The Economics and Potential Protectionism of Food Safety Standards and Inspections. An Application to the U.S. Shrimp Market

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Abstract: We formally investigate the effects of a food inspection system influencing food safety of foreign and domestic food products in the domestic market. Consumers purchase domestic and imported food and value food safety. Potential protectionism à la Fisher and Serra can arise: inspection frequency imposed on foreign producers set by a domestic social planner would be higher than the corresponding policy set by a global social planner treating all producers as domestic. The domestic social planner tends to impose most if not all of the inspection on foreign producers, which improves food safety for consumers and limits the production loss for domestic producers. Despite this protectionist component, inspections address a potential consumption externality such as health hazard in the domestic country when unsafe food can enter the country undetected. We then calibrate the analytical framework to the U.S. shrimp market incorporating key stylized facts of this market. Identifying protectionist inspection requires much information on inspection, safety, damages and costs. We also investigate how to finance the inspection policy from a social-planner perspective. Financing instruments differ between the domestic and international welfare-maximizing objectives.

Keywords: Food safety, standard, inspection, nontariff barriers, HACCP, seafood, shrimp, protectionism.

JEL code: Q17, Q18, Q22, F14

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Introduction

This paper formally explores the potential protectionism and effects of an inspection system to enforce a domestic food safety standard on domestic and foreign producers. The paper delineates the role of inspection as discriminatory trade barrier through foreign producers' difficulties to enter a market but also their legitimate role to internalize potential external effects from risk of illness.

Food safety regulations are a contentious issue in the context of North-South trade with contrasting views on safety regulations either as a barrier (Henson and Loader, 2001; Otsuki et al., 2001a and b; Wilson and Otsuki, 2004) or catalyst driven by consumer concerns (Anders and Caswell, 2009; Jaffee and Henson, 2005). Most of these analyses have focused on standards rather than inspections. Inspections turn standards into implemented standards and determine the effective quality available on the market. Different inspection levels at the border and in domestic plants allow to effectively discriminate between foreign and domestic food producers and to impose differentiated implemented standard via different inspection rates even though the "official" uniform food standard applies to all producers. We focus on the economics of these inspections and analyze their role in trade as protectionist barrier but also as a way to internalize external health effects on consumers. Identifying protectionist inspections is more daunting than one would presume in presence of asymmetric safety levels between foreign and domestic firms.

We assume that a social planner chooses an optimum inspection level to enforce food safety that maximizes domestic welfare (surplus of consumers and domestic producers net of potential health externalities). The standard itself is assumed to have been fixed at a safe level, that is, at which no sickness or negative external effect occurs. Potential protectionism à la Fisher and Serra arises: inspection frequency imposed on foreign producers set by a domestic social planner would be higher than the corresponding policies set by a global planner treating all producers as domestic.

The domestic social planner tends to impose the total or a large part of the inspection on foreign producers to shift cost abroad. Food safety improves (especially for imported food), and domestic producers' losses are limited. Despite this protectionist component, the inspection addresses a consumption externality such as health hazard in the domestic country when unsafe food can enter the country undetected.

The paper then applies the conceptual framework to the U.S. seafood market and more specifically to shrimp. The United States is a significant producer and importer of seafood products. Seafood imports are seldom inspected at the border, raising the issue of unsafe food being imported. Cases of contaminated and unsafe seafood imports have been reported despite extensive food safety standards in existence (Southern Shrimp Alliance, 2007; U.S. Government Accountability Office – GAO, 2001, 2004, and 2009). When inspections occur, they often reveal imported products failing U.S. food safety standards (GAO, 2001 and 2004). Safety problems also affect domestic production, where many products are not processed following existing food safety regulation (GAO, 2001 and 2004). Hence, our set-up and approach fully apply to the U.S. seafood market with its safety standards and inspections at the border and in domestic plants.

Using recent econometric estimates of consumer and producer price responses, cost of production data, and information on the cost of meeting food safety standards for seafood exporting countries, we calibrate a partial equilibrium model of the U.S. shrimp market including imports to derive the socially optimum inspection levels conditioned on a food safety standard. Consumers in the United States and other advanced countries have repeatedly expressed their willingness to pay for better and safer seafood products in the market place and in laboratory experiments. We show that even though the optimal policy is protectionist (as defined in the previous paragraph), it is optimal for an importing country to impose differential implemented standards via tighter inspections on foreign producers.

We also determine the optimum way to finance the inspection policy from a social-planner's perspective. Financing instruments are different under the domestic welfare-maximizing objective as opposed to the case of the international welfare- maximizing objective inclusive of foreign profits.

Related Literature

The results of this paper differ from the previous literature on standards and protectionism (Fisher and Serra 2000; Marette and Beghin, 2010) by focusing on inspections to implement discriminatory effective standards, rather than the standard itself. We also depart from the existing literature on borders inspection, by providing a complete welfare analysis with both conceptual and empirical contributions. From an empirical point of view, the results of this study contribute to the literature on food safety inspection by providing a complete welfare analysis with calibrated estimations. Previous papers by Mayer et al. (2004), Starbird (2005, 2007) and Starbird and Amanor-Boadu (2006) restricted their analyses to the supply chain organization and the determination of inspection policy without explicitly considering consumers' welfare.

In addition, our results extend the literature on how to finance inspections to an open-economy context. In particular, Crespi and Marette (2001) study different types of financing instruments without considering trade issues with foreign producers. We show the consequences of considering foreign welfare rather than just domestic welfare on financing options.

Regarding the shrimp market, our approach differs from previous seafood studies which focus only on the *ex post* evaluation of past measures and imports (Cato and Lima dos Santos, 1998; Debaere, 2005; Anders and Caswell, 2009, among others). Our analysis evaluates future potential, i.e., *ex ante*, policy with a simulation integrating welfare measure, market imperfections, and consumers' valuation of food safety attributes, which can assist decision makers and inform the public policy debate. Our analysis follows the approach proposed by van Tongeren et al. (2009) but with the added focus on inspection rather than the standard itself.

Among the *ex post* analyzes of food safety issues with seafood imports, Anders and Caswell (2009) evaluate the trade impact of the 1997 Hazard Analysis and Critical Control Point regulation (HACCP) on U.S. Seafood imports. They use a gravity model and panel data for 1990-2004 and 33 seafood exporters. Results show a negative and significant effect of the HACCP's introduction on aggregate U.S. seafood imports but with a composition effect penalizing developing countries' products and favouring developed countries' exports. Further, country-level analysis shows that the introduction of HACCP had a positive impact on exports of larger seafood exporters and a negative one on exports of small exporters, independently of the development level of a country. A similar gravity equation investigation of French seafood imports by Peridy, Guillotreau, and Bernard (2000) shows a significantly small impact (elasticity of −0.092) of trade barriers on aggregate seafood imports for the period 1988-1994.

Cato and Lima dos Santos (1998) suggest that the 1997 EU ban on shrimp imports originating from Bangladesh pushed the same shrimps to be exported to Japan and the United States, raising the issue of differential standards and inspection levels across importing countries. More recently, Nguyen and Wilson (2009) estimate a panel gravity model on U.S., European, and Japanese imports of seafood products using disaggregated seafood data and a theoretically consistent gravity model controlling for multilateral resistance. The trade impact of food safety standards is negative and significant but differentiated across seafood products. Shrimps appear to be the most sensitive to changing food safety policies, while fish is the least sensitive.

Using data on shrimp trade Debaere (2005) empirically investigates the effect of trade policy on international prices and on countries' welfare. He shows that EU trade policy (especially strict standards on antibiotic residues compared to the ones applied by the United States) significantly impacted the world shrimp market and shifted exports away from Europe towards the United States in the late 1990s and early 2000s with the added consequence of depressing U.S. prices for shrimp.

Hudson et al. (2003) investigate ex-ante the effects of a potential ban on shrimp imports by the United States from countries non-complying with the Turtle Excluder Device system. They estimate a linear expenditure system to obtain the own-price elasticity of demand for shrimp imports. They find that such a ban will generate a welfare loss for U.S. consumers. The magnitude of the effect will depend on whether lost imports from banned countries are reallocated to other countries.

Alberini et al. (2008) propose a theoretical model of enforcement and compliance in a regulatory environment similar to the one created by HACCP in the seafood industry. Predictions on optimal Food and Drug Administration (FDA) monitoring strategy and firms' compliance efforts are derived. Using FDA seafood inspection data, the authors show that, contrary to the predictions of the model, FDA inspections are based on product risk but not on past compliance. On the other hand, firms' compliance efforts do not increase with the threat of an inspection.

