomes (USDA-ERS, 1999). While no study specifically focuses on consumption of seafood away from home, some have found that significant amount of seafood is consumed in restaurants. An estimate by Keithly (1985) suggested that the quantity of away-from-home seafood products consumed ranged from one-third to two-thirds of all consumption of seafood. A study by Selassie, House, and Sureshwaran (2002) found 57, 62, and 58 percent of meals of shrimp, oysters, and catfish, respectively, were consumed away-from-home. Stewart et al. (2004) predict that per capita spending could rise by 18 percent at full-service restaurants and by 6 percent for fast food between 2000 and 2020.

Currently, over 70 percent of the seafood Americans consume is imported (National Marine Fisheries Service, 2007). Despite relatively stable domestic demand, seafood imports are expected to increase at an average annualized rate of 2.4 percent, over the five years to December 2007 (Ibisworld, 2007). In the United States, imports represent a large share of domestic demand because most of the locally caught species receive a better price in key overseas markets than they do at home (Ibisworld, 2007). According to Ibisworld (2007) the mass U.S. market buys large quantities of less expensive fish species from Thailand, China, Vietnam, India and other sources, which are not available from local catches. Figures 3 and 4 show the upward trend in imports and overall per capita seafood consumption in the United States. The difference between the total and fresh & frozen seafood is processed seafood (canned and cured).

The significant share of imports in U.S. seafood consumption raises concern about their safety. Imports are not necessarily subjected to the same standards of quality and safety control as that of domestic seafood. In the United States, the use of Hazard Analysis Critical Control Points (HACCP) system is considered a means to achieve that end. HACCP operates in the context of an extensive set of requirements for good manufacturing practices and sanitary operating procedures. In addition, there are numerous federal and state regulations that influence the location and timing of harvest and the choices of aquaculture operations (Caswell, 2006). Products from less developed countries are generally perceived to be of lower quality than products of developed countries (Verlegh and Steenkamp, 1999). Although there is no evidence that imported seafood is necessarily riskier, a number of countries exporting seafood to the United States have poorer internal control systems and/or are in tropical areas where toxin and bacteria hazards are higher. Imports become an issue of concern because countries vary in their use of vaccines, feed additives, and antibiotics for farm raised and shellfish (Allshouse et al., 2004). Eighty percent of the total imported edible seafood in 2007 came from less developed countries (U.S. Department of Commerce, U.S. Census Bureau).

The objective of this paper is to examine the welfare effects of COOL implementation on seafood for consumers; as more than 70 percent of seafood consumed in the United States is imported and most of it (by value) is consumed in the foodservice sector. Given that COOL is a retail labeling program and does not cover the foodservice sector, most of the imported seafood consumed in United States is not affected by the

COOL legislation. Moreover, an ERS study reports that away-from-home seafood volume will increase by 30 percent by 2020. The presence of a non-labeled sector raises the possibility of diversion of lower quality seafood into this sector, which would undermine the effectiveness of the law.

To address the economic impact of the COOL law in the foodservice and retail sector, this paper develops a conceptual model that demonstrates the incentive for diversion of imported seafood to the non-labeled sector. The model is a variant of the model of vertical product differentiation by Mussa and Rosen (1978) and it explicitly accounts for differences in consumer attitudes towards foreign and domestic seafood which are facilitated by origin labeling. Consumers are postulated to differ in the utility they derive from the consumption of domestic and foreign seafood. We assume consumers consider foreign fish to be of lower quality compared to domestic fish.[1] Wimberley et al. (2003) found that 80% of U.S. consumers believed that food produced or raised in the United States is fresher and safer than imported food.

The rest of the paper is organized as follows. The next section provides a review of the relevant literature and gives some background information about the COOL law and its application in seafood. A theoretical model is then introduced to examine the economic impacts of COOL implementation. Following a numerical simulation analysis, the results are discussed, and concluding remarks are provided.

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[1] The assumption that consumers of domestic fish perceive it to be of higher quality than imported fish is reinforced by a) the recent safety incidents with imported products, b) media reports on fish farming practices of developing countries and the ineffective inspection of imports, and c) presentation in popular magazine and newspaper article of the healthy seafood guide (table 1), which informs consumers to avoid most imported fish. However, it is not always the case that imported seafood is of lower perceived quality than domestic seafood. For example, Mexican shrimp is considered to have superior flavor and texture over domestic or other imported shrimp.

Background and Related Literature

The Farm Security and Rural Investment Act of 2002 (the Farm Bill) contained a provision that required the United States Department of Agriculture (USDA), to issue country of origin labeling guidelines for voluntary use by retailers who wished to notify their customers of the country of origin and method(s) of production for covered commodities.[2] The Farm Bill also required that a mandatory country of origin labeling program be in place by September 30, 2004. However with the exception of seafood, which was implemented April 04, 2005, the labeling of the rest of the commodities has been deferred to 2008. The law requires that any person who prepares, stores, handles, or distributes a covered commodity for retail sale should maintain a verifiable recordkeeping audit trail and suppliers to retailers are required to provide information indicating the country of origin and method of production of the covered commodity. To convey country of origin information to consumers, the law states that retailers may use a label, stamp, mark, placard, or other clear and visible sign on the covered commodity, or on the package, display, holding unit, or bin containing the commodity at the final point of consumption.[3]

The COOL legislation has accounted for a number of exemptions and exclusions; the foodservice sector is exempted.[4],[5] In addition, butcher shops, fish markets, exporters

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[2] Covered commodities is defined in the law as muscle cuts of beef (including veal), lamb, and pork; ground beef, ground lamb, and ground pork; ***farm-raised fish and shellfish; wild fish and shellfish*;** perishable agricultural commodities (fresh and frozen fruits and vegetables); and peanuts.

[3] For complete information on guidelines, definitions and implications of COOL, see USDA-AMS (2002), Vol. 67, No. 198.

[4] Exemption refers to establishments not required by the law to notify consumers of origin labeling while exclusion refers to covered commodities not required to inform consumers of its origin.

and small grocery stores of annual sales less than $230,000 are also exempt. Excluded commodities include all processed foods (cooked, steamed, cured, smoked and restructured), ingredient in a processed food item, cooked and canned fish.[6] Examples of seafood excluded are salmon in sushi, scallops and shrimp in a seafood medley, shrimp cocktail, crab salad, clam chowder, breaded shrimp, soups, marinated fillets (as an ingredient in another product); fish sticks, surimi (processed); and canned items like tuna, salmon and sardines. Essentially then, the labeling requirement applies to fresh and frozen seafood whether whole, cut into steaks or fillets, or broken into pieces at the retailer's level (USDA-AMS, 2004). Figure 5 highlights the classification of the seafood market under COOL implementation according to products excluded and sector exempt.

USDA-AMS (2004) reports the effect of COOL on retailers and the quantity of fish and shellfish consumed in the retail sector. They find that 93.3 percent of all food store retailers are not subject to the requirements of mandatory COOL. USDA-AMS (2004) estimate that COOL will have an annual effect on 41.4 percent of fish and seafood products moving through retail. This percentage is obtained by multiplying the retail quantity share of total food consumption (62.9 percent) by share of sales of fish and seafood products by retailers affected by COOL (65.8 percent). Overall exempt market

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[5] Foodservice establishments include restaurants, cafeterias, lunchrooms, food stands, saloons, tavern, bars, lounges, or other similar facility operated as an enterprise engaged in the business of selling food to the public. Retailer is defined as a person who is a dealer engaged in the business of selling any perishable agricultural commodity and fish solely at retail with an invoice value in any calendar year of more than $230,000. Retail outlets for food consumed at home include food stores, warehouse clubs, and superstores (USDA-AMS, 2002).

[6] A processed food item is a retail item derived from fish or shellfish that has undergone specific processing resulting in a change in the character of the covered commodity, or that has been combined with at least one other covered commodity or other substantive food components (e.g., breading, tomato sauce); except that the addition of a component (such as water, salt or sugar) that enhances or represents a further step in the preparation of the product for consumption, would not in itself result in a processed food item (USDA-AMS, 2004).

(retailers not subject to the rule and foodservice establishments) account for 62 percent of fish and 75 percent of shellfish.

Effectively COOL is a retail labeling program, which brings us to the question of mandatory labeling in the foodservice sector. The absence of labeling results in an information problem between buyers and sellers. More specifically, buyers are not informed of the origin of seafood that sellers know about.[7] This information deficit may lead consumers to make choices they would not have made with full information. We assume as in Lusk et al. (2006), consumers value origin information through labeling because they associate quality of seafood with its origin. Like nutritional attributes, quality is referred to as credence attribute. A credence attribute implies consumers cannot learn about characteristics of a product readily through inspection or even after consumption (Nelson 1970; Darby and Karni 1973). However, a credence attribute can be transformed to a search attribute as COOL is associated with information about the seafood products that may affect the consumers' perception and evaluation of its quality.[8] Thus, the foodservice sector can be described as a market characterized by imperfect and asymmetric information (Variyam, 2005).[9] In markets where sellers have information about product quality (or origin in our case) that cannot be credibly conveyed to the

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[7] It is reasonable to expect seller's (in this case foodservice operators) awareness of the origin of fish and shellfish. They are better informed about the ingredients used in prepared meals, proportions in which they are mixed, and the cooking methods used.

[8] Search attributes are defined as attributes that can be evaluated prior to purchase (Nelson 1970; Darby and Karni 1973). We assume origin is synonymous with information about quality, hence COOL transforms credence good to search. Lusk et al. (2006) state that country of origin is often associated with product quality.

[9] Imperfect information implies consumers do not know the quality of seafood consumed in the absence of labeling, while asymmetric information implies seller knows relevant information about a product (origin) that the buyer does not know.

buyers (that is buyers have no way of knowing if the information is accurate or truthful), only poor-quality products will be sold (Akerlof, 1970). In such markets, MCOOL may increase social welfare by enabling sellers to credibly convey information and by aiding buyers to choose products that better match their preferences. Antle (1996) and Caswell and Mojduszka (1996) observe markets characterized by imperfect and asymmetric information that can be made to function efficiently through policy options available such as development of private product reputations through advertising, product quality certification and labeling, liability laws, or statutory regulation of either the process or performance standard variety.

The literature on COOL covers both benefits and costs associated with the regulation. Agricultural economists have focused on consumers willingness-to-pay for meat products of U.S. origin (Schupp and Gillespie, 2001; Umberger et al., 2003; Wimberley et al., 2003; Loureiro and Umberger, 2003, 2005; Mabiso et al., 2005; Caswell and Joseph, 2007), quantifying the costs and benefits of COOL (Golan, Kuchler, and Mitchell, 2000; Food Marketing Institute, 2002; Sparks Companies Inc., 2003; Davis, 2003; Hayes and Meyer, 2003; Lusk and Anderson, 2004; USDA-AMS, 2004), on assessing welfare effects of the policy (Plain and Grimes, 2003; Grier and Kohl, 2003; Krissoff et al., 2004; Brester, Marsh, and Atwood, 2004; Lusk and Anderson, 2004; Schmitz, Moss, and Schmitz, 2005), and on COOL being a form of branding or product differentiation strategy (Carter, Krissoff and Zwane, 2006). Lusk et al. (2006) argue that a COOL label, rather than biasing quality perceptions, might actually create quality. However, a comprehensive study examining COOL (USDA-AMS, 2004) finds that the U.S. economy would be worse off after implementing COOL. Their conclusion is based on the assumption that COOL will not change consumers' preference for covered fish and shellfish commodities. They find little evidence that consumers are willing to pay a price premium for COOL and increase their purchase of food items bearing the U.S. origin label as a result of this rule. However, this is a debated point in the literature.[10]

While no one has specifically studied the economic impacts of the non-uniformity of the COOL law, others have noted that loopholes can be taken advantage of. For example, in their study of the consequences of COOL in the pork industry, Iqbal, Kim, and Rude (2006) write "..if U.S. retailers chose not to incur the extra costs of stocking Canadian pork, there are alternative outlets for Canadian pork including processed products and the HRI trade" (p. 19). Similarly, USDA-AMS (2004) state "…majority of the sales of the covered commodity are through channels not affected by this rule, which provides substantial marketing opportunities for products without verifiable country of origin claims". Another example is Tim Hammonds (2003), the president of the Food Marketing Institute (FMI), who says "…ranchers unable to document the history of their animals will find themselves unable to sell to supermarkets forcing their beef into the export or foodservice sectors, which are not covered under COOL regulation".

The potential diversion of lower quality seafood to non-labeled sectors can be inferred from the trade diversion literature. Trade diversion is defined as a shift in trade flows away from firms whose imports are affected by a trade barrier (named firms) to firms that import the same product but are not affected (non-named firms). Trade

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[10] It is important to note that apparently the USDA assumptions are primarily for general food commodities affected by COOL that have been extrapolated and applied to seafood. Such generalizations may not be accurate for seafood. Seafood is a commodity with distinct characteristics compared to meat and agricultural produce. For instance, significant quantity of seafood consumed in the United States is imported, and consumed away from home.

diversion has been covered extensively in the literature (Staiger and Wolak, 1994; Wylie, 1995; Krupp and Pollard, 1996; Prusa, 1997; Vandenbussche, Konings, and Springael, 1999; Pauwels, Vandenbussche, and Weverbergh, 2001; Brenton, 2001; Fukao, Okubo, and Stern, 2003; Baylis and Perloff, 2007). Reasons explaining trade diversion include anticipation or imposition of a trade barrier (for example, antidumping duties), investigation effect-when imposed or threatened to be imposed, or formation of trade blocs such as NAFTA. This paper deals with trade diversion between two sectors as opposed to countries, namely, retail and foodservice due to implementation of COOL in the retail sector. COOL can be considered analogous to a trade barrier. COOL in retail could result in an increase in the quantity of imports to the foodservice sector compared to the quantity of imports in the absence of COOL. This is because the regulation requires labels on seafood sold in the retail sector which can impose costs making imports expensive in the retail sector. These costs can be easily circumvented by diverting imports to the foodservice sector. Additionally, the difference in the quality of domestic and foreign fish make the foodservice sector more attractive to foreign fish as consumers have no way of knowing the origin of seafood in the foodservice sector.

The contributions of this paper is its distinct focus on the economic impacts of partial coverage of COOL in the seafood industry, accounting for imperfect competition among retailers and foodservice sectors, and modeling consumer heterogeneity characterized by different preferences for quality. A related work is USDA-AMS (2004) which is a comprehensive study of COOL on the seafood industry. Using a CGE model they determine costs incurred in the supply chain as a result of this regulation. They assume that retailers are perfectly competitive and COOL does not result in increased consumer demand for domestic products. Plastina and Giannakas (2007) account for imperfect competition among retailers for specialty crops, and consider consumer and producer heterogeneity in determining welfare effects of the supply chain participants when COOL is implemented.

Theoretical model

The model builds on Zago and Pick (2004) who analyze the welfare impact of labeling policies on agricultural commodities with credence attributes. Our analysis considers two scenarios, namely, market presence and absence of COOL. In the absence of COOL, origin of seafood cannot be distinguished by consumers; consequently, quality cannot be ascertained (product appears undifferentiated to consumers), resulting in imperfect and asymmetric information. While consumers are unable to differentiate domestic fish from foreign, we assume that sellers in retail and foodservice sectors can differentiate. In the presence of COOL, however, the sectors are segmented with quality differentiation generating a higher price for domestic fish than foreign fish.[11] Further, two scenarios are considered in the presence of COOL on consumer welfare: Current partial implementation (retail sector labeled) and Total implementation (both retail and foodservice sectors labeled); with and without costs of implementation.[12] In this model, domestic and foreign firms supplying seafood are considered to be perfectly

[11] Assuming that minimum average cost of production is greater for high quality than for low quality, it follows that market equilibrium prices p_H and p_L satisfy the condition $p_H > p_L$ (Antle, 2001).

[12] Fish producers and harvesters will need to create and maintain records to establish origin and production Additional producer and harvester costs include the cost of establishing and maintaining a recordkeeping system for origin and production information, product identification, labor and training. Cost distribution will not be the same for all suppliers of covered commodities. It will depend on the availability of substitute products not covered by the rule and the relative competitiveness of the affected suppliers with respect to other sectors of the U.S. and world economies. Systems need to be implemented to ensure that origin and production information is transferred from producers to the next buyers of their products, and that the information is maintained for the required amount of time.

competitive.[13] Following previous literature, we examine the impact of market power in retail and foodservice sectors on the welfare effects of COOL.[14] The general notions of verification, monitoring, and consumer trust in the COOL labels are assumed.