Disdier and Marette (2010) combine the results of a gravity equation with a partial equilibrium model to determine the welfare impact of a standard. They estimate the effect of a standard capping residues of chloramphenicol, a toxic antibiotic. Their empirical analysis of crustacean imports in the United States, European Union, Canada and Japan suggests that both trade and welfare effects do not necessarily go in the same direction. However, they do not investigate the issue of inspections.

Background on seafood inspection by the FDA

Food safety in many advanced countries, including the United States, is implemented through HACCP, a preventive approach to food safety. This systematic preventive approach imposes food safety standards at critical junctures of food processing susceptible of contamination and health hazards to reduce health risk. The standard enforcement and the suppliers' compliance directly depend on the inspection policy.

The U.S. HACCP program for seafood is managed by the U.S. Food and Drug Administration (FDA). The FDA is supposed to inspect plants and products to make sure that they meet health standards included in and implied by the HACCP system. HACCP was initiated in 1997. The program has been repeatedly criticized as insufficient (GAO, 2001 and 2004). Several papers analyze FDA's seafood inspections, detentions and refusal decisions for products not meeting standards (Ababouch et al., 2005; Allshouse et al., 2003; Buzby et al., 2008). Allshouse et al. (2003) provide the most detailed description. There are two types of detentions: "Regular" detentions of shipments for which physical analysis shows that FDA standards are violated, and detentions without physical analysis. The latter include automatic detentions based on past violations and detentions based on import alerts. The detention without physical analysis is based on past history and/or other information leading to the resumption that the product (and further shipments) may not meet standard. In this case, the shipper or importer should prove that the product satisfies FDA standards.

These investigations convey some key stylized facts. The FDA inspects only a small percentage of imports. Detentions occur seldom. On average, from 1999 to 2001, less than 1% of shipments were detained, and 78% of detained shipments were eventually released for import into the United States. Detentions for fishery/seafood represented 27% of total FDA import detentions (2nd behind vegetables). The major reasons for seafood detentions were (i) adulteration (safety, packaging, sanitary problems – 83.6% of violations), and (ii) misbranding (untruthful or missing labelling – 14.3% of violations). Among exporters, 80 out of 130 exporting countries had violations for adulteration. The number of detentions (for adulteration) per dollar of import value is low (0.46 detention per US$ 1 million of imports). The top three countries in terms of number of violations for adulteration in 2001 were Vietnam, Thailand, and Indonesia. Salmonella was the most common violation for adulteration (34% of the cases). Shrimp and prawns accounted for more than 25% of the detentions for adulteration.

Buzby et al. (2008) provide some statistics of U.S. import refusals from 1998 to 2004 using data from FDA Import Refusal Reports. They reach similar conclusions as the investigations of detention data did. More interestingly, Buzby et al. (2008) describe import alerts. Import alerts can be informational or can call for intensified surveillance of a particular food product from a particular exporter but can also place an exporter/product on detention without physical examination. Shipments are refused entry into the United States, unless the exporter provides evidence (such as test results) to the FDA that its product meets FDA standards. These facts suggest that import inspections and refusals are not a result of a random sampling of imports but rather of some kind of Bayesian process. The U.S. policy initially involves random sampling at the border. Importers with a previous nonconformity record are supposed to be classified into the Automatic Detention List, with their next five consecutive shipments subject to inspection. If requirements are satisfied by the 5 shipments, the importer is moved back to the random sampling list. In reality, inspections may not work as described above (Alberini et al., 2008; GAO, 2001 and 2004).

GAO (2001, 2004) found a myriad of problems with the HACCP program implemented since 1997 by the FDA. With imported products, the FDA does not have equivalence or compliance agreements with any exporting country. U.S. importers are required but not able to demonstrate that imported seafood is produced in accordance with the U.S. HACCP regulation.

When the FDA identifies problems in inspected foreign seafood firms it does not follow up with automatic detention and inspection of products. Few inspections take place: In 1999, less than 1% of imported seafood was subject to laboratory examination. Regarding domestic production, many seafood products are not processed under HACCP because the FDA cannot identify all seafood-processing firms (no registry exists); only the subset of the commercial fishing fleet processing fish on board is subject to HACCP requirements. Furthermore, the FDA does not know whether vessels process fish on board. About 1/3 of seafood products are not required to have a HACCP plan because seafood firms can determine, with FDA acquiescing, that food safety hazards are unlikely. When firms have a HACCP plan, more than half of FDA inspections found violations and the FDA did not issue warning letters in a timely manner. Finally, the FDA does not have objective data to assess the effectiveness of HACCP.

U.S. consumers have recently expressed concerns about FDA inspections. In a recent survey realised by Consumer Reports, two-thirds of respondents said “the FDA should inspect domestic and foreign food-processing facilities at least once a month, more in line with meat inspection practices by USDA” (Consumer Reports, 2008, p.1). While this fact clearly indicates a strong concern by U.S. consumers, no details are given about the willingness to pay (WTP) elicitation or the way to finance such an ambitious program able to satisfy U.S. consumers. This void explains why we pay attention to financing aspects.

Externality and health cost

The externality is twofold. First, there is health risk exposure associated with consuming unsafe food, which is not internalized or known by the consumers. A major concern in that regard is the presence of bacteria (such as salmonella, E-coli, or Listeria monocytogenes) and the widespread use of chemical products and antibiotics to address this sanitary problem. In developing countries, seafood producers often use chloramphenicol to fight against bacteria, which leads to traceable residues in consumer products. There is a well established link between aplastic anemia, carcinogenicity, reproductive toxicity, and exposure to chloramphenicol. The science has not established a threshold for low levels of exposure to chloramphenicol (Food and Agriculture Organization, 2004). The use of chloramphenicol mitigates unsafe production conditions in presence of salmonella, and E-coli among other bacteria but provides another risk of its own.

The second externality is the potential development of bacterial resistance to antibiotics associated with excessive use of antibiotics in seafood farms (Duran and Marshall, 2005). The link of chloramphenicol to antibiotic resistance is tedious (World Health Organization, 2001). Although the science is still being established, a precautionary principle would be legitimate.

Consumers have expressed their willingness to pay for safer food and avoid bacteria such as salmonella (Hayes et al., 1995). Roheim Wessells and Anderson (1995) undertake an experimental study to elicit the willingness to pay of Rhode-Island consumers for various seafood safety inspection and assurance programs using contingent valuation methods. Ten safety alternatives were considered. Respondents value specific information the most, such as date caught, catch site, and temperature since caught. The most valued characteristic was date caught valued at 47 cents above the price of US$ 4.5 per pound, roughly, a 10% premium. Inspections by retailers and processors were the least valued forms of assurance of seafood-safety. The authors also note the limited use of branding in seafood retailing and the lack of incentives to provide information for seafood harvesters. Holland and Roheim Wessells (1998) undertake a similar conjoint analysis for salmon. Strong preferences are elicited for USDA or FDA inspected products relative to non-inspected salmon. The willingness to pay for inspection is much stronger than for production method and price.

The health cost associated with seafood consumption is hard to pin down. The greater ignorance is on the number of seafood-borne illnesses. There is underreporting of cases and outbreaks, and consumers cannot attribute illness to a specific consumption. The lack of inspection and testing of seafood and long term impact of excessive residues of toxic substances and banned antibiotics contribute to the difficulty to estimate health cost. As noted before, FDA only inspects a small share of seafood import and detains about 2% of inspected seafood imports and actively tests a subset of these detained goods. Hence, less than 1% of seafood imports are formally tested (GAO, 2009; Allhouse et al., 2003). Domestically, the FDA does better but still relies extensively on self-reporting by seafood producers and processors and only inspects a fraction of domestic seafood output. HACCP is not applied evenly to the whole industry (e.g., fish processed at sea is often exempted).

Cost of HACCP implementation for foreign and domestic producers

The literature suggests that the implementation cost of food safety standards by foreign producers in developing countries, are initially high. While the fixed cost of doing so is high, the marginal cost of maintaining these standards is small. This marginal cost is even smaller for U.S. domestic seafood producers. Cato and Subasinge (2003) analyzed these costs in the shrimp industry in Bangladesh. The EU had banned shrimp imports from Bangladesh for sanitary reasons. The ban was costly, representing about US$ 15 million in lost revenues from August to December 1997. Some exports resumed in 1998. Bangladesh made significant investments in food safety via HACCP plans. By 1997 the Bangladesh shrimp industry had invested US$ 17.6 million in plant upgrades; its government had invested US$ 382,000 in laboratory and personnel upgrades and had received a small assistance from FAO (US$ 72,000) in training programs. The annual recurring costs to maintain HACCP programs and meet international standards would be about US$ 2.2 million for the industry and US$ 225,000 for the government.

Earlier, Cato and Lima dos Santos (2000) conducted a survey of 19 Bangladesh shrimp processing plants in 1998. The average investment per plant to be in compliance with minimum technical and sanitary standards was US$ 277,155. The annual invested amount to maintain a HACCP plan was US$ 34,875 per plant. The cost per kilogram for plant upgrades was US$ 0.7141 or 6.72% of the 1997 average price received. The marginal cost per kilogram to maintain a HACCP plan was between US$ 0.0327 and US$ 0.0899, representing between 0.31 and 0.85% of the 1997 average price received.

The same authors also report moderate investments by the Bangladesh government in laboratories and personnel to monitor HACCP in the shrimp plants of roughly US$ 200,000 per year since 1997. The total investments (industry, government and foreign institutions) to upgrade Bangladesh shrimp plants to meet minimum HACCP standards represented 9.4% of export sales for one year. The annual marginal cost to maintain the HACCP plan represents 1.26% of export sales per year. The Government's estimated that US$ 14.9 millions were needed to implement the highest levels of HACCP monitoring, which is several orders of magnitude larger than the previously cited figures.

The World Bank (2005) provides a review of the cost in the shrimp industry in Thailand to meet tightened standards on antibiotics (such as the zero tolerance ban applied by the European Union). The compliance costs to Thai shrimp farmers are reported as follows. The use of alternative chemicals increases the average cost of production of black tiger shrimp by 5.7% from the conventional chemical-supplemented shrimp farming method. By shifting to probiotic[1] farming, this cost will decrease by 33%. Moving on to compliance of shrimp processors, their costs would be much higher, at US$ 328 per ton.

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[1] Probiotic supplements are a microbial formulation that maintains water quality.

As highlighted by the World Bank (2005), the government of Thailand allocates a substantial budget to the shrimp industry. Between 1998 and 2002: 56% of the whole budget for fisheries was devoted to the shrimp industry or US$ 5.35 million in 1998 and US$ 0.73 million in 2002. The cost of laboratory services is not included in these figures and represents a bit less than US$ 10/ton of shrimp exports. The additional fixed costs to comply with EU requirements on drug residues amount to US$ 4,301,790. Finally, International Finance Cooperation (2006) provides numerous examples of programs for improving shrimp quality adopted by various countries but without cost estimations.

Cato (1998) has reviewed the available estimates on the cost of implementing and complying with HACCP in various U.S. fish and seafood industries. The cost, annualized typically represents less than 0.5 percent of the price received by producers and processors. The initial cost of implementing HACCP can be high for small plants, but overall the annualized cost is low, past the first year of implementation. For example, the annualized cost of HACCP for the U.S. shrimp processing industry was US$ 0.009 per pound, or about 0.3 percent of the price charged by processors with a pass-through to consumers of US$ 0.025 per pound. Similarly, HACCP cost estimates for U.S. blue crab plants hover around US$ 0.02 per pound, or 0.33 percent of processor price. For breaded products, added cost per pound of product for compliance was US$ 0.01 for small plants and US$ 0.0002 for large plants with no effects on consumer prices. Cost per pound of molluscan shellfish and other products produced were estimated at US$ 0.05 for small plants and US$ 0.003 for larger plants. Although it is difficult to find more recent estimates of the cost of HACCP, these older figures suggest that these costs were small and smaller than for compliance of a foreign producer.

A simple conceptual model

We consider a parsimonious framework to highlight the essence of forces at work and then to calibrate simulations. A representative foreign producer offers a proportion $0 \le \lambda_f \le 1$ of non-contaminated products meeting the safety standard and a proportion $(1-\lambda_f)$ of contaminated products failing the standard and entailing damage for the importing country.[2] Similarly, a representative domestic producer offers proportions of non-contaminated products meeting the standard and of contaminated products failing the standard and entailing consumer damage as described later.

A foreign producer has a probability γ_f of being inspected when its product reaches the border (the same analysis is developed with probability of being inspected for the domestic producer). When products are inspected, the inspection provides perfect information about the products' safety at a marginal inspection cost *H* for the importing country. The inspection procedure is not subject to diagnostic errors for simplicity.[3]

With probability $(1-\gamma_f)$ the foreign producer is not inspected. This producer is able to sell all products and to benefit from a per-unit price for the sold shrimps. A proportion of the products is non-contaminated, that is, there is no heath damage for the importing country. A proportion of the foreign products is contaminated and there is a per-unit external damage *e* for the consumer of the importing country. The proportion is exogenously given, which corresponds to a short-term situation for which producers cannot improve the safety of their products for reacting to an inspection policy. A similar assumption holds for domestic producers.

With probability γ_f, imported shrimps are inspected and a proportion of them passes the

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[2] The proportion λ_f could be interpreted as probability of having non-contaminated products and sell the products on the domestic market. It is assumed predetermined to the policy implementation. Making the proportion endogenous significantly complicates the computation of the optimum inspection rates without offering additional insight on the protectionist potential of the inspection policy under the domestic regulator.

[3] The inspection procedure could be subject to a diagnostic error (false positive test) in an extension.

standard test and the producer receives the same per-unit price p . The proportion fails the test and the producer loses this proportion of products. In this case, for simplicity we assume there is no way to sell and divest the rejected product elsewhere.[4] Other punishment schemes could be conceived. Foreign producers' profits are now briefly discussed.

For a foreign producer with output q_f , the cost function is $\frac{1}{2} c_f q_f^2 + k_f(\lambda_f) q_f + K_f(\lambda_f)$ where c_f is a variable cost parameter. $k_f(\lambda_f)$ and $K_f(\lambda_f)$ are respectively the marginal cost and the sunk cost linked to proportion λ_f of safe products. For a same proportion λ_f , these costs may differ from the respective domestic costs, $k_d(\lambda_f)$ and $K_d(\lambda_f)$, to express heterogeneous access to food safety technology and ease of implementation.

We assume that the price received by the foreign producer is parametric (price-taker). For a foreign producer the expected profit is

$$\pi_f(p,\lambda_f,\gamma_f) = \left[(1-\gamma_f)+\gamma_f\lambda_f\right] p q_f - \frac{1}{2} c_f q_f^2 - k_f(\lambda_f) q_f - K_f(\lambda_f). \tag{1}$$

Profit maximization yields individual firm supply functions before the inspection equal to

$$q_f^S(p,\lambda_f,\gamma_f) = \frac{[(1-\gamma_f)+\gamma_f\lambda_f]p - k_f(\lambda_f)}{c_f}. \tag{2}$$

By taking into account the probability of inspection and the proportion of safe products, the foreign supply effectively sold by the foreign producer (after the inspection) is

$$Q_f^S(p,\lambda_f,\gamma_f) = [(1-\gamma_f)+\gamma_f\lambda_f] q_f^S(p) = [(1-\gamma_f)+\gamma_f\lambda_f] \frac{[(1-\gamma_f)+\gamma_f\lambda_f]p - k_f(\lambda_f)}{c_f}. \tag{3}$$

Using a similar approach for domestic producers, we assume that their expected profit is

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[4] A drastic sanction is assumed in this paper, since a rejected shipment is not necessarily destroyed and could be used for animal feeding or redirecetd to other markets. It is also possible to consider less drastic sanctions as monetary penalties. However the lower monetary penalty, the higher is the number of inspections necessary for maintaining incentives. We plan to investigate this point in a subsequent revision. Fixing the optimal penalty is tricky since a large penalty may be non-operative when the penalty is higher the firms' profits and equity, leading to "judgment-proof firms".

$$\pi_d(p,\lambda_d,\gamma_d)=\left[(1-\gamma_d)+\gamma_d\lambda_d\right]pq_d-\tfrac{1}{2}c_dq_d^2-k_d(\lambda_d)q_d-K_d(\lambda_d), \tag{4}$$

where notations linked to subscript *d* have a similar interpretation to the one detailed for foreign producers. The domestic supply effectively sold by domestic producers (after the inspection) is

$$Q_d^S(p,\lambda_d,\gamma_d)=[(1-\gamma_d)+\gamma_d\lambda_d]\frac{[(1-\gamma_d)+\gamma_d\lambda_d]p-k_d(\lambda_d)}{c_d}. \tag{5}$$

The demand of a representative consumer is derived from a quasi-linear utility function that consists of quadratic preferences for the market good of interest and an additive numéraire:

$$U(q,v)=aq-Irq-bq^2/2+v\ , \tag{6}$$

where q is the consumer's consumption of shrimps and v is the numéraire. The terms $a,b>0$ allow capturing the immediate satisfaction of the consumer from consuming shrimps. The aversion linked to a disease is captured by the term $-Irq$. The parameter *I* represents the knowledge regarding the disease, the aversion brought by the bad shrimps is captured by the negative sign and by parameter *r,* the overall damage per unit consumed.