We consider a one-period game under vertical differentiation, with two qualities for a single good. The domestic country is the United States and the foreign country is the major exporter of seafood to United States. It is reasonable to assume the quality, k, of seafood is exogenous. Quality of seafood products is defined here to depend on location and conditions of catch or aquaculture, processing, and handling throughout the supply chain (Caswell, 2006). In keeping with the assumptions that domestic seafood industry is regulated by the government with stricter policies, and foreign seafood industry does not have to follow comparable restrictive standards, domestic firm produces high quality seafood and the foreign firm produces products that are assumed to be of lower quality, or at least perceived as such. Thus, quality can be either low (k_L) or high (k_H). Domestic and foreign firms produce seafood with different production technologies and costs of production. Parameters c_L and c_H reflect production costs for the two qualities such that $c_L < c_H$. That is, foreign fish can be produced (and sold, since supply is competitive) at a lower price than domestic fish.

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[13] The seafood supply chain is characterized by fish farmers (harvesters/producers), intermediaries (processors, importers, wholesalers and handlers) and retailers/foodservice establishments. For simplicity we consider two levels: firms and establishments; where firms include fish farmers and intermediaries, and establishments are defined as retailers/foodservice establishments. Firms are further classified as foreign and domestic according to the origin of seafood supplied.

[14] Evidences of market power exercised by retailers over suppliers and consumers are highlighted in Sexton et al. (2003) and Richards and Patterson (2003).

Supply side

Following Zago and Pick (2004) and Bureau, Marette, and Schiavina (1998), we assume each firm j (supplier of seafood to retail/foodservice), where $j = 1$ to n, maximizes a profit π_{ij}, and produces a quantity $q_{ij} \in \Re_+$ of the type $i = L, H$ where i represents quality. The aggregate supply $q_i = Q_i(w_i)$ is the summation of individual supply q_{ij} for each quality i. w_i is the market price of selling seafood to retail/foodservice sector. The overall firms' surplus Π_i is the sum of individual profits π_{ij}. The analytical expressions of aggregate surplus for firms of quality i seafood and aggregate supply function are:[15]

(1) $$\pi_{ij} = q_{ij} w_i - 0.5 c_i \left(q_{ij}\right)^2,$$

(2) $$Q_i(w_i) = w_i / c_i$$

Demand side

To analyze consumer welfare, consider a conceptual model of heterogeneous consumers. The model is a variant of the classic model of vertical product differentiation by Mussa and Rosen (1978) and it explicitly accounts for differences in consumer attitudes towards quality of fish. There is a continuum of consumers indexed by their preference θ for fish quality, which is uniformly distributed over $\left[0, \overline{\theta}\right]$ with density $1/\overline{\theta}$.[16] The size of both sectors is normalized to one. We assume that each consumer buys at most one unit of the good with quality k. The associated utility is:

(3) $$U = \theta\, k - p$$

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[15] The first order conditions imply $\dfrac{\partial \pi_{ij}}{\partial q_{ij}} = 0 \Rightarrow \sum_{j=1}^{n} \dfrac{\partial \pi_{ij}}{\partial q_{ij}} = 0 : w_i - c_i \sum_{j=1}^{n} q_{ij} = 0 \Rightarrow w_i - c_i Q_i = 0$.

[16] It should be noted that as the lower bound of the taste distribution is equal to zero, the market will not be entirely covered, i.e., some consumers prefer not to buy the good offered.

where p is the price of the good of quality k and consumers' willingness to pay for a quality k, is given by θk. Aggregate demand depends on consumers' belief about the quality i.e. consumers' information about the origin of seafood available in the market. Without COOL, consumers believe they are consuming seafood of expected quality $\bar{k}$ while with COOL, consumers relate origin information of seafood to their perceived quality, denoted by k_H and k_L.[17]

Before COOL: The Undifferentiated Market

In the absence of COOL, origin and production method cannot be determined by the consumers. That is, there is imperfect information in the market. Further, there is asymmetric information as sellers are aware of the origin and production of fish while consumers cannot identify them. In the extreme case, if a consumer has imperfect information about the quality of the product, sellers will resort to selling the lowest possible quality of a good. Lusk et al. (2006) state "… consumers will make an assumption about the average quality of the product on the market. Because the market will contain products from a variety of origins, the expected quality of the product on the market might fall well below the perceived quality of the domestic product".

We make the assumption that without COOL, sellers in retail and foodservice sector sell only foreign seafood because, in the context of this model, they do not have an

[17] Weighted average quality would depend on consumers' awareness of quality difference by origin and association of quality with practices of countries. We assume that with asymmetric information in the non-labeled market, consumers evaluate seafood quality using a simple average: $\bar{k} = \frac{k_H + k_L}{2}$

incentive to sell domestic seafood.[18] Figure 6 shows schematically the seafood market in the absence of COOL.

The retail and foodservice sectors are considered two separate markets. In both markets, consumers are heterogeneous in their preference for quality and are postulated to differ in the utility or marginal willingness to pay that they derive from the consumption of seafood. We assume that consumers have the same valuation for seafood in the two markets. A unique price $\overline{p}$ develops in both the sectors and consumers have an expected quality $\overline{k}$ as mentioned above.

The conditional indirect utility function of a consumer with preference parameter θ in the retail and foodservice market is given by:

$$(4) \qquad U = \begin{cases} \theta_l \overline{k} - \overline{p} & \text{if consumes a unit of seafood of expected quality } \overline{k} \text{ at price } \overline{p} \\ 0 & \text{if consumes nothing} \end{cases}$$

where $l = r$ for retail and $l = f$ for foodservice. The consumer indifferent between buying seafood or not receives the same level of utility from consuming or not in the two sectors-retail and foodservice. Thus, the indifferent consumer can be characterized as:

$$(5) \qquad \theta_l^{'} = \frac{\overline{p}}{\overline{k}}$$

[18] The framework considered here implies that consumers do not know the actual quality of seafood supplied and would consume foreign seafood in the absence of labeling because there is also uncertainty about the extent to which it is potentially unsafe for their health. However, when information is available about the origin of seafood, some consumers are willing to pay more for domestic seafood.
In the absence of information regarding the origin of seafood, domestic and foreign fish are marketed together and the price received by establishments is the same regardless of which product is produced (pooling equilibrium; see Akerlof 1970). The absence of a premium for domestic seafood when they are not segregated, coupled with increased costs of producing domestic seafood, result in the profitability of the domestic fish being lower than that of foreign fish. In this case the supply of domestic seafood is not incentive compatible; market forces lead to failure of the market to satisfy expressed consumer demands. Hence, only foreign seafood is sold.

Consumers with valuation for quality greater than $\theta_l^{'}$ will buy seafood and the consumers with valuation for quality lower than $\theta_l^{'}$ will not buy seafood. Thus, the demand for seafood in a market with no differentiation can be found by aggregating the quantity consumed by consumers with $\theta_l > \theta_l^{'}$. With $\overline{\theta}_l = 1$, the demand at retail or foodservice corresponds to:

(6) $$D_l(\overline{p}) = 1 - \frac{\overline{p}}{\overline{k}}$$

To determine equilibrium quantity and price before COOL implementation, we solve the profit maximization function for the retailer and foodservice. Then, derived demand at the retailer and foodservice level is equated with supply of foreign firms. The two sectors are each characterized by *N* identical retailers and *N* identical foodservice establishments competing with each other, and have market power over consumers. [19]

The individual **retailer/foodservice establishment** m $(m = 1,...,N)$ maximizes a profit given by:

(7) $$\max_{q_{lm}} \prod_{lm}^{BC} = \left[\overline{p}(Q_l) - w_L\right] q_{lm}$$

where $l = r, f$ and $\overline{p}(Q_l) = \overline{k}(1 - Q_l)$ is the inverse demand for non-labeled seafood in retail or foodservice. w_L represents price of foreign seafood paid by retailers and foodservice establishments to foreign firms.[20] The first order conditions of (7) imply:

[19] Dimitri, Tegene, and Kaufman (2003) review studies on market power of retailer over both consumers and producers in the fresh produce market. Here we assume retailer/foodservice has market power only in selling, i.e. they behave as oligopolists.

[20] We assume the retail and foodservice sector incur the same costs of purchasing seafood and that is the only cost (for e.g., no transportation costs) for simplicity.

(8) $$\frac{\partial \Pi_{lm}^{BC}}{\partial q_{lm}} = 0 \Rightarrow \sum_{m=1}^{N} \frac{\partial \Pi_{lm}^{BC}}{\partial q_{lm}} = 0 : \bar{k}\left(1 - Q_l\left(1 + \sum_{m=1}^{N} \Theta_{lm}\right)\right) = w_L$$

where $\Theta_{lm} = \frac{\partial Q_l}{\partial q_{lm}} \frac{q_{lm}}{Q_l}$ represent conjectural variation elasticity on the demand faced by the retailer/foodservice establishment m. It is defined as the percentage change of the aggregate quantities demanded caused by a percentage change in quantities sold by the establishment. Following Porter (1983) and Bresnahan (1989), aggregating over identical retail/foodservice establishment m, each weighted by its market share $1/N$ implies $\frac{1}{N}\sum_{m=1}^{N} \Theta_{lm} = \frac{1}{N} N\Theta_l = \Theta$. Equation (8) can then be written as:

(9) $$\bar{k}(1 - Q_l(1 + \Theta)) = w_L$$

The parameter $\Theta \in [0,1]$ where zero implies the establishments have no market power, while a higher value represents a higher degree of market power and $\Theta = 1$ implies perfect collusion.

Equating derived demand (9) facing the foreign firms aggregated over retail and foodservice establishments with supply (2) indicate the following:

(10) $$\frac{\bar{k} - w_L}{\bar{k}\lambda} + \frac{\bar{k} - w_L}{\bar{k}\lambda} = \frac{w_L}{c_L}$$

where $\lambda = (1 + \Theta)$. Solving for w_L gives the equilibrium quantities and prices:

(11) $$w_L^k = \frac{2\bar{k}c_L}{\bar{k}\lambda + 2c_L}$$

(12) $$Q_l^k = \frac{\bar{k}}{\bar{k}\lambda + 2c_L}$$

(13) $$\overline{p}^{k} = \frac{(\overline{k}\Theta + 2c_L)\overline{k}}{\overline{k}\lambda + 2c_L}$$

The superscript notation k refers to equilibrium in the absence of COOL, and subscript l as mentioned before refers to retailer or foodservice sector. Using (13), consumers' surplus in the absence of COOL can be calculated by integrating consumer utility at equilibrium for consumers who consume a unit of seafood with preference θ_l:

(14) $$CS_l^{BC} = \int_{\theta_l^{'}}^{1} (\theta_l \overline{k} - \overline{p}^{k}) d\theta_l = \frac{\overline{k}^3}{2(\overline{k}\lambda + 2c_L)^2}$$

Consumer welfare before implementing COOL can be considered as a benchmark when evaluating the effects of COOL implementation. Equation (14) is used to aggregate consumer surplus in the two sectors to get expected consumer welfare:

(15) $$CS^{BC} = \frac{\overline{k}^3}{(\overline{k}\lambda + 2c_L)^2}$$

and it depends positively on the expected quality of seafood and negatively on the costs of producing low quality fish and oligopoly power of establishments.

For the purpose of welfare analysis of the COOL implementation, we also consider *real* consumer surplus. In other words, consumers in reality are consuming seafood of quality k_L instead of expected quality $\overline{k}$. Thus, we compute *real* consumer surplus. The aggregate *real* consumer surplus for the same set of consumers and prices in equilibrium as before is illustrated in figure 7 and given as:

(16) $$CS_{real}^{BC} = \int_{\theta_l^{'}}^{1} \left(\theta_l k_L - \overline{p}^{k}\right) d\theta_l = \frac{\overline{k}\left(\overline{k}k_L - \Delta k\left(\overline{k}\Theta + 2c_L\right)\right)}{\left(\overline{k}\lambda + 2c_L\right)^2}$$

where $\Delta k = k_H - k_L$

COOL in Retail: The partially differentiated market

a. Zero costs of implementing COOL

With COOL in the retail sector, consumers can distinguish between the domestic and foreign seafood indexed by quality k_H and k_L respectively. As mentioned earlier, perceived quality $k_H > k_L$, and corresponding prices for seafood in retail are p_H and p_L, with $p_H > p_L$. Again let us consider two firms; domestic and foreign selling to two sectors: retail and foodservice. If consumers prefer domestic fish, the label would allow consumers to discriminate between foreign and domestic seafood. Suppose all domestic seafood (higher quality) is supplied to retail (because it is labeled) and foreign seafood (lower quality) is supplied to both the foodservice (non-labeled sector) and the retail sector, where it is labeled as such. By identifying seafood with their origin, retailers can convey implicit product quality information to consumers and a separating equilibrium that efficiently sort consumers into markets for different qualities (in our case origin) with corresponding prices may be attained. However, in the foodservice sector, in the absence of labeling, only foreign seafood is demanded (see footnote 18). Thus, COOL facilitates quality differentiation in retail and consumers have a choice between them as illustrated in figure 6.

As in the previous model, there is a continuum of consumers with preference θ for quality, and with total mass of one distributed uniformly between zero and one, i.e., $\theta \in [0,1]$. In this case, consumers in retail can differentiate seafood by means of perceived quality, while in foodservice, seafood are characterized by expected quality. With COOL facilitating the differentiation in terms of the origin of seafood in retail sector, the indirect utility of a consumer in the two sectors is given by:

$$(17)\qquad U=\begin{cases}\theta k_H - p_H & \text{if consumes a unit of domestic seafood in labeled (retail) sector}\\ \theta k_L - p_L & \text{if consumes a unit of foreign seafood in labeled (retail) sector}\\ 0 & \text{if consumes nothing}\end{cases}$$

Similarly,

$$(18)\qquad U=\begin{cases}\theta \bar{k} - \bar{p} & \text{if consumes a unit of foreign seafood in non-labeled sector}\\ 0 & \text{if consumes nothing}\end{cases}$$

where $k_L \le \bar{k} \le k_H$. There are two indifferent consumers in the retail sector: one between consuming domestic seafood and foreign seafood (θ_{HL}), and one between consuming foreign seafood and not consuming at all (θ_{L0}). Thus, retail consumers with valuation $\theta \in [0, \theta_{L0})$ will not consume seafood, while those with $\theta \in [\theta_{L0}, \theta_{HL}]$ will consume the low-quality seafood and the others $\theta \in (\theta_{HL}, 1]$ will consume the high-quality seafood. Similarly, in the foodservice sector, consumers are indifferent between consuming foreign seafood and not consuming at all (θ_f). Accordingly, the indifferent consumers (using 17 and 18) and demand for each quality of seafood can be found by aggregating the quantity consumed of each type in the two sectors and are given by:

Retail:

$$(19)\qquad \theta_{HL}=\frac{p_H - p_L}{k_H - k_L} \qquad D_L(p_H, p_L)=\frac{p_H - p_L}{k_H - k_L}-\frac{p_L}{k_L}$$

$$\theta_{L0}=\frac{p_L}{k_L} \qquad D_H(p_H, p_L)=1-\frac{p_H - p_L}{k_H - k_L}$$

Foodservice:

$$(20)\qquad \theta_f=\frac{\bar{p}}{\bar{k}} \qquad D_f(\bar{p})=1-\frac{\bar{p}}{\bar{k}}$$

To determine equilibrium quantity and price, profit maximization function for individual retailer and foodservice is solved first:

Each **retailer m** maximizes a profit given by:

$$(21) \qquad \max_{q_{Hm}, q_{Lm}} \prod_r^{AC} = [p_H(Q_H, Q_L) - w_H]q_{Hm} + [p_L(Q_H, Q_L) - w_L]q_{Lm}$$

where $p_H(Q_H, Q_L) = k_H - k_H Q_H - k_L Q_L$ and $p_L(Q_H, Q_L) = k_L(1 - Q_H - Q_L)$ are the inverse demand for domestic and foreign seafood in retail. w_H and w_L represent price paid by retailer for domestic and foreign seafood. The first order conditions of (21) imply:

$$(22) \qquad \begin{aligned} k_H - k_H Q_H \lambda - k_L Q_L \lambda &= w_H \\ k_L - k_L Q_L \lambda - k_L Q_H \lambda &= w_L \end{aligned}$$

Each **foodservice establishment m** maximizes a profit given by:

$$(23) \qquad \max_{q_{fm}} \prod_f^{AC} = [\bar{p}(Q_f) - w_L]q_{fm}$$

where $\bar{p}(Q_f) = \bar{k}(1 - Q_f)$ is the inverse demand for seafood in foodservice sector. The first order conditions of (23) imply:

$$(24) \qquad \bar{k}(1 - Q_f \lambda) = w_L$$

Following COOL, two markets emerge: one for the high-quality seafood, and the other for low-quality. The supply in the two markets is:

$$(25) \qquad \begin{aligned} Q_H(w_H) &= \frac{w_H}{c_H} \\ Q_L(w_L) &= \frac{w_L}{c_L} \end{aligned}$$

Equating aggregate derived demand of retail and foodservice sectors (22 and 24) with supply of domestic and foreign firms (25) indicate the following:

$$(26)\quad \begin{aligned} &\frac{\Delta k-(w_H-w_L)}{\Delta k\lambda}=\frac{w_H}{c_H} \\ &\frac{\bar{k}-w_L}{\bar{k}\lambda}+\frac{w_H k_L-k_H w_L}{k_L\Delta k\lambda}=\frac{w_L}{c_L} \end{aligned}$$

For equilibrium quantities and prices in the two sectors and prices of domestic and foreign firms (27) see appendix I. Consumers' surplus in retail and foodservice sector for this scenario is given as:

$$(28)\quad \begin{aligned} &CS_r^{AC}=\int_{\theta_{L0}}^{\theta_{HL}}\left(\theta k_L-p_L^k\right)d\theta+\int_{\theta_{HL}}^{1}\left(\theta k_H-p_H^k\right)d\theta \\ &CS_f^{AC}=\int_{\theta_f}^{1}\left(\theta\bar{k}-\bar{p}^k\right)d\theta \end{aligned}$$

The expected consumer welfare after implementing COOL is obtained by aggregating consumer surplus in retail and foodservice sector (28). Refer to appendix I for the expression.