We assume that consumers are not aware of the specific characteristic, or *I*=0. This assumption can be relaxed with *I*>0, particularly with an intense press coverage or by the effect of the country-of-origin labeling (COOL) program that may lead to product differentiation based on the origin, when safety levels differ according to the origin.[5] The maximization of this utility under budget constraint (*v*+*pq*=*R*) leads to the demand $Q^d(p)=(a-p)/b$. The consumer surplus is then $U(Q^d(p),R-pQ^d(p))$.

The expected damage per unit of consumption *r* is not internalized by consumers and is defined as following. Recall that if foreign products are not inspected with a probability $(1-\gamma_f)$,

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[5] The COOL program is not always clearly identified by consumers. A causal observation at local grocery stores seems to confirm the little differentiation induced by COOL. Moreover, Lusk and Anderson (2004) show that consumers are made increasingly worse off with the program implementation. The imperfect substitution arising from COOL could be formalized with an Armington CES structure in demand.

contaminated foreign products enter the market in a proportion $(1-\lambda_f)$. Foreign supplies are inspected with a probability γ_f under which no contaminated products enter the market. With a per-unit damage *e,* the expected per unit damage linked to foreign products (after the inspection stage) is given by $r_f = \left[(1-\gamma_f)(1-\lambda_f)\right]e$ and the expected per unit damage linked to domestic products (after the inspection) is given by $r_d = \left[(1-\gamma_d)(1-\lambda_d)\right]e$. The expected damage per-sold unit is defined by $r = \left[r_f Q_f^S(p) + r_d Q_d^S(p)\right] / \left[Q_f^S(p) + Q_d^S(p)\right]$.

For a situation with given values of γ_d, γ_f, the equilibrium price clears the market by equalizing demand and overall supply leading to an equilibrium quantity Q_A. Figure 1 shows domestic demand (*D*), foreign supply (S_F) and the total supply (*S*) (the domestic supply is omitted for clarity in figure 1). The price, *p*, is located on the vertical axis and the quantity, *q*, is shown along the horizontal axis.

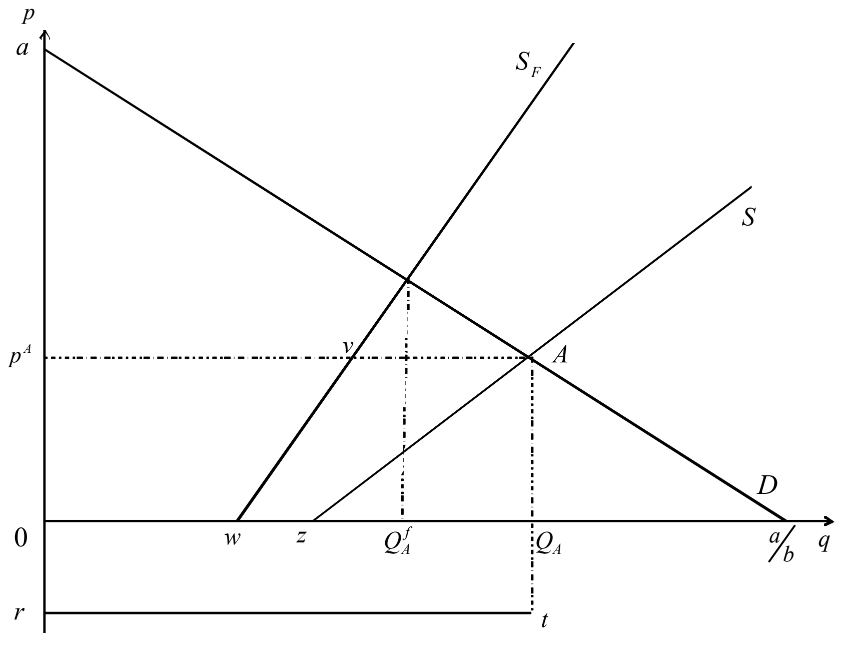


Figure 1. Market Equilibrium

In figure 1, Q_A^f is the foreign output and is domestic output. The gross profits correspond to area $Owvp^A$ for foreign producers (since sunk costs are zero) and area $wzAv$ for domestic producers. The usual surplus of domestic consumers corresponds to area p^AAa. The damage linked to contaminated products does not impact the demand since $I=0$. However, the cost of ignorance should be accounted for in the welfare calculations and is equal to represented by the area $0rtQ_A$. Domestic welfare is the sum of domestic profits, consumer surplus, cost of ignorance and overall cost of inspection. This welfare is given by area p^AvwzAa-$0rtQ_A$ when the cost of inspection is zero. International welfare is the sum of domestic welfare and foreign producer surplus and is given by area $0zAa$ -$0rtQ_A$ when the cost of inspection is zero. Analytical expressions for equilibrium values as well as for all the components of welfare are easy to compute and can be provided upon request. Reinforcing the inspection policy leads to a shift of supply functions to the left, since it reduces the possibility for dangerous products to enter the market. However, this reduces the expected per-unit damage r influencing the cost of ignorance. The regulatory choice balances the negative and positive marginal impacts of inspection policies on welfare.

With both domestic and foreign products having some probability of being inspected at a marginal cost H, the overall cost of inspection is $H[\gamma_d q_d^S(p,\lambda_d,\gamma_d)+\gamma_f q_f^S(p,\lambda_f,\gamma_f)]$. For an equilibrium price p^A, the domestic welfare is defined by

$$\begin{aligned} W_d(\gamma_d,\gamma_f) = {} & \pi_d(p^A,\lambda_d,\gamma_d)+U(Q^d(p^A),R-p^AQ^d(p^A))-Q_f^S(p^A)r_f-Q_d^S(p^A)r_d \\ & -H[\gamma_d q_d^S(p,\lambda_d,\gamma_d)+\gamma_f q_f^S(p,\lambda_f,\gamma_f)] \end{aligned} . \qquad (7)$$

Recall that $r_f=\left[(1-\gamma_f)(1-\lambda_f)\right]e$ and $r_d=\left[(1-\gamma_d)(1-\lambda_d)\right]e$. The domestic regulator abstracts from the foreign producers' profit for determining its policy. The international global welfare includes foreign producers and is defined by

$$W_i(\gamma_d,\gamma_f)=\pi_f(p^A,\lambda_f,\gamma_f)+W_d(\gamma_d,\gamma_f). \tag{8}$$

The "domestic" regulator maximizes the domestic welfare given by (7), while the regulator caring about global welfare maximizes the international welfare given by (8).

We now turn to the determination of the optimal probabilities γ_d, γ_f. For the domestic regulator, the first-order conditions are given by

$$\begin{cases} \dfrac{\partial W_d(\gamma_d^*,\gamma_f^*)}{\partial \gamma_d}=0 \\ \dfrac{\partial W_d(\gamma_d^*,\gamma_f^*)}{\partial \gamma_f}=0 \end{cases}, \tag{9}$$

and with the second-order conditions for concavity being satisfied. For the "international" regulator, the first-order conditions are given by

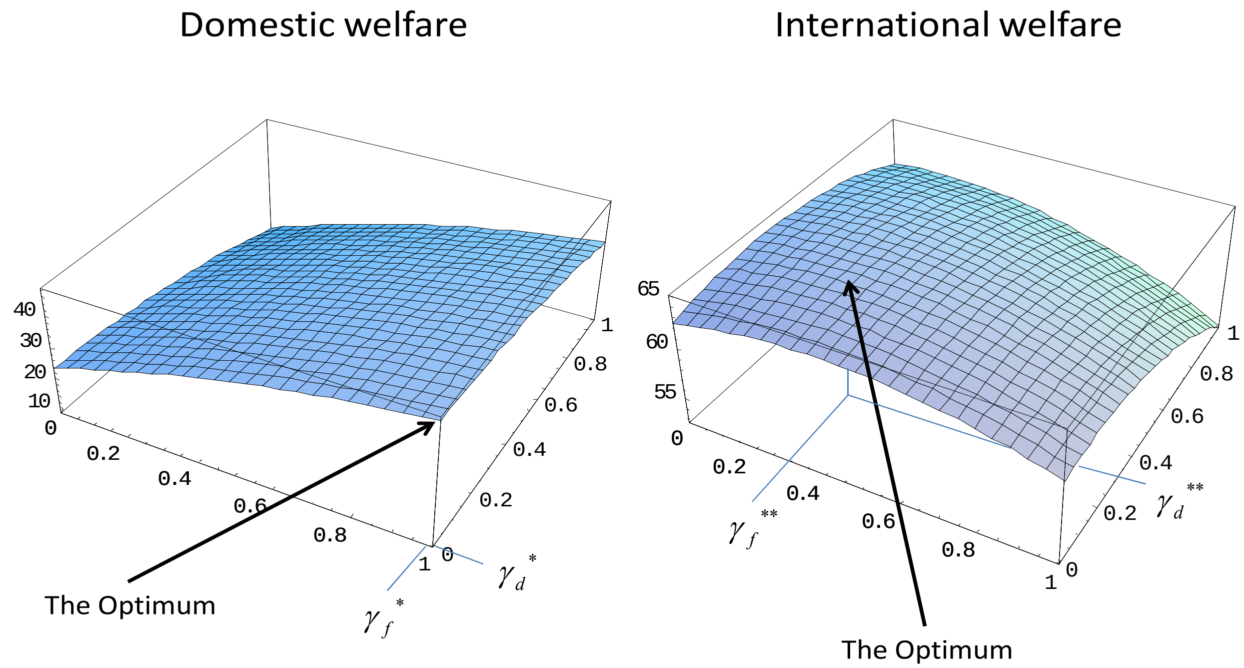
$$\begin{cases} \dfrac{\partial W_i(\gamma_d^{**},\gamma_f^{**})}{\partial \gamma_d}=0 \\ \dfrac{\partial W_i(\gamma_d^{**},\gamma_f^{**})}{\partial \gamma_f}=0 \end{cases}, \tag{10}$$

with a similar check on second order conditions.