Similar to our previous argument, consumer surplus in retail is *real* as there is no mismatch between *real* quality supplied and perceived quality. But the *real* consumer surplus in the foodservice sector (non-labeled) is different and defined similar to the before COOL market. The expressions for *real* consumer surplus in the foodservice sector and the aggregate *real* consumer surplus can be found in appendix I.

b. With costs of implementation

Let us now assume there are costs related to COOL implementation. The costs are considered at two levels: Cost of labeling/recordkeeping borne by retailers *b* and operating costs (segregation and identity preservation costs) *y*. Domestic firms bear the latter costs whereas foreign firms do not. The reason being that imports inform the "ultimate purchaser" of their country of origin with labels; it is not contingent on COOL implementation.[21] The profit maximization equations and equilibrium quantities and prices are as follows:

Each **retailer m** maximizes a profit given by:

$$(32)\qquad \max_{q_{Hm},q_{Lm}} \prod_r^{AC} = [p_H(Q_H,Q_L) - w_H - b]q_{Hm} + [p_L(Q_H,Q_L) - w_L - b]q_{Lm}$$

Each **foodservice establishment m** maximizes a profit given by:

$$(33)\qquad \max_{q_{fm}} \prod_f^{AC} = [\overline{p}(Q_f) - w_L]q_{fm}$$

Following COOL, domestic firms supplying high-quality seafood incur an additional cost *y* while the foreign firms' supply function of low-quality seafood remains unchanged. Supply in the two markets can be written as:

$$(34)\qquad \begin{aligned} Q_H(w_H) &= w_H/(c_H + y) \\ Q_L(w_L) &= w_L/c_L \end{aligned}$$

Equating aggregate demand facing the domestic and foreign firms with supply (34), and expected consumer welfare is the following:

$$(35)\qquad \begin{aligned} &\frac{\Delta k - (p_H + p_L)}{\Delta k\lambda} = \frac{w_H}{c_H + y} \\ &\frac{\overline{k} - w_L}{\overline{k}\lambda} + \frac{k_L(w_H + b) - k_H(w_L + b)}{k_L\Delta k\lambda} = \frac{w_L}{c_L} \end{aligned}$$

$$CS^{AC} = \int_{\theta_{L0}}^{\theta_{HL}} (\theta k_L - p_L^k)d\theta + \int_{\theta_{HL}}^{1} (\theta k_H - p_H^k)d\theta + \int_{\theta_f}^{1} (\theta\overline{k} - \overline{p}^k)d\theta$$

The expressions for expected consumer welfare after implementing COOL with costs, the *real* consumer surplus and equilibrium prices and quantities can be found in appendix I.

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[21] Ultimate purchaser has been defined as the last U.S. person who will receive the product in the form in which it was imported.

COOL in Retail and Foodservice: The totally differentiated market

a. Zero costs of implementing COOL

Now, consider the case where COOL is implemented in both the retail and foodservice sectors. There is no informational asymmetry with consumers able to determine origin and make informed choices. An important outcome of uniform regulation in both sectors is that there is no scope for diversion. Figure 6 represents the scenario of a totally differentiated market. Assuming zero implementation costs of labeling, the profit-maximization equation for individual **retailer/foodservice establishment m** becomes:

(39) $$\max_{q_{Hlm}, q_{Llm}} \prod_{lm}^{AC} = \left[p_H(Q_{Hl}, Q_{Ll}) - w_H\right]q_{Hlm} + \left[p_L(Q_{Hl}, Q_{Ll}) - w_L\right]q_{Llm}$$

where $p_H(Q_{Hl}, Q_{Ll}) = k_H - k_H Q_{Hl} - k_L Q_{Ll}$ and $p_L(Q_{Hl}, Q_{Ll}) = k_L - k_L Q_{Hl} - k_L Q_{Ll}$ are the inverse demand for domestic and foreign seafood in retail or foodservice. All other variables are as previously defined. The first order conditions of (39) imply:

(40) $$\begin{aligned} k_H - k_H Q_{Hl}\lambda - k_L Q_{Ll}\lambda &= w_H \\ k_L - k_L Q_{Ll}\lambda - k_L Q_{Hl}\lambda &= w_L \end{aligned}$$

Equating aggregate derived demands of retail and foodservice sectors (40) with supply of the domestic and foreign firms (25) indicate the following:

(41) $$\begin{aligned} \frac{\Delta k - (p_H + p_L)}{\Delta k\lambda} + \frac{\Delta k - (p_H + p_L)}{\Delta k\lambda} &= \frac{w_H}{c_H} \\ \frac{k_L w_H - k_H w_L}{k_L \Delta k\lambda} + \frac{k_L w_H - k_H w_L}{k_L \Delta k\lambda} &= \frac{w_L}{c_L} \end{aligned}$$

Refer to appendix I for equilibrium prices and quantities, and total consumer welfare. Consumer surplus at retail or foodservice sector when both are labeled is given by:

(43) $$CS_l^{\overline{AC}} = \int_{\theta_{L0}}^{\theta_{HL}} (\theta k_L - p_L^k) d\theta + \int_{\theta_{HL}}^{1} (\theta k_H - p_H^k) d\theta$$

The consumer surplus in a totally differentiated market is the *real* consumer surplus unlike CS^{AC} (29 and 37) and CS^{BC} (15) in partially differentiated and undifferentiated markets respectively.

b. With costs of implementation

Here, labeling cost *b* is applicable to foodservice establishments as well, i.e., both retailers and foodservice sectors bear this cost. As before, cost *y* is borne only by the domestic firms. The profit-maximization equation for individual **retailer/foodservice establishment m** becomes:

(45) $$\max_{q_{Hlm}, q_{Llm}} \prod_{lm}^{AC} = [p_H(Q_{Hl}, Q_{Ll}) - w_H - b] q_{Hlm} + [p_L(Q_{Hl}, Q_{Ll}) - w_L - b] q_{Llm}$$

The first order conditions of (44) imply:

(46) $$\begin{aligned} k_H - k_H Q_{Hl}\lambda - k_L Q_{Ll}\lambda &= p_H + b \\ k_L - k_L Q_{Ll}\lambda - k_L Q_{Hl}\lambda &= p_L + b \end{aligned}$$

Equating aggregate derived demand facing the domestic and foreign firms (46) with supply (34) indicate the following:

(47) $$\begin{aligned} \frac{\Delta k - (p_H + p_L)}{\Delta k \lambda} + \frac{\Delta k - (p_H + p_L)}{\Delta k \lambda} &= \frac{w_H}{c_H + y} \\ \frac{k_L(w_H + b) - k_H(w_L + b)}{k_L \Delta k \lambda} + \frac{k_L(w_H + b) - k_H(w_L + b)}{k_L \Delta k \lambda} &= \frac{w_L}{c_L} \end{aligned}$$

Total consumer surplus, equilibrium prices and quantities can be found in appendix I.

Analysis

The COOL law aims to improve consumer welfare. Considering the pre-COOL scenario as the benchmark, we try to determine the effect of COOL (partial and total implementation) on consumer welfare. As mentioned previously, we also consider market power at the retailer and foodservice level and implementation costs in consumer welfare comparisons. Following the definition of trade diversion which is referred to as a shift in trade flows away from firms whose imports are affected by a trade barrier (named firms) to firms that import the same product but are not affected (non-named firms), we consider diversion as a percentage of the relative share of foreign seafood increase in foodservice sector with partial implementation of COOL. Finally, we also examine producer welfare (profits) at the retail and foodservice level with COOL.

Using Mathematica 5.1 we first calibrate the model to have a proper functioning market.[22] We normalize $c_L, k_L = 1$ and determine values for c_H, k_H in the feasible region of the functioning market. Within the feasible region, to analyze the effect of change in marginal production costs on consumer welfare and diversion, we fix k_H at 1.1 and vary c_H from 200% to 300% of c_L. Similarly, to infer the effect of change in quality we fix c_H at 4 and vary k_H from 110% to 210% of k_L.[23] We allow c_H, k_H to have differences in marginal costs and quality, respectively from 10% to 100%. Finally, we also vary market power parameter Θ from 0% to 100%, fixing k_H at 1.1 and c_H at 4.[24]

When we examine scenarios with positive implementation costs, we set $b = 0.07$ and $y = 0.0025$. These are the first year implementation costs of COOL estimated per pound of seafood, for retailers and producers respectively (USDA-AMS, 2004).

[22] A proper functioning market is defined as a market where all prices and quantities are positive.

[23] The values $k_H = 1.1, c_H = 4$ are both within the feasible region.

[24] We abbreviate pre-COOL market as BC, partial COOL implementation as PC, and total COOL implementation as TC in the numerical simulation figures.

Figures 9 to 26 are numerical simulations which show the effects of varying marginal production costs, quality and market power parameter on consumer welfare (Expected and *Real*), diversion percentage and profit at the retail and foodservice level. In the figures we abbreviate pre-COOL market as BC, partial COOL implementation as PC and total COOL implementation as TC.

a. ***Effect of varying c_H on diversion percentages (figures 9 and 11)***

We examine diversion by comparing the quantity of low-quality fish sold in the foodservice sector under partial implementation of COOL to the quantity sold without COOL (see figure 8 for the formula used). Our initial hypothesis is that an unintended consequence of partial COOL is the diversion of low-quality fish to the non-labeled market. Figures 9 and 11 show that diversion increases with an increase in the production costs of high-quality fish under both perfect competition and market power, and also with and without considering the cost of implementing COOL. Pre-COOL market is characterized by foreign seafood supply only whereas, with partial COOL, domestic seafood is also supplied to the labeled sector. Increasing differences in the production costs make domestic fish more expensive relative to foreign fish. The difference in price makes foreign fish more attractive to consumers, therefore putting downward pressure on its price (compared to the pre-COOL scenario). This effect results in increased quantities of low-quality fish being supplied in the non-labeled sector.

Diversion is greater with costs of COOL implementation. Labeling costs are borne by retailers on both domestic and foreign fish. Operating costs are imposed only on domestic firms. This results in domestic and foreign fish in retail sector becoming more expensive than foreign fish in foodservice sector. Foreign fish in the non-labeled market is cheaper due to price competition. Diversion occurs due to an increase in the quantity of foreign seafood sold in the non-labeled sector compared to the pre-COOL quantity in the foodservice sector.

b. Effect of varying k_H on diversion percentages (figures 10 and 12)

When the quality of domestic fish increases, diversion of foreign seafood into the non-labeled market increases under both perfect competition and market power, and also with and without costs of implementing COOL (figures 10 and 12). The pre-COOL market is characterized by supply of low-quality foreign fish only, which consumers perceive to be of expected quality $\bar{k}$. With partial COOL, high-quality domestic fish is also supplied to the labeled sector; non-labeled sector behaves similar to the pre-COOL market. As quality increases, for pre-COOL scenario: $\bar{k}$ which is a function of k_H increases, price of fish increases, reducing quantity. Similarly for partial COOL scenario: $\bar{k}$ in foodservice sector and k_H in retail sector increases, price of corresponding quality of fish increases, reducing their quantity sold. The magnitude of price increase of high-quality fish is greater than the price increase for expected quality fish. Price competition in partial COOL between domestic and foreign seafood leads to price of expected quality fish in non-labeled sector being lower than price of expected quality fish in foodservice sector in the pre-COOL scenario. Thus, the quantity of low-quality fish sold in the non-labeled sector after COOL implementation would be greater than pre-COOL. As before diversion is greater with costs of COOL implementation.

c. Effects of varying c_H on consumer surplus (figures 13, 14, 17 & 18)

When the cost of producing and transforming domestic seafood (c_H) increases relative to foreign seafood (c_L), consumer surplus decreases in all scenarios under perfect competition and market power. Increasing differences in the production costs result in making domestic fish more expensive to consumers. The price to consumers of domestic fish increases which reduces consumer surplus; assuming all exogenous parameters are constant. Pre-COOL surplus is not affected as we consider only foreign supply of seafood. Thus, increase in c_H results in diversion in partial COOL scenario, thereby reducing consumer surplus, and substitution of high-quality fish by low-quality fish in total COOL scenario.

When no costs of implementation are considered, we anticipate that a total implementation of COOL will result in greater consumer surplus than partial implementation. However, figures 13 and 17 show that expected consumer surplus is greatest with partial COOL. This result can be rationalized by realizing that expected welfare in the partial COOL scenario does not take into account the *real* quality k_L of foreign fish supplied to consumers in the non-labeled sector, rather it is based on consumers' belief of quality $\bar{k}$, where $\bar{k} > k_L$. Thus, while consumers expect to be getting quality $\bar{k}$, they are in fact consuming seafood of perceived lower quality. Because consumer utility is dependent on the quality of the product consumed, consumer surplus is necessarily higher when consumers believe they are getting $\bar{k}$ rather than k_L. Considering that consumers are truly receiving quality k_L, the comparison of *real* consumer surplus (figures 14 and 18) under different scenarios of implementation reveals that it is greatest with total COOL.

Considering the actual consumer welfare (*real* surpluses in figures 14 and 18), consumer welfare is greatest with total COOL followed by partial COOL and pre-COOL. Consumer surplus under total COOL is greatest because both sectors are labeled, which leads to expected quality being equal to *real* quality. In other words, consumers are aware of the quality of fish they consume and can make informed choices. Increase in production costs result in making domestic fish in retail and foodservice expensive, reducing quantity of domestic seafood demanded. Whereas, demand for foreign seafood increases as expensive domestic seafood is substituted by foreign seafood. Diversion of low-quality fish to the non-labeled sector, where it can masquerade as a higher quality, leads to decreasing consumer welfare under partial COOL. Thus, as substitution effect is less than diversion effect, consumer welfare in total COOL is greater than welfare in partial COOL. Pre-COOL consumer surplus is the lowest because the market is non-labeled and consumers are supplied only with low-quality foreign fish.

When costs of implementation are considered for *real* consumer welfare (figures 14 and 18), consumer surplus under partial COOL is greater than total COOL. Post-COOL, domestic firms bear operating costs across partial and total COOL scenarios. However, the non-labeled sector in partial COOL does not bear the costs of labeling. This results in seafood sold in the labeled sector at a higher price than without costs of implementation. Similarly, diversion in partial COOL scenario is greater than without costs of implementation. More costs are imposed on consumers of domestic and foreign seafood under total COOL compared to partial COOL. Cost effect in total COOL scenario is greater than diversion effect in partial COOL, which implies consumer welfare under partial COOL is greater than total COOL when costs of implementation are considered.

d. Effect of varying k_H on consumer surplus (figures 15, 16, 19 and 20)

Expected consumer surplus increases in all scenarios under perfect competition and market power (figures 15 and 19). *Real* consumer surplus increases for total and partial COOL scenario, but decreases for pre-COOL (figures 16 and 20). The increases in high quality k_H, assuming all other exogenous parameters constant, can be interpreted as an increase in expected consumer welfare. *Real* consumer surplus is lower for the pre-COOL market (relative to partial COOL) as consumers are being supplied only with low quality fish despite their belief of expected quality consumption of fish. However, as the quality of domestic fish increases, the expected quality increases, which increases the price and reduces the quantity of (foreign) fish consumed. Thus, *real* consumer surplus decreases before COOL is implemented. Under partial and total COOL implementation, *real* consumer surplus increases with differences in quality because some of the high-quality fish is substituted for low-quality fish in the labeled market causing a positive impact on consumer surplus.

Real consumer surplus is greatest with total COOL (with and without costs of implementation) followed by partial COOL and pre-COOL as seen in figures 16 and 20. Following our previous discussion, consumer surplus under total COOL is greatest due to substitution of low-quality fish by high-quality fish in the labeled market. Partial COOL is characterized by two opposite effects on consumer welfare- substitution effect in retail (labeled sector) and expected quality effect in foodservice sector (non-labeled sector). The former results in positive consumer welfare, while the latter results in diversion, which decreases consumer surplus. With market power, consumer surplus decreases for partial COOL, as quantity of fish is restricted compared to without market power, and expected quality effect is greater than substitution effect. Absence of labeling in the pre-COOL market results in consumer surplus being the lowest in this scenario as only low quality foreign seafood is supplied despite consumers' belief of expected quality. Expected consumer surplus is greatest with partial COOL due to the mismatch of expected and *real* quality as previously mentioned.

e. Effect of varying c_H and k_H on profits (figures 24 and 25)

Increasing costs of production decreases profits of retail and foodservice sectors (figure 24). Profits are greatest under partial COOL followed by total COOL and pre-COOL. Increasing c_H results in diversion in partial COOL scenario, therefore profits of foodservice sector is greater than retail sector, which in turn makes profits under partial COOL greater than total COOL. Absence of production costs associated with domestic seafood and implementation costs in the foodservice sector under partial COOL, cause foodservice sector profits to be the greatest. Pre-COOL profits show no change with increasing c_H as only foreign seafood is supplied.

Effect of increasing quality on profits is seen in figure 25. Profits of retail and foodservice sectors increase with increasing quality. Profits are greatest for partial COOL followed by pre-COOL and total COOL. As k_H increases expected quality of fish increases, but in reality low-quality fish is supplied. Consumers pay a higher price for low-quality seafood, which increases profits in the non-labeled market. Pre-COOL profits increase at a greater rate than partial and total COOL due to mismatch of quality perceived and quality supplied in the non-labeled market. Increase in quality also leads to diversion making profits in foodservice sector greater than profits in retail under partial COOL. Thus, aggregate profits are maximized in partial COOL scenario.

f. Effect of varying Θ on consumer surplus, diversion percentages, and profit (figures 21, 22, 23 and 26)

Market power exerted by retail and foodservice establishments result in decreasing consumer welfare and diversion across all scenarios, and increasing profits. The decrease can be attributed to the reduction in quantity of seafood sold in both retail and foodservice sector, i.e., overall quantity is restricted when establishments exercise market power. The decrease in *real* consumer welfare from a perfectly competitive market to perfect collusion is approximately 50 percent across all scenarios, assuming quality and production costs are fixed. Similarly, diversion of low-quality seafood into the foodservice sector reduces from a perfectly competitive market to perfect collusion by 35 to 50 percent. Profits increase with market power exerted by retail and foodservice sectors, as higher prices can be charged for seafood by establishments.

Conclusions

The seafood market in the United States is characterized increasingly by imported fish and shellfish from developing countries. The costs of production of domestic seafood are higher than those of the imported due to strict regulations and quality control processes in the United States. With the implementation of COOL in September 2006 in the seafood market, and the exemption of the foodservice sector from mandatory labeling, there is a potential for diversion of lower quality imports to the non-labeled sector. In other words, while labeling satisfies the market demand for information provision, exemptions of the law creates incentives for the diversion of imports, which are lower in quality than domestic seafood, to the non-labeled sector. The diversion of lower quality seafood to the non-labeled market segment has consequences on the welfare impact of the implementation of COOL.

This paper develops a conceptual model of heterogeneous consumers that examines the consequences of COOL implementation on consumer welfare. Numerical simulation results show that consumer welfare decreases with increasing costs of production as fish becomes more expensive. Increasing quality differences increase consumer welfare due to higher quality of seafood supplied. Diversion increases with increase in production costs and quality. In the pre-COOL scenario, only foreign seafood is assumed to be supplied, while after COOL implementation domestic seafood is also supplied. This difference in the nature of supply leads to foreign firms having a higher incentive to sell in the non-labeled sector with COOL implementation. Market forces create an incentive for foreign firms to masquerade lower quality fish as higher quality and to circumvent the additional costs associated with COOL implementation.

Consumer welfare is the greatest when COOL is implemented in both the retail and foodservice sectors than under the current implementation in retail only. Total implementation helps consumers in making informed choices and reduces the potential diversion. Consumer welfare is the lowest in the pre-COOL scenario due to the mismatch of *real* and expected quality of fish. Consumers assume they are buying fish of a higher quality than it is. Market power exercised at the retail and foodservice sector are detrimental to consumer welfare as expected while it decreases diversion. This is attributed to the decrease in the overall quantity of seafood sold in the market. Thus, our study shows that labeling can mitigate asymmetric information problems arising from the credence nature of seafood products, correct supply-side market failures, and enhance consumer welfare.

Our work has relevant policy implications. The effectiveness of implementing COOL in the seafood industry needs to be reconsidered due to its unintended consequences of diverting imported seafood towards the non-labeled market. The current state of the food industry, with numerous recent safety scares and popularization of safe seafood choices, has contributed to the perception that foreign fish is of lower quality than domestic fish. The nature of the industry characterized by a majority of imported seafood consumed away from home poses a real question on the credibility of retail-COOL as a consumer-welfare-increasing policy. Though some labeling is perhaps better than none at all, partial labeling can lead to undermining the true effectiveness of the regulation. Further work will involve empirical work on popular seafood, like shrimp, to determine the effect of COOL on consumer welfare pre- and post-COOL implementation.

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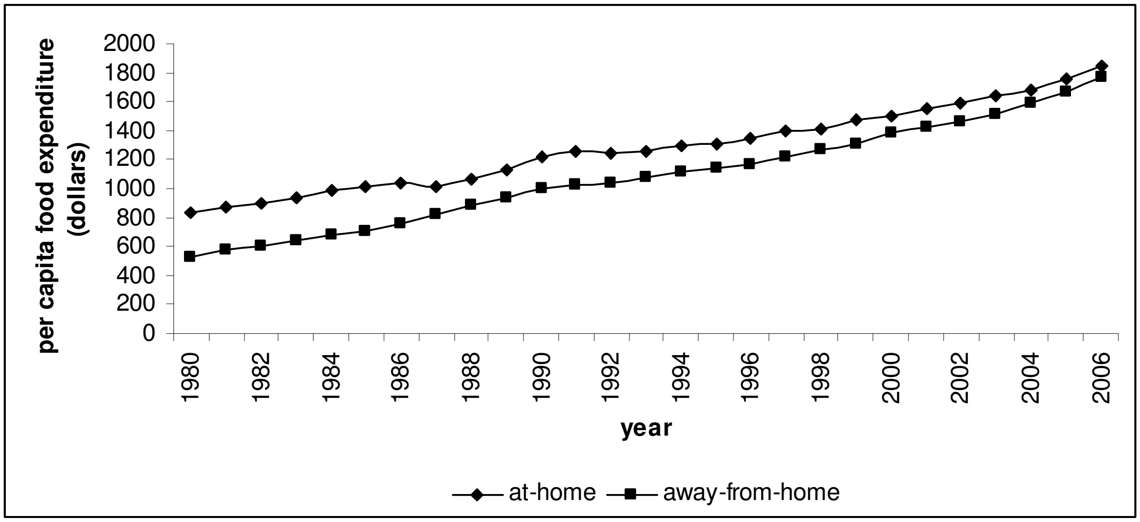
Table 1: Healthy seafood guide

	Twice a week	Once a week	Once a month	Avoid
Suggestions on frequency of Seafood consumption based on their mercury levels, origin and method of production. Some tips to ease decision making: In general opt for U.S. farmed fish over wild (exception- wild salmon) and American fish over imported (example- American farmed shrimp) *fish is high in mercury or other contaminants.	Anchovies	Halibut; *Pacific*	Basa; *Vietnam*	Caviar; *Imported* wild
	Barramundi; *U.S.* farmed	Sablefish; *Alaska or Canada*	Clams; wild	Chilean sea bass*
	Catfish; *U.S.*	Tuna- Albacore*; *U.S. or Canada*	Cod; *Pacific*	Cod; *Atlantic*
	Caviar; *U.S.* farmed		Crab- Blue, King, Snow; *U.S.**	Crab- king; *Imported*
	Char; *Arctic* farmed		Flounder and sole; *Pacific*	Crawfish; *China*
	Clams, mussels, and oysters; farmed		Haddock	Flounder and sole; *Atlantic*
	Crab, Dungeness and Stone		Lobster; *American or Maine*	Grouper*
	Crawfish; *U.S.*		Mahimahi	Haddock
	Herring; *Atlantic*		Sablefish; *California, Oregon, or Washington*	Halibut; *Atlantic*
	Mackerel; *Atlantic*		Salmon; *California, Oregon, or Washington* wild	Monkfish
	Salmon; *Alaskan* wild		Scallops; *New England or Canada*	Orange roughy*
	Sardines		Shrimp; *U.S. or Canada* wild	Rockfish; *Pacific*
	Scallops; farmed		Squid	Salmon; *Atlantic* farmed
	Shrimp; *U.S.* farmed		Swordfish; *U.S.**	Shark*
	Striped bass; farmed		Tilapia; *Latin America*	Shrimp and prawns; *Imported*
	Sturgeon; farmed		Tuna- Albacore, light, yellowfin; *Imported or U.S.**	Skate
	Tilapia; *U.S.*			Snapper, red
	Trout, rainbow; farmed			Swordfish; *Imported**
				Tilapia; *Asia*
				Tuna-bluefin, yellowfin; *Imported**

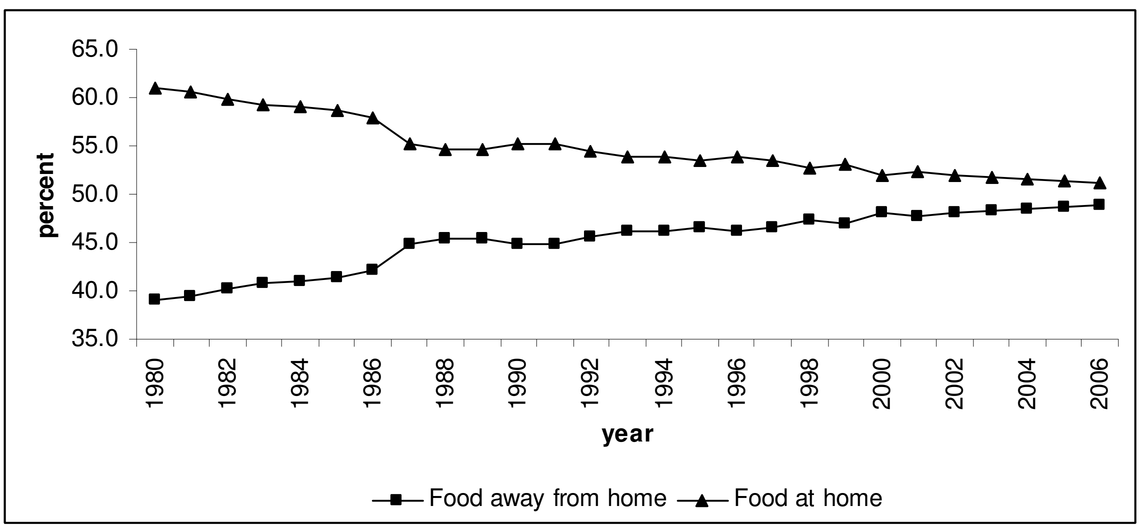
Source: www.environmentaldefense.org/seafood

Figure 1: U.S. per capita food expenditure.



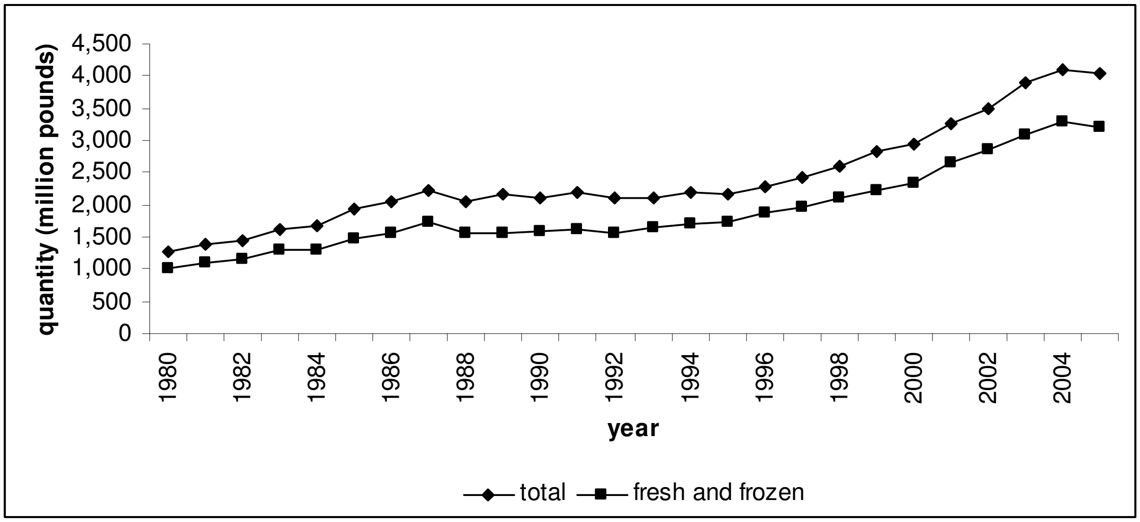
Source: USDA-ERS

Figure 2: Share of total food expenditures spent on food at home and away from home.



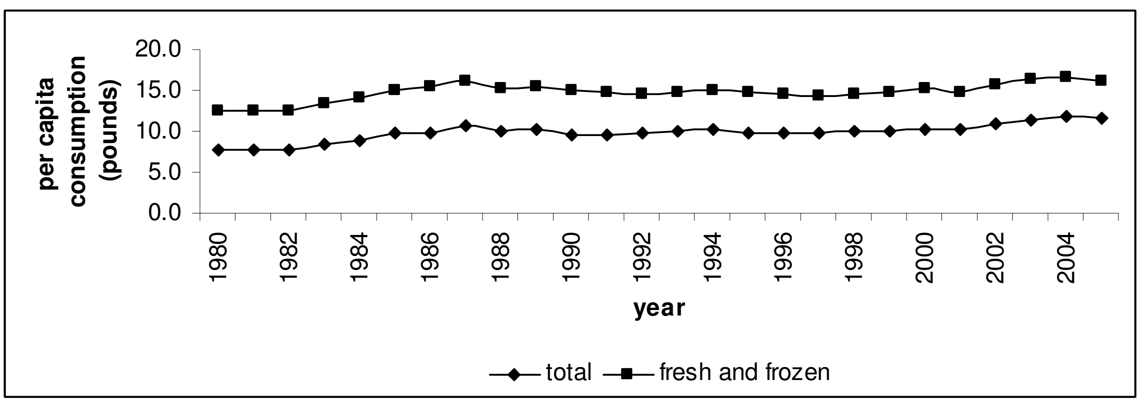
Source: USDA-ERS

Figure 3: Seafood imports.



Source: USDA-ERS

Figure 4: Seafood per capita consumption.