The social planners' problems cannot be solved analytically and we resort to simulations. Before introducing the calibration linked to the shrimp market in the United States, we introduce basic simulations to highlight underlining important mechanisms.

One simple but illuminating case consists in assuming symmetric producers and no cost for food safety, implying $\lambda_f=\lambda_d$, $c_f=c_d$, $K_f(\lambda)=K_d(\lambda)=0$, and $k_f(\lambda)=k_d(\lambda)=0$. For a heuristic purpose, we fix exogenous proportions $\lambda_f=\lambda_d=0.5$, demand intercept $a=25$, cost $c_f=c_d=2$, per-unit damage e=15, and marginal cost of inspection $H=2$.

Figure 2 clearly shows that the inspection policies crucially differ when the objectives to maximize are domestic or global as defined by (7) and (8). When the domestic welfare is maximized the inspection processes differ with a probability of control $\gamma_f^* = 1$ imposed on foreign producers and a probability of control $\gamma_d^* = 0$ imposed on domestic producers, despite the strict similarity between producers (see the left chart).[6] By imposing all the controls on the foreign producers the regulator limits the externality coming from the consumption and foreign producers profit decreases because of the complete elimination of the proportion $(1-\lambda_f)$ of tainted products. Domestic producers benefit from this elimination since the equilibrium price increases after the elimination of foreign-tainted products.


Domestic welfare

International welfare

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[6] Exclusion of foreign producers could occur when proportion $(1-\lambda_f)$ of tainted products is relatively high leading to a negative profit (1). Marette (2007) and Marette and Beghin (2010) detail the producers' exclusion/exit linked to regulation.

Figure 2. Numerical illustration of optimal inspection policies

Conversely, when international welfare is maximized the optimum inspection rates $\gamma_d^{**} = \gamma_f^{**} = 0.31$ are similar for all producers because of the strict similarity between producers (see the right chart). By imposing similar controls on domestic and foreign producers, the international regulator limits the externality by equally sharing the effort induced by the partial elimination of tainted products. Note that $\gamma_d^{**} + \gamma_f^{**} < \gamma_f^{*} = 1$, which means that the effort imposed by the domestic regulator is higher than the cumulated effort imposed by the international regulator taking into account the foreign profits. To sum up, there is a distortion in the domestic choice compared to the international choice. This result was not underlined by the previous literature.

Compared to figure 2, we may consider numerous situations with different parameters. For instance, when risks differ with safer domestic food ($\lambda_f < \lambda_d$), the optimal controls maximizing the international welfare are such that $\gamma_d^{**} < \gamma_f^{**}$. The global planner would seemingly be protectionist. More controls are imposed on foreign producers compared to domestic producers because foreign products are not as safe as domestic products. With everything else equal, the change of the foreign proportion $\lambda_f = 0.3$ leads to a policy maximizing the international welfare and defined by the inspection frequencies $\gamma_f^{**} = 0.64$ and $\gamma_d^{**} = 0.09$, while inspection frequencies $\gamma_f^{*} = 1$ and $\gamma_d^{*} = 0$ still maximize domestic welfare. From the international welfare defined by (8), it is legitimate to differentiate the inspection policy with $\gamma_f^{**} > \gamma_d^{**}$ since $\lambda_f < \lambda_d$. This is an interesting result since the possibility of legitimate discrimination readily arises from the difference in the proportions of safe products

λ_f and λ_d. The evaluation of the inspection policy maximizing the international welfare is crucial to characterize policies as protectionist or not with $\gamma_f^{**} < \gamma_f^{*}$ in the sense of Fisher and Serra.

The Shrimp application

The model previously described is calibrated to estimate welfare effects linked to welfare-maximizing inspection rates which are implemented as inspection reinforcements over some initial arbitrary pre-existing levels. Prior to the reinforcement of the inspection, parameters of the model are initially calibrated such as to replicate prices and quantities for 2006 (see table 1).

With the observed quantity sold $\hat{Q}$, the observed price $\hat{p}$, and the direct price elasticity $\hat{\varepsilon}$ $(= p \cdot dQ^D / (Q^D \cdot dp))$ obtained from econometric estimates whose sources are indicated in table 1, the calibration leads to estimated values for the demand parameters equal to $1/\tilde{b} = -\hat{\varepsilon}\hat{Q}/\hat{p}$, $\tilde{a} = \tilde{b}\hat{Q} + \hat{p}$. For the supply side, both domestic and foreign supplies are calibrated with the same price elasticity of supply. With the baseline scenario for 2006 (before the reinforcement of the policy), the calibration of (3) and (5) is made for an initial inspection equal to $\gamma = 0.01$.[7] The parameters used for the calibration are presented in table 1.

Table 1. Values of parameters in 2006 for the calibrated model of the U.S. Shrimp market

Variable	value
Consumption in 2006 (tons)	732 595
Imports in 2006 (tons)	593 729
Domestic production for the domestic market in 2006 (tons)	138 866
Price[1] in 2006 (US$)	6.97
Own-price elasticity of demand[2]	-1.01
Own-price elasticity of supply[3]	0.77

Note: Quantities and prices in 2006 come from FAO (2009).

[1] The domestic price is estimated by dividing the value of imports by the quantity of imports (FAO, 2009), since the import price is equal to the domestic price by arbitrage.

[2] Hudson et al. (2003) for shrimps in the United States by taking the average of own prices elasticities of demand over the 4 destinations in table 4 (p.236).

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[7] With the baseline scenario (before the reinforcement of the policy), it could be assumed that the initial inspection rate is equal to 0.01 or $\gamma = 0.01$ (close to the official statistics reported in SSA, 2007 or in GAO, 2001).

[3] International Institute for Fisheries Economics and Trade (2004) for the aquaculture of shrimps by taking the average of own prices elasticities of demand over the top 5 world producers of shrimps in table 3 (p.5).

The following simulations provide useful information in a context where data linked to border inspections are difficult to collect. Ababouch, Gandini, and Ryder (2005) in their exhaustive study of border cases mention these difficulties arising from complex access to and treatment of data. The parameters selected for the simulation show diverse plausible situations that could emerge.

Several cases for the value of the per-unit damage *e* are presented in the simulations. For ease of interpretation, this damage can be expressed as a percentage of the initial-equilibrium price *p* used in the baseline scenario. We now turn to the results.