Source: USDA-ERS

Figure 5: Overview of the classification of the seafood market under COOL implementation

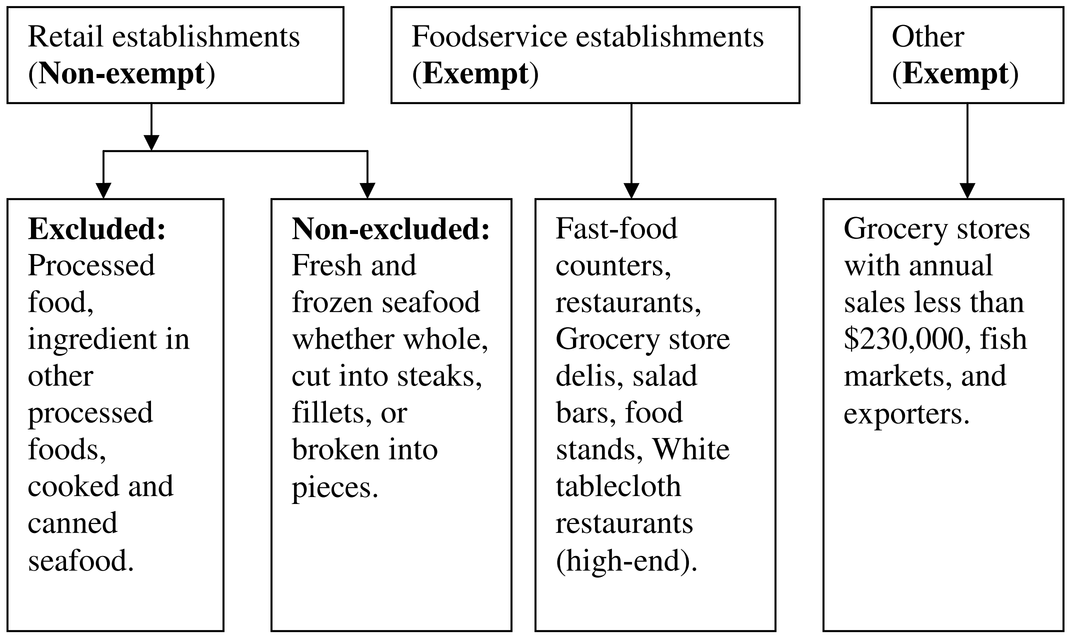


Figure 6: Market scenarios for COOL

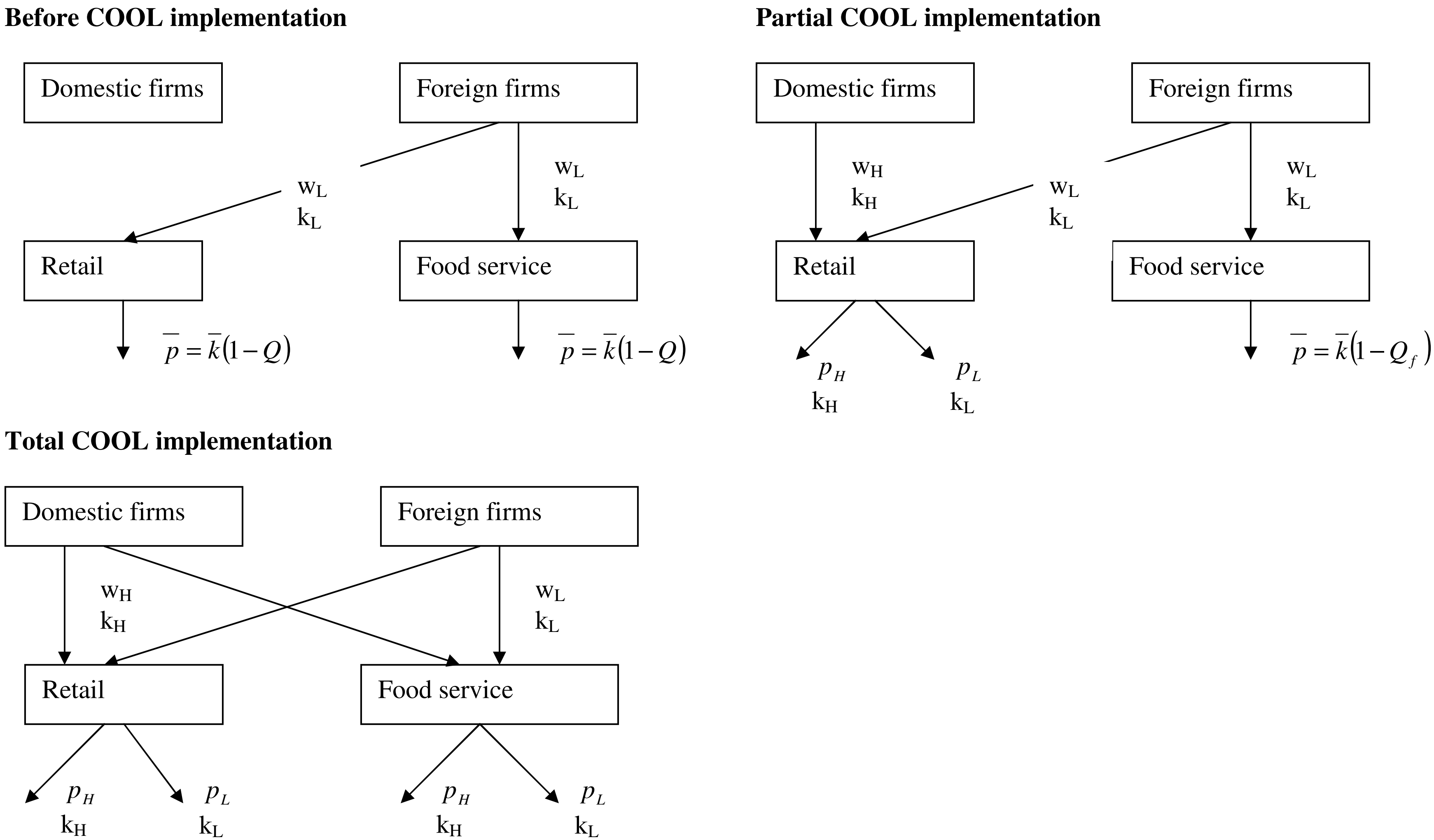
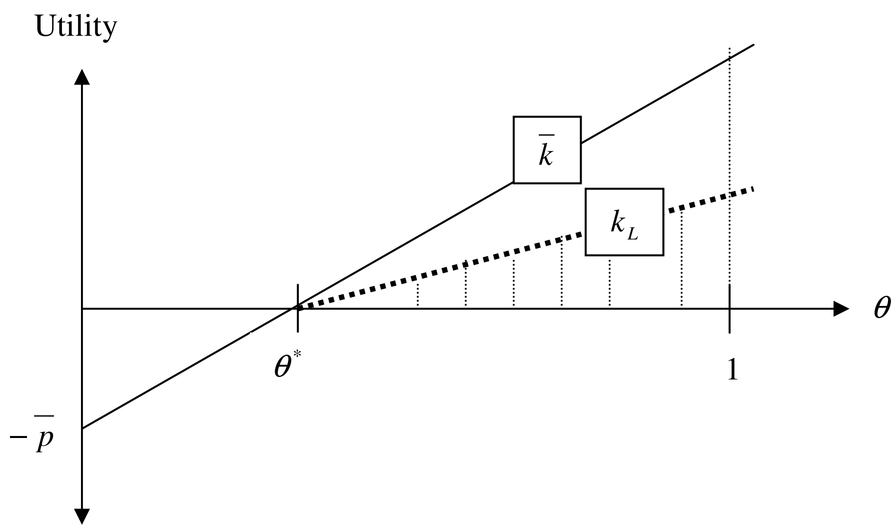


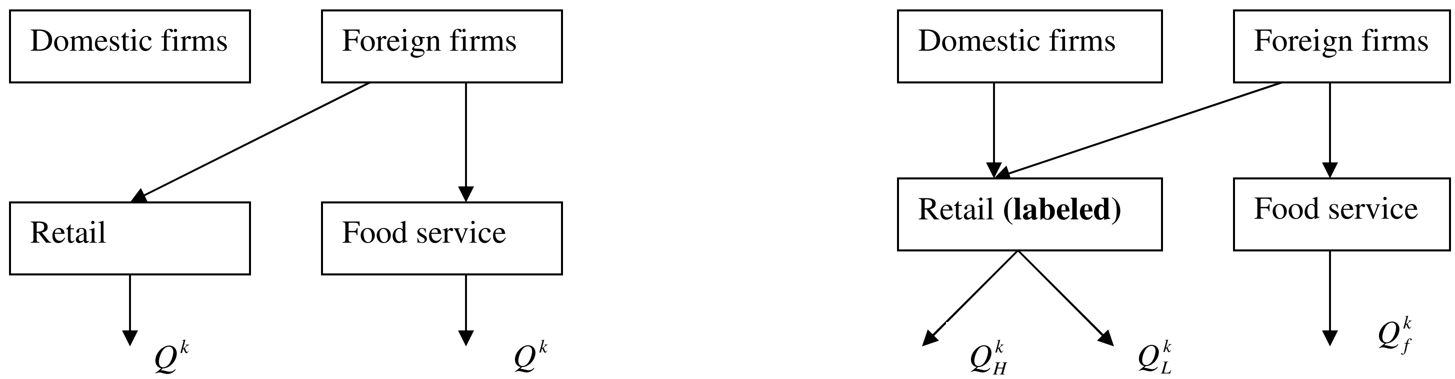
Figure 7: Consumer Surplus in the non-labeled sector



The shaded region represents the *real* consumer surplus in the non-labeled sector.

Figure 8: Diversion

a Pre-COOL implementation **b. Post-COOL implementation**



Diversion as a percentage of relative share = $$\frac{\dfrac{Q_f^k}{Q_f^k + Q_H^k + Q_L^k} - \dfrac{Q^k}{Q^k + Q^k}}{\dfrac{Q^k}{Q^k + Q^k}}$$

Figure 9: Diversion percentage ($\Theta = 0$, $k_H = 1.1$)

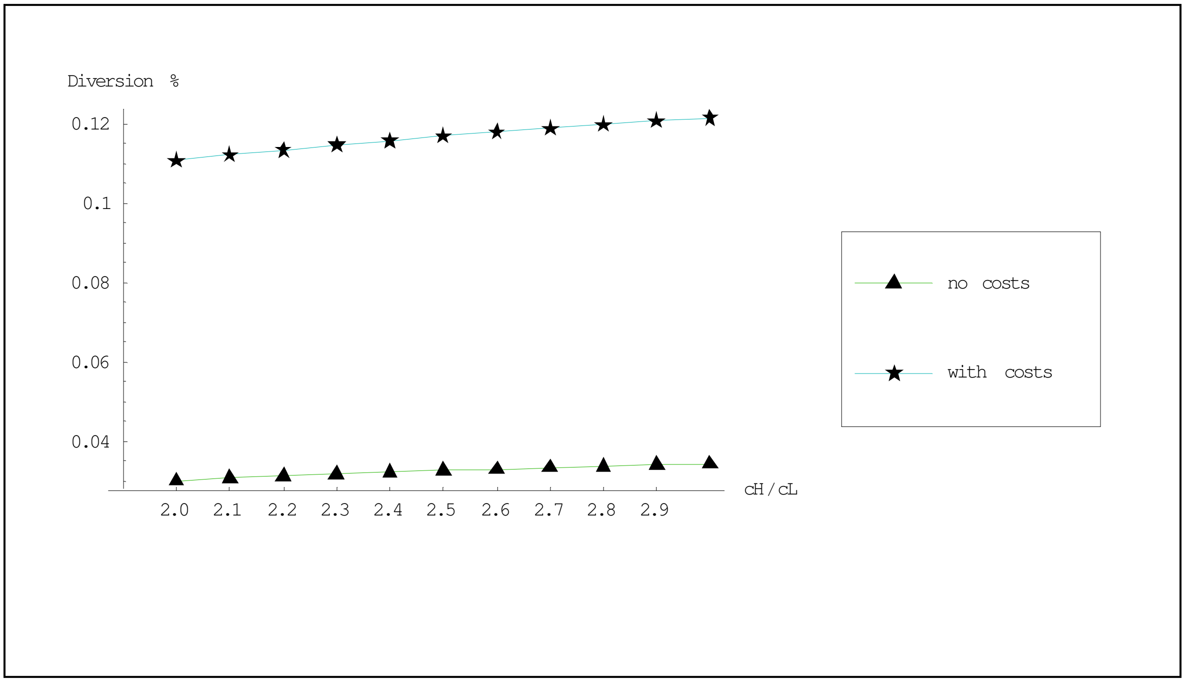


Figure 10: Diversion percentage ($\Theta = 0$, $c_H = 4$)

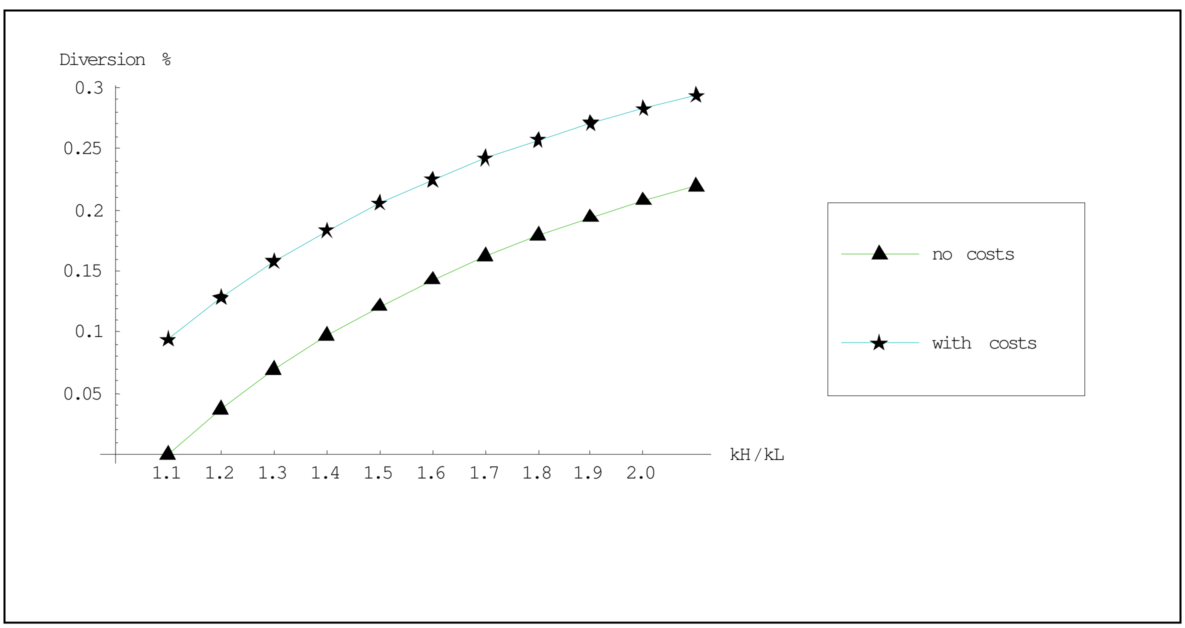


Figure 11: Diversion percentage ($\Theta = 0.5$, $k_H = 1.1$)

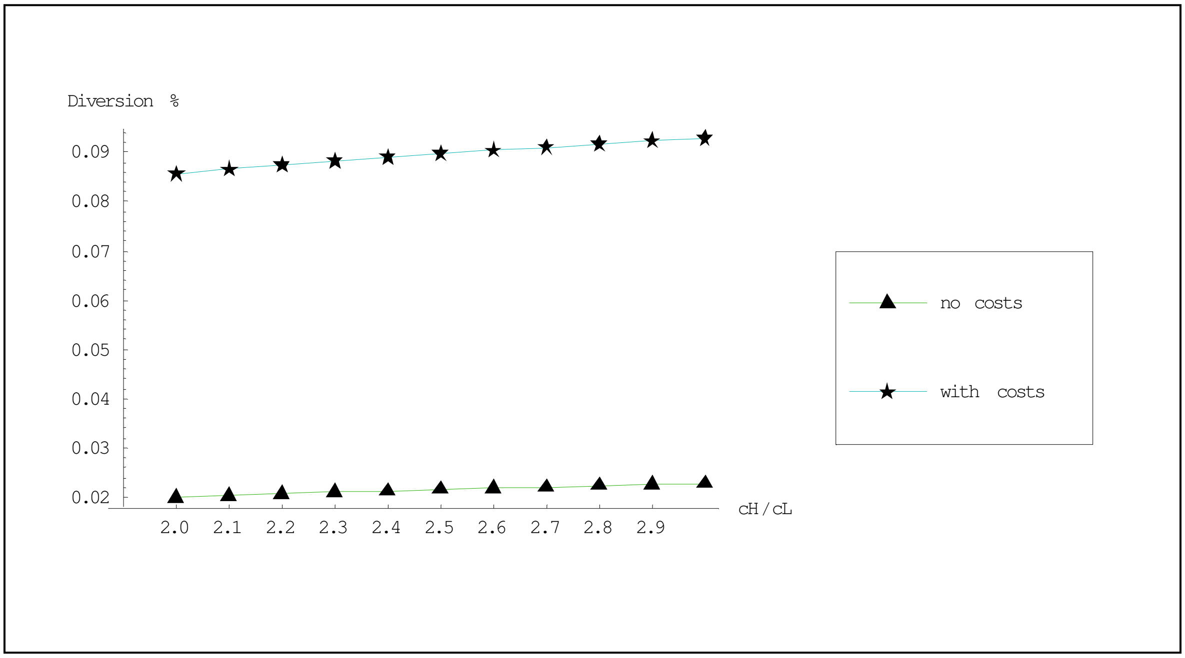


Figure 12: Diversion percentage ($\Theta = 0.5$, $c_H = 4$)

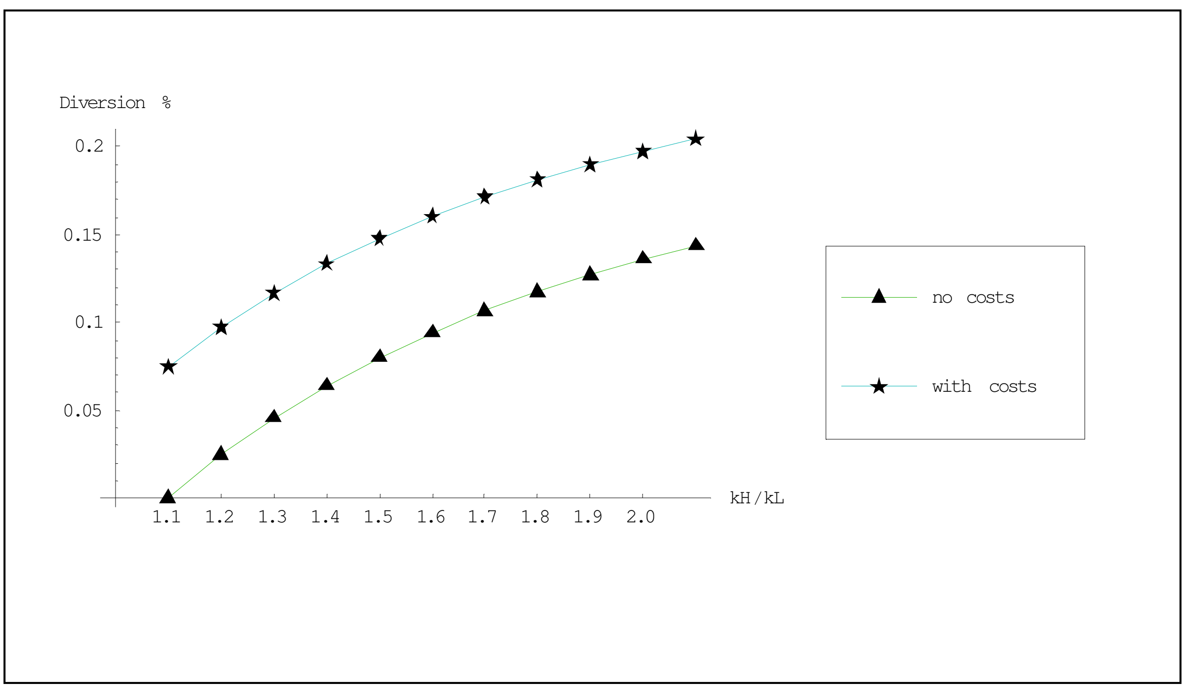


Figure 13: Expected consumer surplus ($\Theta = 0$, $k_H = 1.1$)

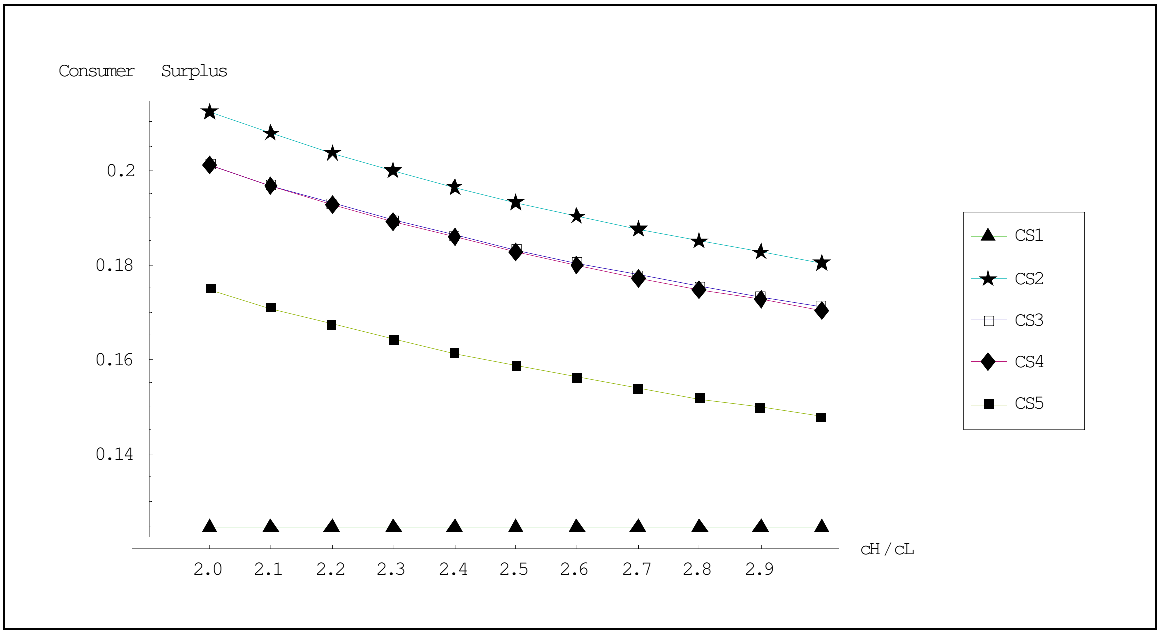


Figure 14: *Real* consumer surplus ($\Theta = 0$, $k_H = 1.1$)

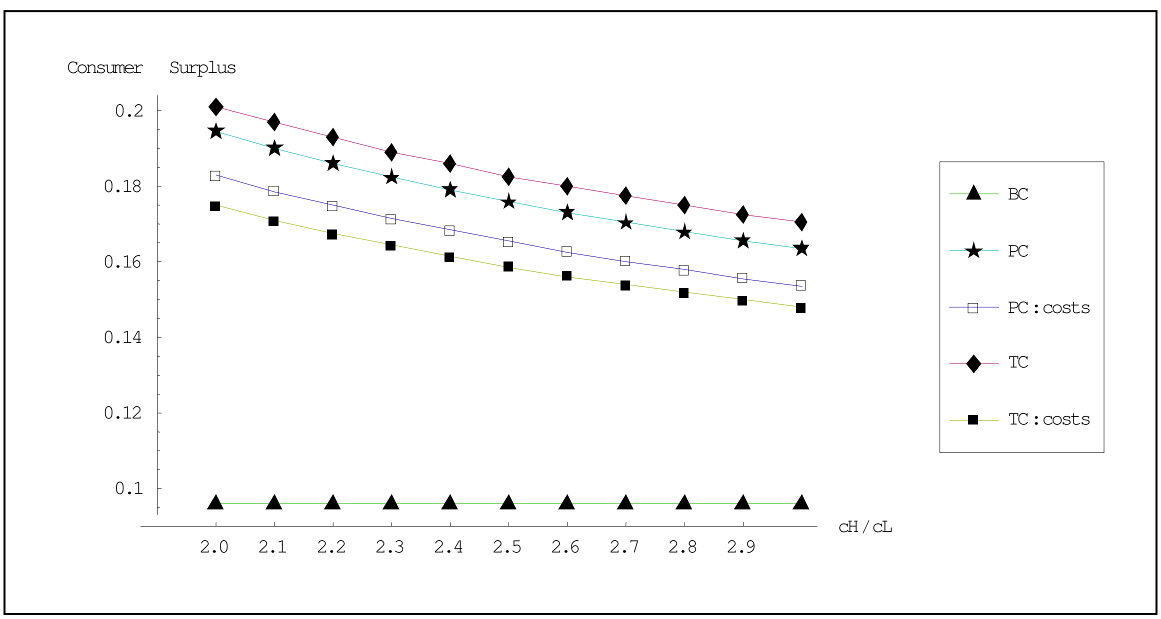


Figure 15: Expected consumer surplus ($\Theta = 0$, $c_H = 4$)

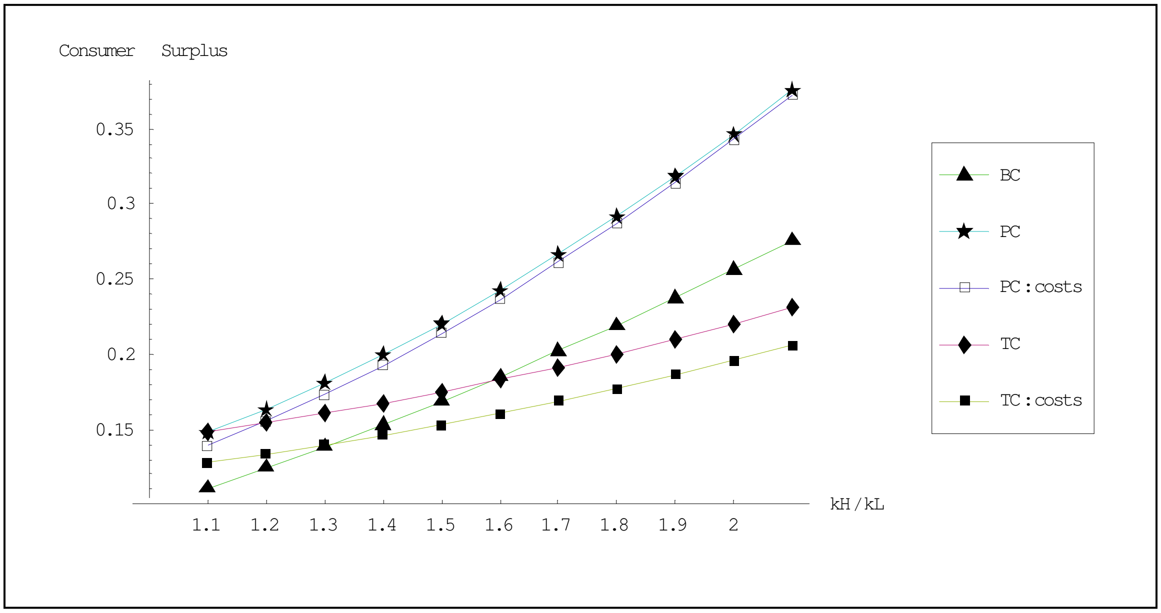


Figure 16: *Real* consumer surplus ($\Theta = 0$, $c_H = 4$)

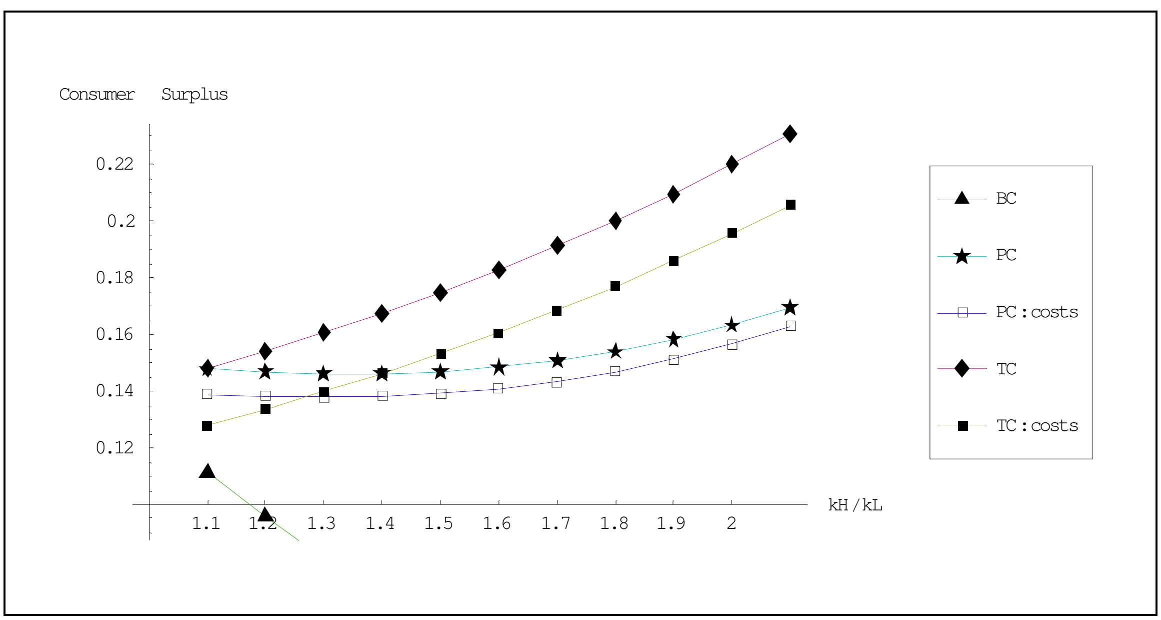


Figure 17: Expected consumer surplus ($\Theta = 0.5$, $k_H = 1.1$)

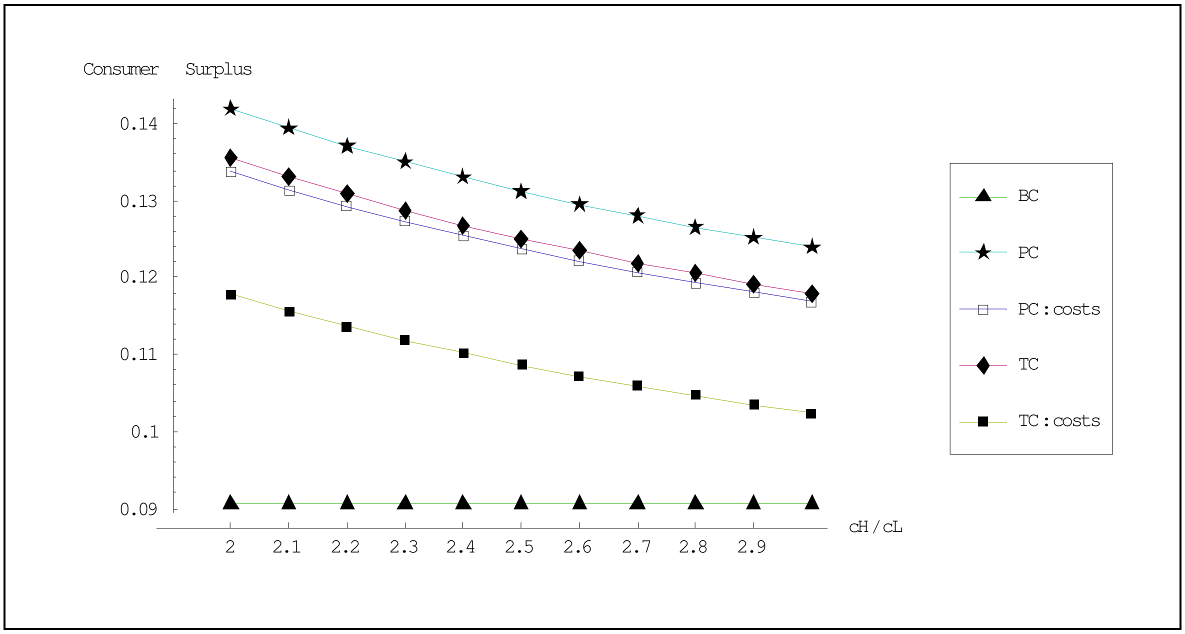


Figure 18: *Real* consumer surplus ($\Theta = 0.5$, $k_H = 1.1$)