Table 2 presents surplus variation between different situations. Five cases are presented to account for potential sensitivity to some parameters. The first column details the surplus variation for different agents coming from maximizing the domestic welfare with γ_f^* and γ_d^* (optimal values given parameters in table 1) compared to the baseline calibration with $\gamma_f = \gamma_d = 0.01$. A positive variation for an agent means a gain coming from the optimal domestic policy. The second column details the surplus variation coming from maximizing the international welfare with γ_f^{**} and γ_d^{**} (optimal values given parameters in table 1) compared to the baseline scenario with $\gamma_f = \gamma_d = 0.01$. The third column presents surplus differences for different agents under the maximized international and domestic welfares. For each row, the value in column 3 is the difference between column 2 and column 1. All the scenarios assume a relative low cost of inspection (*H*=0.1)

Table 2. **Surplus variation between different scenarios for the year 2006 (US$ and percent)**

Case 1: High per unit damage *e*. Equal foreign and domestic shares of safe food *H*=0.1, $\lambda_f = \lambda_d = 0.6$, $e = p$	**Domestic versus baseline**	**International versus baseline**	**International versus domestic**
Optimum probabilities of inspection	$\gamma_f^{\ *} = 1, \gamma_d^{\ *} = 0$	$\gamma_f^{\ **} = 0.29, \gamma_d^{\ **} = 0.29$	$\gamma_f^{\ **} = 0.29, \gamma_d^{\ **} = 0.29$
Reference probabilities of inspection	$\gamma_f = \gamma_d = 0.01$	$\gamma_f = \gamma_d = 0.01$	$\gamma_f^{\ *} = 1, \gamma_d^{\ *} = 0$
Domestic consumers and cost of ignorance (surplus variation)	822,309,331(162%)	403,461,626(79%)	- 418,847,705(-82%)
Domestic producers (profit variation)	171,769,821(29%)	- 64,878,915(-11%)	- 236,648,737(-40%)
Domestic welfare (with cost of controls)	948,546,528(86%)	317,826,006(29%)	- 630,720,521(-57%)
Foreign exporters (profit variation)	- 1,091,031,654(-43%)	- 277,393,269(-11%)	813,638,384(32%)
International welfare (variation)	- 142,485,126(-3%)	40,432,736(1%)	182,917,863(5%)
Case 2: High per unit damage *e*. Safer domestic food (higher domestic share). *H*=0.1, $\lambda_f = 0.6$, $\lambda_d = 0.7$, $e = p$	**Domestic versus baseline**	**International versus baseline**	**International versus domestic**
Optimum probabilities of inspection	$\gamma_f^{\ *} = 1, \gamma_d^{\ *} = 0$	$\gamma_f^{\ **} = 0.33, \gamma_d^{\ **} = 0.01$	$\gamma_f^{\ **} = 0.33, \gamma_d^{\ **} = 0.01$
Reference probabilities of inspection	$\gamma_f = \gamma_d = 0.01$	$\gamma_f = \gamma_d = 0.01$	$\gamma_f^{\ *} = 1, \gamma_d^{\ *} = 0$
Domestic consumers and cost of ignorance (surplus variation)	835,634,699(138%)	368,655,393(61%)	- 466,979,306(-77%)
Domestic producers (profit variation)	170,788,654(28%)	46,303,688(7%)	- 124,484,965(-21%)
Domestic welfare (with cost of controls)	960,887,605(80%)	395,965,121(33%)	-564,922,484(-47%)
Foreign exporters (profit variation)	- 1,090,817,843(-43%)	- 356,995,704(-14%)	733,822,138(29%)
International welfare (variation)	-129,930,237-3%	38,969,4161%	168,899,6534%
Case 3: Very high damage per unit *e*. Equal foreign and domestic shares of safe food. *H*=0.1, $\lambda_f = \lambda_d = 0.6$, $e = 2p$	**Domestic versus baseline**	**International versus baseline**	**International versus domestic**
Optimum probabilities of inspection	$\gamma_f^{\ *} = 1, \gamma_d^{\ *} = 1$	$\gamma_f^{\ **} = 1, \gamma_d^{\ **} = 1$	$\gamma_f^{\ **} = 1, \gamma_d^{\ **} = 1$
Reference probabilities of inspection	$\gamma_f = \gamma_d = 0.01$	$\gamma_f = \gamma_d = 0.01$	$\gamma_f^{\ *} = 1, \gamma_d^{\ *} = 1$
Domestic consumers and cost of ignorance (surplus variation)	3,088,775,065 (203%)	3,088,775,065(203%)	0 (0%)
Domestic producers (profit variation)	- 234,144,685(-39%)	- 234,144,685(-39%)	0(0%)
Domestic welfare (with cost of controls)	2,796,849,352(301%)	2,796,849,352(301%)	0(0%)
Foreign exporters (profit variation)	- 1,001,098,110(-39%)	- 1,001,098,110(-39%)	0(0%)
International welfare (variation)	1,795,751,242(112%)	1,795,751,242(112%)	0(0%)

Table 2 (cont). Surplus variation between different scenarios for the year 2006

Case 4: Low damage per unit *e*. Equal foreign and domestic shares of safe food. *H*=0.1, $\lambda_f=\lambda_d=0.6$, $e = p/2$	**Domestic versus baseline**	**International versus baseline**	**International versus domestic**
Optimum probabilities of inspection	$\gamma_f^* = 0.73, \gamma_d^* = 0$	$\gamma_f^{**} = 0, \gamma_d^{**} = 0$	$\gamma_f^{**} = 0, \gamma_d^{**} = 0$
Reference probabilities of inspection	$\gamma_f = \gamma_d = 0.01$	$\gamma_f = \gamma_d = 0.01$	$\gamma_f^* = 0.73, \gamma_d^* = 0$
Domestic consumers and cost of ignorance (surplus variation)	128,158,928 (25%)	- 9,751,492(-1%)	- 137,910,420(-27%
Domestic producers (profit variation)	286,795,990(48%)	4,366,339(0.7%)	- 282,429,650(-48%)
Domestic welfare (with cost of controls)	387,489,865(35%)	- 5,385,152(-0.4%)	- 392,875,017(-35%
Foreign exporters (profit variation)	-1,602,257,121(-63%)	18,668,517(0.7%)	1,620,925,638(64%)
International welfare (variation)	-1,214,767,256(-33%)	13,283,364(0.3%)	1,228,050,620(34%)
Case 5: Very low damage per unit *e*. Equal foreign and domestic shares of safe food. *H*=0.1, $\lambda_f=\lambda_d=0.6$, $e = 0.3 \times p$	**Domestic versus baseline**	**International versus baseline**	**International versus domestic**
Optimum probabilities of inspection	$\gamma_f^* = \gamma_d^* = 0$	$\gamma_f^{**} = \gamma_d^{**} = 0$	$\gamma_f^{**} = \gamma_d^{**} = 0$
Reference probabilities of inspection	$\gamma_f = \gamma_d = 0.01$	$\gamma_f = \gamma_d = 0.01$	$\gamma_f^* = \gamma_d^* = 0$
Domestic consumers and cost of ignorance (surplus variation)	1,708,249(0.08%)	1,708,249 (0.08%)	0(0%)
Domestic producers (profit variation)	2,185,076 (0.3%)	2,185,076 (0.3%)	0(0%)
Domestic welfare (with cost of controls)	3,893,326(0.1%)	3,893,326(0.1%)	0(0%)
Foreign exporters (profit variation)	9,342,412 (0.3%)	9,342,412 (0.3%)	0(0%)
International Welfare (variation)	13,235,739 (0.2%)	13,235,739 (0.2%)	0(0%)

Note: Relative variation (%) compared to the baseline scenario (in columns 1 and 2) and to the domestic welfare (in column 3) in parentheses.

We first discuss case 1 of table 2, for which the per-unit damage *e* is high and equal to the initial price p of the baseline scenario. Recall from figure 1, that the higher the inspection policy, the higher is the price increase and the related distortions. Domestic consumers and producers prefer the domestic policy defined by γ_f^*, γ_d^* (first column) compared to the international policy defined by $\gamma_f^{**}, \gamma_d^{**}$ (second column), which explains a negative third column. Under the domestic policy, consumers benefit from the high-domestic controls γ_f^*=1 imposed on foreign producers and reducing the expected damage per-sold unit. The overall damage reduction coming from the higher inspection relative to what it would be under the international policy outweighs the consumer loss linked to the greatest price distortion. Domestic producers also benefit from the high-domestic control $\gamma_f^*=1$ imposed on foreign producers compared to what it would be under international controls. They benefit from a price increase without any quantity reduction because of $\gamma_d^* = 0$. However, for foreign producers who lose under both schemes, the international policy defined by $\gamma_f^{**}, \gamma_d^{**}$ (second column) is less distortive than the domestic policy defined by γ_f^*, γ_d^* (first column) with $\gamma_f^* > \gamma_f^{**} + \gamma_d^{**}$, which explains a positive third column. Aggregate international welfare decreases relative to the baseline scenario when the domestic policy menu (γ_f^*, γ_d^*) is selected (first column), whereas international welfare increases when the international policy is selected (second column). The domestic policy is deemed protectionist since $\gamma_f^* > \gamma_f^{**}$ and $\gamma_d^* < \gamma_d^{**}$, in the spirit of Fisher and Serra (2000). Note that the variations of the international welfare are low while the variations for domestic agents or foreign producers are large, that is, transfers among agents are large. In the first column, the negative variation of the international welfare when the domestic policy is imposed means that the foreign-producers' loss offsets the gains of domestic producers and consumers.