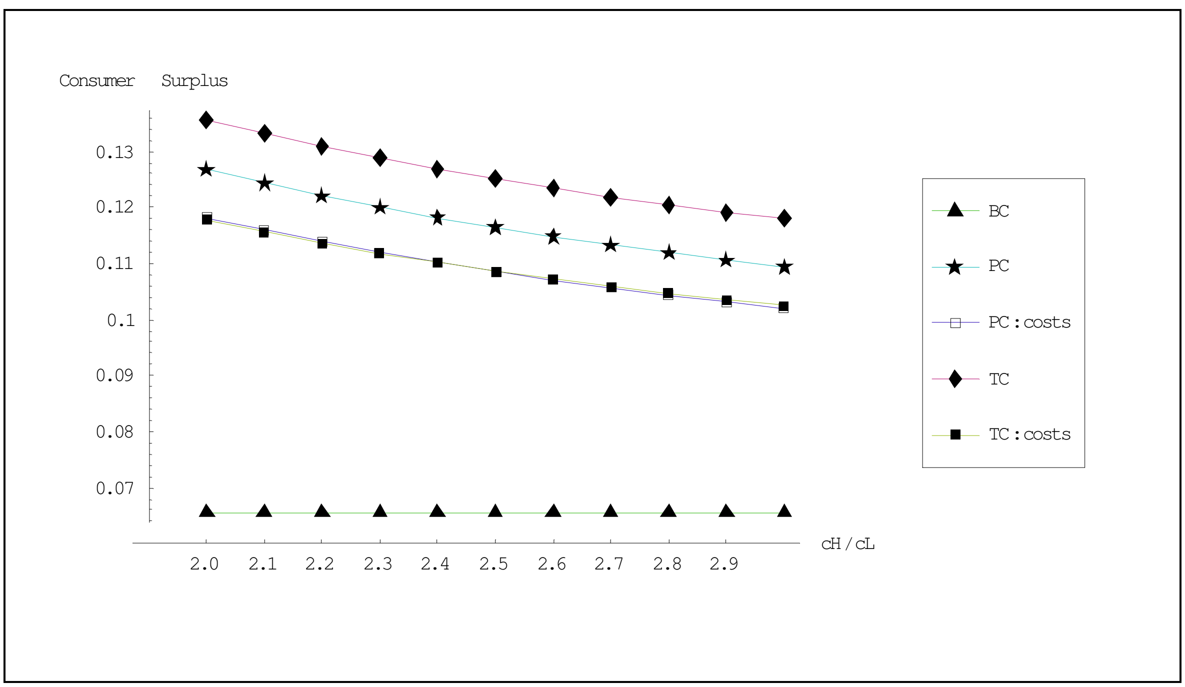


Figure 19: Expected consumer surplus ($\Theta = 0.5$, $c_H = 4$ **)**

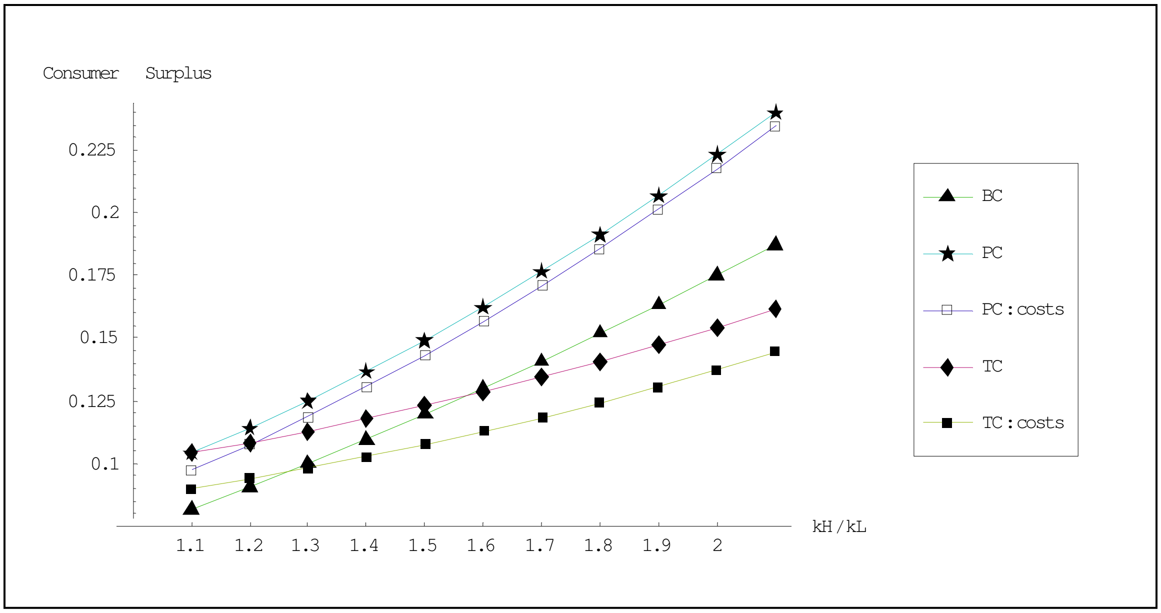


Figure 20*: Real* consumer surplus ($\Theta = 0.5$, $c_H = 4$ **)**

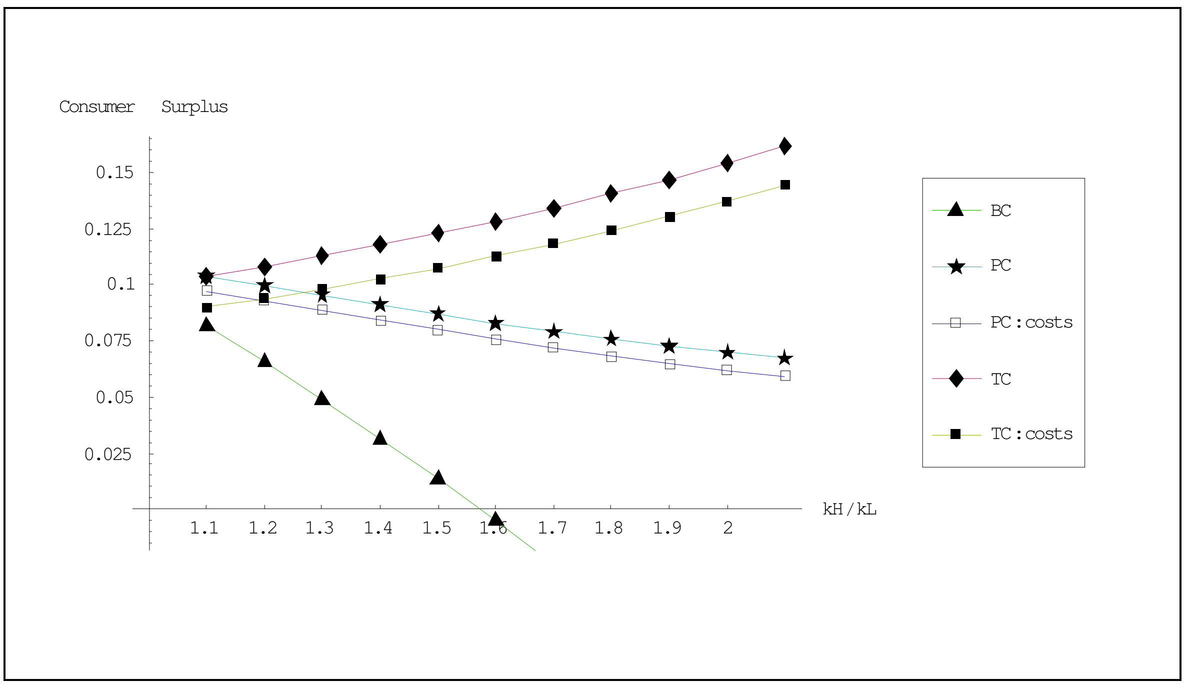


Figure 21: Diversion percentage ($k_H = 1.1$, $c_H = 4$)

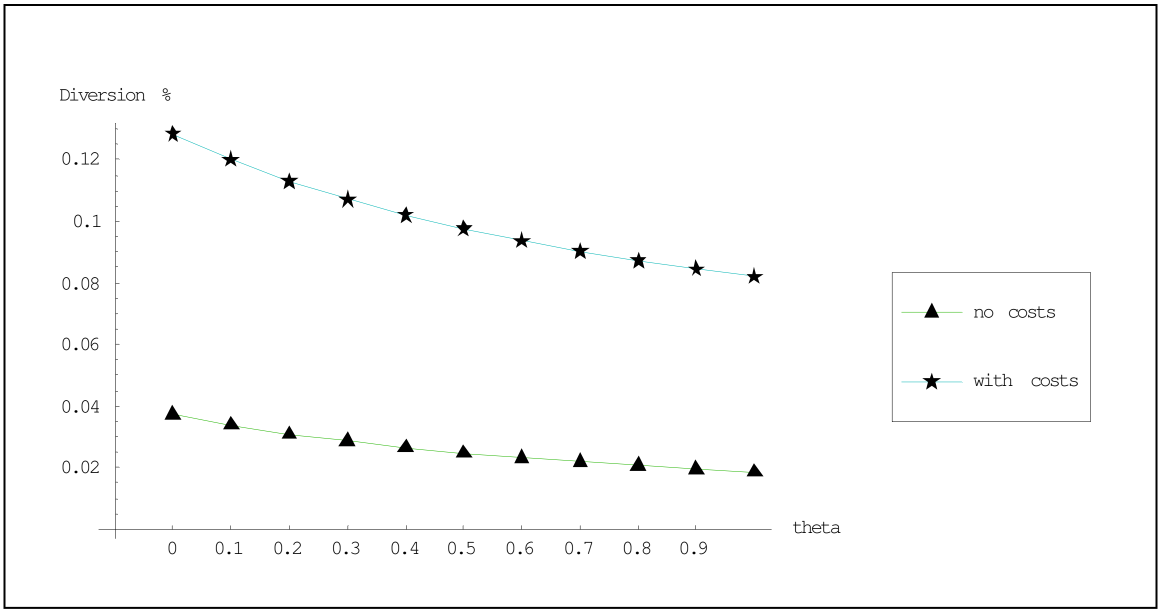


Figure 22: Expected consumer surplus ($k_H = 1.1$, $c_H = 4$)

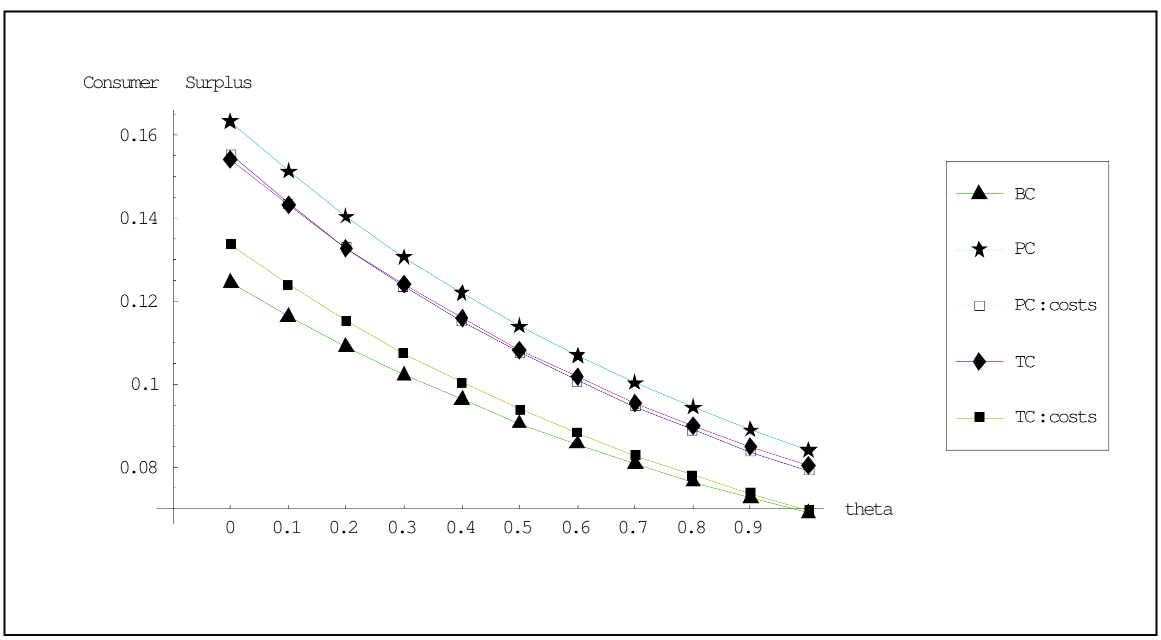


Figure 23: *Real* consumer surplus ($k_H = 1.1$, $c_H = 4$)

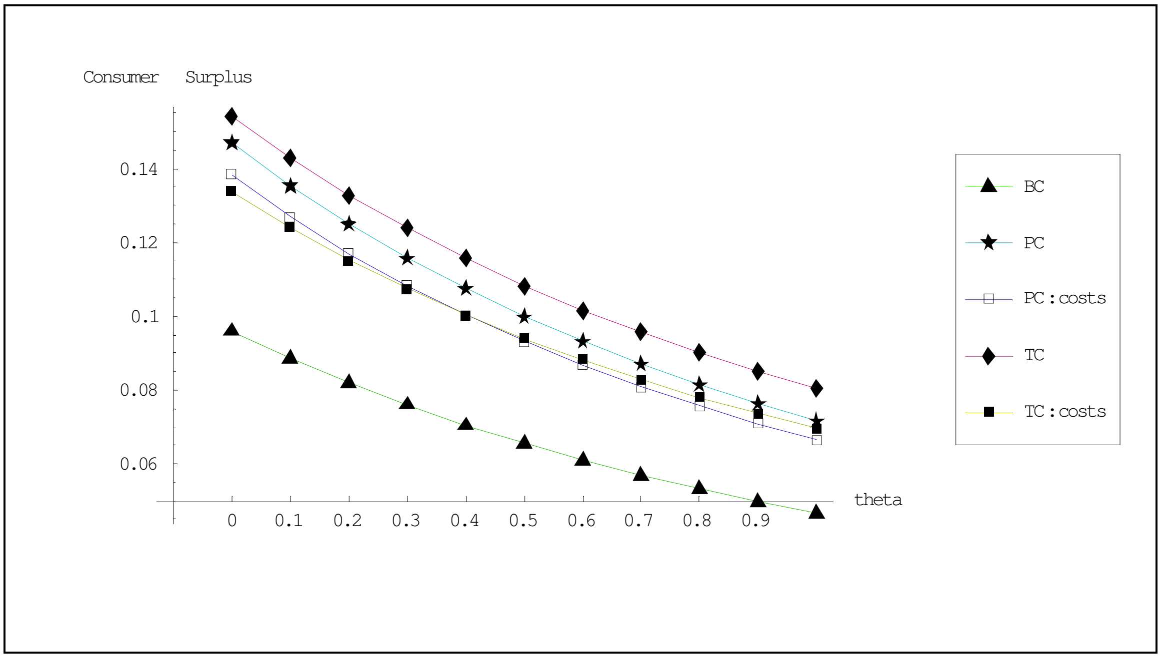


Figure 24: Profit ($\Theta = 0.5$, $k_H = 1.1$)

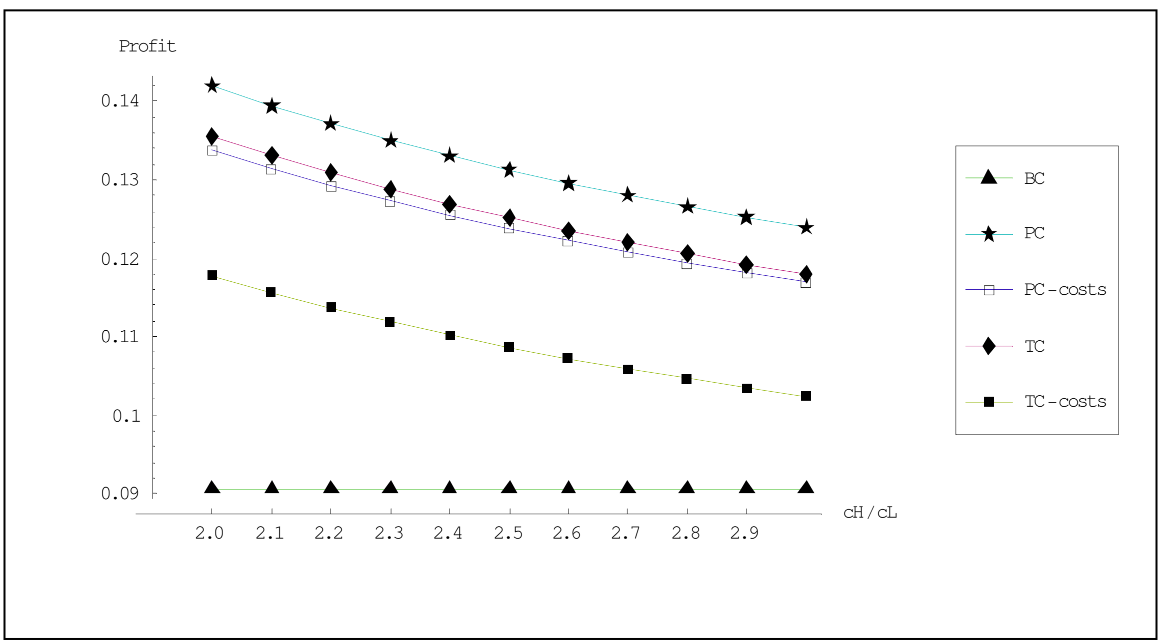


Figure 25: Profit ($\Theta = 0.5$, $c_H = 4$)