Case 2 keeps the high per unit damage and introduces a larger domestic share of safe output. The case shows it is legitimate (non protectionist) from the international point of view to impose a higher level of control on foreign producers compared to domestic producers, with $\gamma_f^{**} > \gamma_d^{**}$, because of a higher risk for foreign products with $\lambda_f = 0.6$ and $\lambda_d = 0.7$. Foreign exporters, especially from developing countries, tend to have a lower expected quality because meeting the standard is relatively more costly and inspections are uncertain, two documented stylized facts for shrimps. As case 1 does, case 2 shows that the domestic regulator imposes an excessive level of inspection because of the relationship $\gamma_f^* > \gamma_f^{**} + \gamma_d^{**}$. The inspection rates are protectionist because $\gamma_f^* > \gamma_f^{**}$ and $\gamma_d^* < \gamma_d^{**}$. Observing the inspection level for domestic firm lower than the inspection level for foreign firms is not the appropriate criteria, but rather one should compare their respective levels under domestic and international regulators.

Case 3 assumes a very high value of the per-unit damage *e* and similar foreign and domestic safety levels. In this case the optimum domestic policy corresponds to the foreign policy since the relatively high damage requires a systematic control of all products. Indeed both probabilities under both welfare maximizations reach the maximum equal to one, while the expected damage *r* completely disappears since no tainted products enter the domestic country.

In case 4, the per unit damage *e* is set low and leads to no inspections under the international welfare criteria, while the domestic regulator imposes inspections on foreign producers. Eventually, when the cost of inspection *H* increases relative to the per unit damage, the rates of inspection decrease for all cases 1 to 4 (a case that is not shown in the table 1).

In case 5, there is no protectionism since the controls would be counterproductive and they are equal to zero under both "maximized" domestic and international welfare.[8] Domestic consumers slightly benefit from the reduction of inspections compared to the baseline scenario because of relatively low damage *e* and savings from not implementing costly inspections and the absence of price distortion through inspections.

A stringent inspection policy may influence the proportion λ_f of non-contaminated

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[8] The value of *e* for case 5 is likely to correspond to the one provided by experimental studies or by consumers' surveys. The percent price premium for safe products over conventional product is equal to 30%. We draw on the value suggested by Hayes et al. (1995) for the United States. In an experimental economics study, Hayes et al. (1995) found respondents willing to pay 15% to 30% more for food that is essentially completely safe from five pathogens in the United States, including salmonella. We could retain a value equal to w=0.3. We apply the price p used for the initial calibration, which means that the per-unit damage is equal to $e = 0.3 \times p$ (as in case 5 of table 2) for each country and leads to the cost of ignorance.

products meeting the safety standard. It was the case for shrimps, when the policy for reducing the use of chloramphenicol (an antibiotic) led to the selection of alternative species less sensitive to residues by producers (such as the *Penaeus Vannamei*). Making $\lambda_f, \lambda_d, \gamma_f, \gamma_d$ jointly endogenous leads to complex computations with multiple roots. However, the choice of λ_f, λ_d is subject to the same differences when domestic welfare and international welfare are taken into account. In the following example using parameters of table 1, we restrict our attention to a situation with an inspection policy $\gamma_d = \gamma_f = 0.3$, marginal costs $k_f(\lambda_f) = k_f(\lambda_f) = 0$ and fixed safety costs $K_f(\lambda_f) = 1000000000\left(\lambda_f\right)^2$ and $K_d(\lambda_d) = 500000000\left(\lambda_d\right)^2$. These values guarantee concavity of profits functions and positive profits with $0 \leq \lambda_d \leq 1, 0 \leq \lambda_f \leq 1$.

As firms face a probability of being controlled, the maximization of the firms' profits leads to the selection of $\lambda_d' = 0.25, \lambda_f' = 0.42$. Despite the cost differences, the effort by foreign producers is higher than the one by domestic producers, since the higher market share for foreign producers allow them to bear a larger sunk cost. We now turn to decisions taken by a regulator maximizing the domestic welfare or the international welfare and imposing the same standard on foreign and domestic producers. The regulator maximizing the domestic welfare would select a standard $\lambda^* = 1$ imposed to all firms. The regulator maximizing the international welfare would select a standard $\lambda^{**} = 0.85$. As for the inspection policy, the domestic regulator will try to impose a higher standard since the fixed cost $K_f(\lambda_f)$ is only incurred by the foreign producer and not passed on to the domestic consumers. Note that the characterization of the protectionism is based on the comparison between $\lambda^* = 1$ (namely, the domestic choice) and $\lambda^{**} = 0.85$ (the international choice) and not on the comparison between $\lambda^* = 1$ (the domestic choice) and

$\lambda_f' = 0.42$, that is, the private choice by the foreign firms reacting to the inspection policy $\gamma_d = \gamma_f = 0.3$. The comparison between a policy maximizing the domestic welfare and a policy maximizing the international welfare is necessary for delineating the frontier between the legitimate regulation reducing the consumer' damage and the protectionism injuring foreign producers.

Protectionist and discriminatory pressures and possible distortions imposed on foreign producers are not limited to the probabilities of inspection or phyto-sanitary standards. Another important regulatory decision considered here deals with alternative ways to finance controls and their implications for welfare and potential protectionism. This problem has been overlooked by the previous literature.

How to finance inspections?

This section complements the previous one, since it also shows that the way to finance the inspection may also have protectionist consequences. For selected levels of inspection decided by the regulator (as in the previous section), alternative ways to finance inspection could be selected if the regulator is missing public funds coming from federal taxes and/or if the program has to be self-sufficient. Two fiscal instruments can be considered, namely, a fixed fee (whatever the quantity sold) and a per-unit fee imposed on firms. For simplifying the analysis, those fees are the same for foreign and domestic producers, which differs from the previous section were discriminations were possible.

To further simplify the analytical expressions, we keep the previous notations and we assume a symmetric configuration for producers with $\lambda_f = \lambda_d = \lambda$, $c_f = c_d = c$, $\gamma_f = \gamma_d = \gamma$. Moreover, we assume $k(\lambda) = K(\lambda) = 0$ and $b = 1$ for the demand parameter in (6). Obviously, the results of this section could be combined with the previous results defining different probabilities γ_f and γ_d. We can rewrite the profit previously defined by (1), as

$$\pi_f(p,\lambda,\gamma,g,G) = \left[(1-\gamma)+\gamma\lambda\right]pq_f - \tfrac{1}{2}cq_f^2 - g\left[(1-\gamma)+\gamma\lambda\right]q_f - G, \quad (11)$$

with a fixed fee G paid by the producer and a per-unit fee g paid per-sold unit. These fees account for refused goods as showed in (13) below. Note that, after the inspection, the sold units are $\left[(1-\gamma)+\gamma\lambda\right]q_f$ for foreign producers. The profit maximization yields individual firm supply function before the inspection equal to

$$q_f^S(p) = \frac{[(1-\gamma)+\gamma\lambda]p - \gamma g}{c}, \quad (12)$$

with $[(1-\gamma)+\gamma\lambda]q_f^S(p)$ corresponding to the supply function after the inspection (the same can be done for domestic producers). Note that the fixed fee G does not influence the chosen output but only impacts the profit. It is chosen such that the budget constraint of the regulator is satisfied. Similarly to the previous section, the equilibrium price is p^A. With this per-unit fee g paid for each sold unit and this fixed fee G, the budget constraint linked to the inspection and the fees is:

$$H\gamma[q_d^S(p^A)+q_f^S(p^A)] = g[(1-\gamma)+\gamma\lambda][q_d^S(p^A)+q_f^S(p^A)] + 2G, \quad (13)$$

where γ is the probability of inspection applied to output and H is the marginal cost of inspection. The per-unit fee g paid per-sold units accounts for all inspected units including the withdrawn units. With $r_f = r_d = r$ and with sold products $Q(p^A) = [(1-\gamma)+\gamma\lambda][q_d^S(p^A)+q_f^S(p^A)]$, the domestic welfare previously given by (7) is defined by

$$W_d = \pi_d(p^A,\lambda,\gamma,g,G) + U(Q(p^A), R - p^A Q(p^A)) - rQ(p^A), \quad (14)$$

with $r = \left[(1-\gamma)(1-\lambda)\right]e$. The international welfare is defined by

$$W_f = \pi_f(p^A, \lambda, \gamma, g, G) + W_d. \tag{15}$$

For given values of λ and γ, the "domestic" regulator maximizes the domestic welfare given by (14) subject to (13), while the "international" regulator maximizes the international welfare given by (15) subject to (13). Result 1 and figure 3 are useful to illustrate the financing choices by a regulator balancing the budget defined by (13). The per-unit fee *g* is located along the horizontal axis, and the welfare is located along the vertical axis.

Result 1. *When domestic welfare is maximized, the per unit fee paid by all producers is* $g^* = \dfrac{\left[c + 2\left(1+\gamma(1-\lambda)\right)^2\right]\left[\gamma H + 2e(1-\gamma)\left[(1-\gamma)+\gamma\lambda\right](1-\lambda)\right] - 2a\left[(1-\gamma)+\gamma\lambda\right]^3}{c\left[(1-\gamma)+\gamma\lambda\right]}$, *linked to a fixed fee* $G^* = \dfrac{(a-g^*)\left[\gamma H - g^*(1-\gamma(1-\lambda))\right](1-\gamma(1-\lambda))}{c+2(1-\gamma(1-\lambda))^2}$.

When the international welfare is maximized, the per unit fee paid by all producers is $g^{**} = \dfrac{\gamma H + e(1-\gamma)(1-\lambda)\left[(1-\gamma)+\gamma\lambda\right]}{(1-\gamma)+\gamma\lambda}$, *and with fixed fee* $G^{**} = \dfrac{(a-g^{**})\left[\gamma H - g^{**}(1-\gamma(1-\lambda))\right](1-\gamma(1-\lambda))}{c+2(1-\gamma(1-\lambda))^2}$.

Result 1 shows that the selected fees are completely different because of different welfare criteria. When the international welfare is maximized, the per-unit fee g^{**} is positive and greater than the fee $x = \gamma H / [(1-\gamma)+\gamma\lambda]$ that would satisfy (13) with *G=0* (see *x* in figure 3). It is socially optimal to internalize the cost of inspection into the price, as well as the per-unit damage $r = e(1-\gamma)(1-\lambda)$ as a Pigouvian tax. As $g^{**} > \gamma H / [(1-\gamma)+\gamma\lambda]$, the corresponding fixed fee G^{**} is negative to balance the budget, which means that firms receive a fixed subsidy that partially compensates the incurred cost linked to the per-unit fee g^{**}. This is an interesting result since it rationalizes having HACCP bankrolled by the domestic regulator (see the previous section on HACCP). Note that with this mechanism, consumers and firms finance the inspection since the per-unit fee g^{**} is passed onto consumers via the equilibrium price.

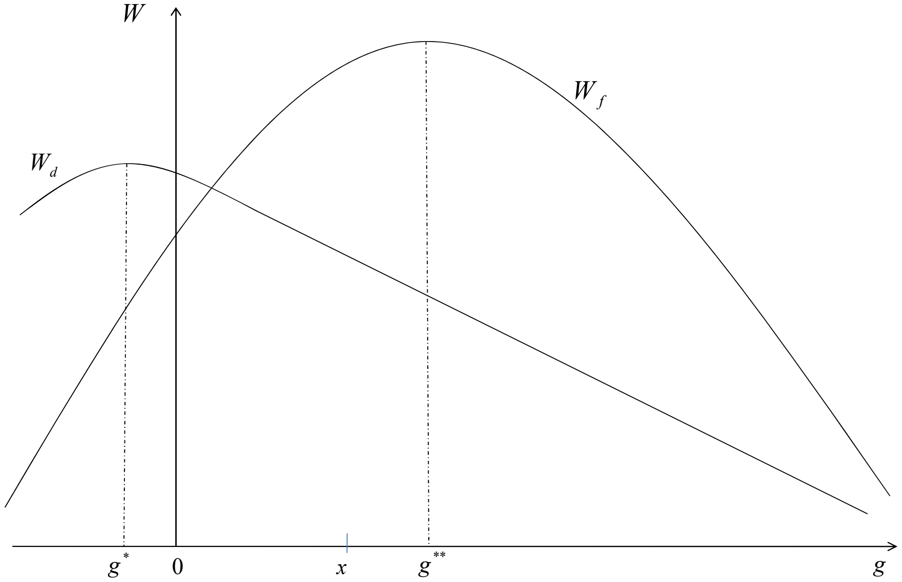

Figure 3. Per-unit fees *g* under different scenarios

When the domestic welfare is maximized, the per-unit fee g^* is negative for relatively medium-values of H and the corresponding fixed fee G^* is positive to balance budget constraint (13). It means that both firms mainly finance the inspection with a fixed fee that is not passed on to consumers into the price. This allows the domestic regulator to finance the inspection policy via the fixed fee that is incurred by domestic and foreign firms. One part of the financing is passed onto foreign firms (and countries) and not passed onto domestic consumers. The domestic choice is distorted compared to international one because the foreign country bears a larger share of the financing. As foreign producers are not considered in the domestic welfare, it is optimal to use the fixed fee not passed on to consumers. This result was overlooked in the previous literature on inspection that does not broach international trade *per se*. When H is relatively large, the fee g^{*} is positive.

The domestic mechanism (g^{*}, G^{*}) can be judged protectionist compared to the international mechanism (g^{**}, G^{**}) since the domestic mechanism decreases the foreign profit, compared to a situation maximizing the international welfare.

This simple model of financing may lead to extensions. In particular, the exclusion of foreign producers could be studied. The financing instruments could be different between foreign and domestic producers, which would re-enforce the discrimination and the protectionism with higher positive fees imposed on foreign producers compared to domestic producers. The domestic regulator could be tempted to select fees such that the foreign profit is negative leading to foreign-producers exit $(\pi_f(p^A, \lambda, \gamma, g, G) < 0)$. This possibility would reinforce the distortion of the domestic choice compared to the international choice. Eventually, another extension could restrict the analysis to welfare maximization for which both g and G are positive. This additional constraint can be added as the positive values of the fees for limiting the firms' transfers. In this case, choices are the following. When the international welfare is maximized, the per unit fee paid by all producers is $x = \gamma H / [(1-\gamma) + \gamma\lambda]$, linked to a fixed fee G equal to 0 as implied by the budget constraint (13) (see x on figure 1). When domestic welfare is maximized, the per-unit fee paid by all producers is zero, linked to a fixed fee G^{**} >0 to balance the budget. The interpretation of this result is similar to the one given after result 1.

To focus on the main economic mechanisms and to keep the mathematical aspects transparent, the analytical framework was sparse. In order to fit different problems coming from various contexts, the following four extensions could be integrated into the former model. (i) For simplicity, the proportions of contaminated product were exogenous. In a dynamic context firms would react and improve their safety. The previous model could have safety endogenously determined in profit maximization. Food producers can increase the probability of offering safer products by incurring a fixed/variable cost that varies with the producers' origin. For a safety level the costs are such that $k_i(\lambda)'>0$, $k_i(\lambda)''>0$, and $K_i(\lambda)''>0$. The stronger the inspection policy, the higher would be the choice of λ_f and λ_d (a catalyst role). (ii) Next, the damage could be internalized with information feeding into the demand (I>0 in equation (6)) leading to a demand shift by informed consumers. In this context, government regulation is not the only approach deserving consideration. Other measures include voluntary practice, codes of good conduct, and "private" standards. One extension of interest would be a voluntary standard/certification system in which each firm can opt out. (iii) We abstracted from quality signaling (via guarantees, brand investment) and reputation in a context of repeat purchases under imperfect information. Repeat purchases with internalized damage (with $I>0$) may lead to no new information for consumers since safety of a good could be revealed in the very long term, which ruins the possibility of signals or reputation. (iv) The inspection policy implemented by the United States for the shrimp industry and trade could be described in more details and lead to better estimates of the implications of the inspection system. The collect of information should mainly focus on the proportion of contaminated products, the characteristic of the inspection such as diagnostic errors described in note 3 and the related cost of inspection H.

Conclusion

This paper explored the potential protectionism of food safety inspection system to implement a food standard and its influence on safety choices by foreign and domestic producers selling food in the domestic market. Inspections play a key role to turn safety standards into a discriminatory implementation of the food standard, leading de facto to discriminatory effective or implemented standards, often raising the average quality of imports above that of domestic goods. The way these inspections are financed can also re-enforce the protectionist nature of the inspections. All these effects occur in absence of any rent seeking by firms. Even when considering global welfare, discriminatory non protectionist inspection can arise if domestic and foreign firms have heterogeneous cost structures.

This paper shows that more attention should be given to the way domestic and foreign products are inspected and the way these inspection policies are financed. Whatever the instrument (inspection, standard or fees for financing the regulation), we showed the comparison between a policy maximizing the domestic welfare and a policy maximizing the international welfare is necessary for delineating legitimate regulation reducing the consumer' damage from protectionism injuring foreign producers. A larger question is what should policy maker do in light of non discriminatory principles in trade agreements? For example, domestic treatment under the WTO would suggest that these differences in inspection rates and their financing may be inconsistent with the Agreement.

The empirical analysis raise interesting issues related to the actual U.S. policy. It seems to be neither a protectionist measure nor a catalyst, given its very low frequency of inspections. Despite some shortcomings, welfare measures developed in this paper help streamline the amount of money earmarked to public-inspection programs. In essence, more attention should be given to the economic analysis of food safety of shrimps and to the optimal inspection policy at the border and in domestic plants and its welfare effects.

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