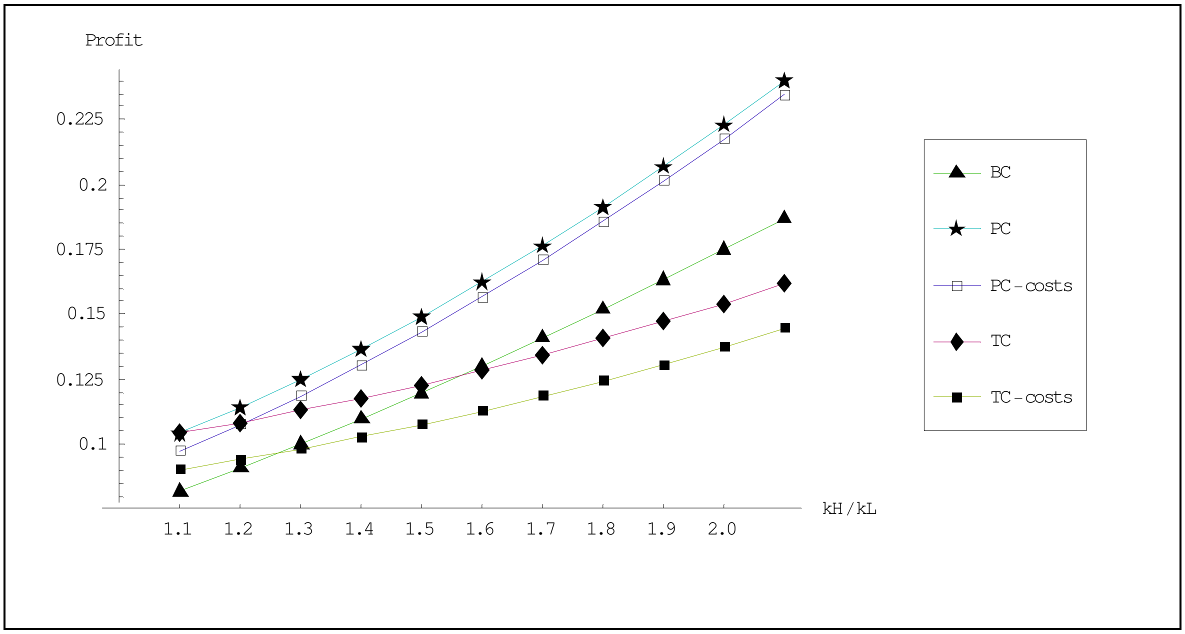
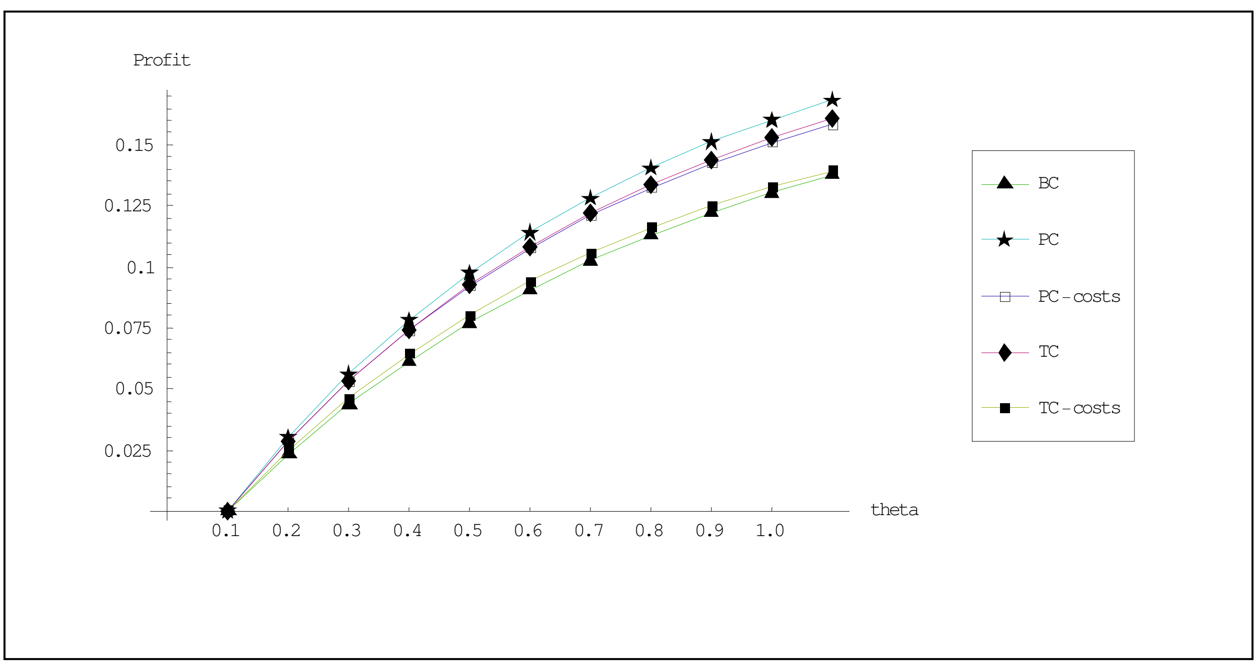


Figure 26: Profit ($k_H = 1.1$, $c_H = 4$)



APPENDIX I

Equilibrium prices and quantities:

1. Partial implementation of COOL

a. With no costs of implementation (27)

$$w_H^k = \frac{2c_H\left(\bar{k}\Delta k(k_L\lambda + c_L) + 2k_H k_L c_L\right)}{\omega},$$

$$w_L^k = \frac{2\bar{k}k_L c_L(\Delta k\lambda + 2c_H)}{\omega},$$

$$Q_H^k = \frac{\Delta k k_L\lambda + 2k_H c_L}{\omega},$$

$$Q_L^k = \frac{2\bar{k}k_L c_H\lambda - c_L\left(2\bar{k}k_H\lambda + \Delta k c_H\right)}{\omega\lambda},$$

$$Q_f^k = \frac{2\bar{k}\omega - \left(4\bar{k}k_L c_L(\Delta k\lambda + 2c_H)\right)}{2\bar{k}\omega\lambda}$$

$$p_H^k = \frac{\begin{pmatrix} k_H\Theta(\Delta k\lambda + c_H)\left(2\bar{k}(k_L\lambda + c_L) + k_L c_L\right) + \\ k_H k_L c_L\left(\Theta(2k_H\lambda + c_H) + 4c_H\right) + 2\bar{k}\Delta k c_H(k_L\lambda + c_L)\end{pmatrix}}{\omega\lambda},$$

$$p_L^k = \frac{k_L\begin{pmatrix} \lambda\left(2\bar{k}\Delta k\lambda(k_L\Theta + c_L) + k_L c_L\Theta(2k_H + \Delta k)\right) + \\ 2c_H\left(\bar{k}\Theta(k_L\lambda + c_L) + c_L\left(k_L\Theta + 2\bar{k}\right)\right)\end{pmatrix}}{\omega\lambda},$$

$$\bar{p}^k = \frac{2\bar{k}\omega\lambda - \left(2\bar{k}\omega - \left(4\bar{k}k_L c_L(\Delta k\lambda + 2c_H)\right)\right)}{2\omega\lambda},$$

$$\omega = 2\left[\bar{k}c_L(k_H\lambda + c_H) + k_L\left(\bar{k}\lambda + c_L\right)(\Delta k\lambda + c_H)\right]$$

$$CS^{AC} = \frac{\begin{matrix} k_L\left[k_H c_L\left(2\bar{k}\lambda + c_H\right) - k_L c_H\left(2\bar{k}\lambda + c_L\right)\right]^2 + \\ \bar{k}\left[2\bar{k}k_L\lambda(\Delta k\lambda + c_H) + c_L\left(2\bar{k}k_H\lambda + \Delta k c_H\right)\right]^2 + \\ 4\lambda\left[\bar{k}\Delta k(k_L\lambda + c_L) + 2k_H k_L c_L\right] \\ \left[\bar{k}k_H\Delta k\lambda(k_L\lambda + c_L) + k_L\Delta k c_L(k_H\lambda - c_H) + 2\bar{k}k_L^2 c_H\lambda\right]\end{matrix}}{2\lambda^2\omega^2} \tag{29}$$

$$CS_{freal}^{AC} = \frac{\begin{matrix} -\left[2\bar{k}\lambda(\Delta k\lambda + c_H) + c_L\left(2\bar{k}k_H\lambda + \Delta k c_H\right)\right] \\ \begin{bmatrix} \lambda c_L\left(k_L\left(k_H^2 - 5k_H k_L + 2k_L^2\right) + \Delta k\Theta\left(k_H^2 + 3k_H k_L - 2k_L^2\right)\right) + \\ \Delta k c_H c_L(k_H\Theta + 3k_L\lambda) + 2\bar{k}k_L\lambda(\Delta k + c_H)(\Delta k\Theta - k_L)\end{bmatrix}\end{matrix}}{2\lambda^2\omega^2} \tag{30}$$

$$CS_{real}^{AC}=\frac{\begin{array}{l}k_L\left[2\bar{k}k_Hc_L\lambda+c_H\left(\Delta kc_L-2\bar{k}k_L\lambda\right)\right]^2+\\4\lambda\left[\bar{k}\Delta k\left(k_L\lambda+c_L\right)+2k_Hk_Lc_L\right]\\\left[2\bar{k}k_L^2c_H\lambda+\bar{k}k_H\Delta k\lambda\left(k_L\lambda+c_L\right)+\Delta kk_Lc_L\left(k_H\lambda-c_H\right)\right]\\-\left[2\bar{k}\lambda\left(\Delta k\lambda+c_H\right)+c_L\left(2\bar{k}k_H\lambda+\Delta kc_H\right)\right]\\\left[\begin{array}{l}\lambda c_L\left(2\bar{k}k_H^2\Theta-5k_Hk_L^2\lambda+k_L\lambda\left(k_H^2+2k_L^2\right)\right)+\Delta kc_Hc_L\left(k_H\Theta+3k_L\lambda\right)+\\2\bar{k}k_L\lambda\left(\Delta k\lambda+c_H\right)\left(k_H\Theta-k_L\lambda\right)\end{array}\right]\end{array}}{2\lambda^2\omega^2} \quad (31)$$

b. With costs of implementation (36)

$$w_H^k=\frac{\left(c_H+y\right)\left(2\bar{k}\Delta k\left(k_L\lambda+c_L\right)+2c_L\left(2k_Hk_L-\bar{k}b\right)\right)}{\sigma},$$

$$w_L^k=\frac{2\bar{k}c_L\left(\Delta k\lambda\left(k_L-b\right)+\left(c_H+y\right)\left(2k_L-b\right)\right)}{\sigma},$$

$$Q_H^k=\frac{2\bar{k}\Delta k\left(k_L\lambda+c_L\right)+2c_L\left(2k_Hk_L-\bar{k}b\right)}{\sigma},$$

$$Q_L^k=\frac{\left(c_H+y\right)\left(2\bar{k}\lambda\left(k_L-b\right)-c_L\left(\Delta k+2b\right)\right)-2\lambda\left(\bar{k}k_Hc_L+b\Delta k\left(\bar{k}\lambda+c_L\right)\right)}{\sigma\lambda},$$

$$Q_f^k=\frac{2\bar{k}\sigma-\left(4\bar{k}c_L\left(2k_L-b\right)\left(c_H+y\right)+\Delta k\lambda\left(k_L-b\right)\right)}{2\bar{k}\sigma\lambda}$$

$$p_H^k=\frac{\begin{array}{l}\lambda\left(k_H\Theta+b\right)\left(2\bar{k}\Delta k\left(k_L\lambda+c_L\right)+k_Lc_L\left(\Delta k+2k_H\right)\right)+\\2\left(c_H+y\right)\left(\bar{k}\left(k_L\lambda+c_L\right)\left(k_H\Theta+\Delta k\right)+bk_L\left(\bar{k}\lambda+c_L\right)+k_Hk_Lc_L\left(\lambda+1\right)\right)\end{array}}{\sigma\lambda},$$

$$p_L^k=\frac{k_L\left(\begin{array}{l}2\left(c_H+y\right)\left(\bar{k}c_L\left(\lambda+1\right)+\left(k_L\Theta+b\right)\left(\bar{k}\lambda+c_L\right)\right)+\\\lambda\left(2\bar{k}\Delta k\lambda\left(k_L\Theta+b+c_L\right)+c_L\left(2k_H+\Delta k\right)\left(k_L\Theta+b\right)\right)\end{array}\right)}{\sigma\lambda},$$

$$\bar{p}^k=\frac{2\bar{k}\sigma\lambda-\left(2\bar{k}\sigma-\left(4\bar{k}c_L\left(2k_L-b\right)\left(c_H+y\right)+\Delta k\lambda\left(k_L-b\right)\right)\right)}{2\sigma\lambda},$$

$$\sigma=2\left[\bar{k}k_L\Delta k\lambda^2+\left(c_H+y\right)\left(\bar{k}k_L\lambda+c_L\left(\bar{k}+k_L\right)\right)+c_L\lambda\left(\bar{k}k_H+\Delta kk_L\right)\right]$$

$$
CS^{AC} = \frac{\begin{array}{l} \bar{k}\left[2\lambda\left(\Delta k\left(\bar{k}k_L\lambda + bc_L\right) + \bar{k}k_H c_L\right) + (c_H + y)\left(2\bar{k}k_L\lambda + c_L(2b+\Delta k)\right)\right]^2 + \\ k_L\left[2\lambda\left(\Delta kb\left(\bar{k}\lambda + c_L\right) + \bar{k}k_H c_L\right) + (c_H + y)\left(2b\left(\bar{k}\lambda + c_L\right) + \Delta kc_L - 2\bar{k}k_L\lambda\right)\right]^2 + \\ 4\lambda\left[\bar{k}\Delta k(k_L\lambda + c_L) + c_L\left(2k_H k_L - \bar{k}b\right)\right] \\ \left[\begin{array}{l} k_H\Delta k\lambda\left(\bar{k}k_L\lambda + \left(\bar{k} + k_L\right)c_L\right) + k_L(c_H + y)\left(2\bar{k}k_L\lambda - c_L\Delta k\right) - \\ b\left(\lambda\left(2\bar{k}k_L\Delta k\lambda + c_L\left(2k_L\Delta k + \bar{k}k_H\right)\right) + 2k_L(c_H + y)\left(\bar{k}\lambda + c_L\right)\right) \end{array}\right] \end{array}}{2\lambda^2\sigma^2} \tag{37}
$$

$$
CS^{AC}_{real} = \frac{1}{2}\left[\begin{array}{l} \dfrac{k_L\left(2\lambda\left(c_L\left(\bar{k}k_H + b\Delta k\right) + b\bar{k}\Delta k\lambda\right) + (c_H + y)\left(c_L(\Delta k + 2b) - 2\bar{k}\lambda(k_L - b)\right)\right)^2}{\lambda^2\sigma^2} + \\ \dfrac{\begin{array}{l} 2\left(\bar{k}(\Delta kk_L\lambda + bc_L) - c_L\left(\bar{k}\Delta k + 2k_H k_L\right)\right) \\ \left(\begin{array}{l} 2k_L(c_H + y)\left(\Delta kc_L - 2\bar{k}\lambda(k_L - b)\right) - 2\Delta kk_H\lambda\left(\bar{k}k_L\lambda + c_L\left(\bar{k} + k_L\right)\right) + \\ 4k_L b\left(c_L\left(c_H\lambda + y + k_H^2 + 5k_H k_L - 4k_L^2\right) + \bar{k}\Delta k\lambda^2\right) \end{array}\right) \end{array}}{\lambda\sigma^2} - \\ \dfrac{1}{\lambda}\left[\left(2\bar{k} - \dfrac{\Phi}{\sigma}\right)\left(\dfrac{2\bar{k}\lambda - \left(2\bar{k} - \dfrac{\Phi}{\sigma}\right)}{2\bar{k}\lambda}\right)\right] + 2k_L\left(\dfrac{1}{2} - \dfrac{1}{2}\left[\dfrac{-2\bar{k}\lambda + \left(2\bar{k} - \dfrac{\Phi}{\sigma}\right)}{2\bar{k}\lambda}\right]^2\right) \end{array}\right] \tag{38}
$$

$$
\Phi = 4\bar{k}c_L\left[(c_H + y)(2k_L - b) + \Delta k\lambda(k_L - b)\right]
$$

2. Total Implementation

a. With no costs of implementation (42)

$$
w_H^k = \frac{2c_H(\Delta kk_L\lambda + 2k_H c_L)}{\varpi},
$$

$$
w_L^k = \frac{4k_L c_L c_H}{\varpi},
$$

$$
Q_{Hl}^k = \frac{\Delta kk_L\lambda + 2k_H c_L}{\varpi},
$$

$$
Q_{Ll}^k = \frac{2k_L c_H}{\varpi},
$$

$$
p_H^k = \frac{4k_H c_L\left(\bar{k}\Theta + c_H\right) + \Delta kk_L(k_H\lambda\Theta + 2c_H)}{\varpi},
$$

$$
p_L^k = \frac{k_L\left((\Delta kk_L\lambda + 2k_H c_L)\Theta + 2c_H(k_L\Theta + 2c_L)\right)}{\varpi},
$$

$$
\varpi = \left[2c_H(k_L\lambda + 2c_L) + \lambda(\Delta kk_L\lambda + 2k_H c_L)\right]
$$

$$CS^{\overline{AC}} = \frac{\left(\Delta k k_L \lambda + 2k_H c_L\right)\left(k_H\left(\Delta k k_L \lambda + 2k_H c_L\right) + 4k_L^2 c_H\right) + 4k_L^3 c_H^2}{\varpi^2} \quad (44)$$

b. With costs of implementation (48)

$$w_H^k = \frac{2(c_H + y)\left[\Delta k k_L \lambda + 2c_L(k_H - b)\right]}{\mu},$$
$$w_L^k = \frac{2c_L\left[2(k_L - b)(c_H + y) - b\Delta k \lambda\right]}{\mu},$$
$$Q_{Hl}^k = \frac{\Delta k k_L \lambda + 2c_L(k_H - b)}{\mu},$$
$$Q_{Ll}^k = \frac{2(k_L - b)(c_H + y) - b\Delta k \lambda}{\mu},$$
$$p_H^k = \frac{2(c_H + y)\left(k_L\left(k_H \Theta + \Delta k + b\right) + 2k_H c_L\right) + \left(k_L \Delta k \lambda + 2k_H c_L\right)\left(k_H \Theta + b\right)}{\mu},$$
$$p_L^k = \frac{k_L\left[2(c_H + y)(k_L \Theta + 2c_L + b) + 2c_L(k_H \Theta + b) + \Delta k \lambda (k_L \Theta + b)\right]}{\mu},$$
$$\mu = \left[2(k_L \lambda + 2c_L)(c_H + y) + \lambda\left(\Delta k k_L \lambda + 2k_H c_L\right)\right]$$

$$CS^{\overline{AC}} = \frac{\begin{array}{c} k_L\left[b\Delta k \lambda - 2(c_H + y)(k_L - b)\right]^2 + \left[k_L \Delta k \lambda + 2c_L(k_H - b)\right] \\ \left[k_L \Delta k \lambda (k_H - 2b) + 2k_H c_L (k_H - b) + 4k_L (c_H + y)(k_L - b)\right] \end{array}}{\mu^2} \quad (49)$$