Chapter 7
Border Inspection and Trade Diversion: Risk Reduction vs. Risk Substitution

Qiong Wang, Eli P. Fenichel, and Charles A. Perrings

Introduction

International trade increasingly brings previously separated geographical regions into contact with one another and increases the frequency of those contacts. These trends bring many benefits to the trading partners involved, but increasing international trade also facilitates the spread of pathogens and increases disease risks. The rapid growth of trade, transport, and travel across national borders has increased the frequency of introduction, establishment, and spread of invasive infectious pathogens (Jones et al. 2008). The development of new trade pathways and the growth in the number and volume of commodities traded increase the likelihood that novel infectious pathogens are introduced to importing or stop-over countries. The growth in trade volumes has increased the risk that introduced pathogens establish and spread, because it has increased the frequency with which infectious pathogens are introduced (Cassey et al. 2004; Dalmazzone 2000; Semmens et al. 2004). Other factors such as the bioclimatic similarities between trading partners, the vulnerability of ecosystems in the importing countries, and risk management policies adopted by both importing and exporting countries also influence the risks of invasive infectious pathogens (Wiens and Graham 2005).

The impact of infectious diseases on human wellbeing may be direct or indirect. Infectious pathogens cause indirect effects by successfully establishing in novel environments, which can lead to irreversible functional and structural change in local ecosystems including extinction of species (Collins and Storfer 2003; Gurevitch and Padilla 2004; Lips et al. 2006; Williamson 1996). For example, avian pox and

Q. Wang
School of Sustainability, Arizona State University, Tempe, AZ, USA

E.P. Fenichel (✉) • C.A. Perrings
School of Life Sciences and ecoServices Group, Arizona State University, Tempe, AZ, USA
e-mail: eli.fenichel@asu.edu

D. Zilberman et al. (eds.), *Health and Animal Agriculture in Developing Countries*, Natural Resource Management and Policy 36, DOI 10.1007/978-1-4419-7077-0_7,

avian malaria significantly contributed to the extinction of endemic Hawaiian birds following the pathogens introduction from Asia (Simberloff 1996). Chytrid fungus, an emerging infectious disease of amphibians, is playing a major role in the global decline of amphibian populations (Daszak et al. 1999).

Many emerging diseases are zoonoses, they can be transmitted from non-human to human hosts, and cause direct impacts on people (Cleaveland et al. 2001). Examples include H5N1 (Kilpatrick et al. 2006), West Nile virus (Lanciotti et al. 1999), and SARS (Guan et al. 2003; Li et al. 2005). In addition to the potential for zoonoses, animal pathogens impose substantial economic costs on agricultural producers. Invasive pathogens have caused substantial economic losses in agriculture, forestry, and other segments of the U.S. economy (Pimentel et al. 2000, 2002, 2005). Losses include both the direct costs of control, and the forgone benefits of trade interruptions. The outbreak of foot-and-mouth disease (FMD) in the U.K. in 2001, for example, caused the European Union to ban Great Britain from exporting livestock, meat, and animal products to non-British member countries, resulting in substantial trade losses. By the time the outbreak had ended, FMD had cost the U.K. £8 (approximately $16) billion. Thirty-nine percent of the costs, £355 (approximately $710) million, were borne by agricultural producers (DEFRA 2002). Losses due to trade restrictions and business interruption can motivate disease eradication programs even in cases when the direct productivity losses are not great (Horan and Wolf 2005). The potential economic damage associated with animal pathogens motivates significant investment in mitigation strategies that prevent the introduction of pathogens or control their spread. For example, the U.S. spends approximately $106 million each year on the inspection and control (detection, eradication, etc.) of bovine tuberculosis costs (Wolf et al. 2008).

The primary source of novel animal disease risk is international trade in animal products (Otte et al. 2007; Pavlin et al. 2009). Other things being equal, higher trade volumes increase the cumulative probability that infectious animal pathogens appear at the border, while higher levels of screening effort at the border reduce the probability that pathogens that appear at the border are dispersed within the country (Perrings et al. 2010). To address these risks, importing countries typically adopt a range of border control measures extending from outright bans on trade in risky goods, or with risky trading partners, to inspection and interception regimes designed to reduce the likelihood of the introduction of infectious pathogens. Such unilateral defensive measures are the only measures allowed under the General Agreement on Tariffs and Trade (GATT) and the 1994 Sanitary and Phytosanitary (SPS) Agreement (Perrings et al. 2010). In all cases, the cost of these measures is borne by the trading parties, and hence directly affects the cost of imported goods. If we define the landed postinspection cost of imports to be the c.i.f.i. price – cost, insurance, freight, inspection – then any positive level of inspection (and interception) implies that the c.i.f.i. price of imports is strictly greater than the c.i.f. price.

There is a considerable body of work addressing the appropriate level of inspection and interception effort that relates the direct costs of inspection to the expected damage costs of introductions (Leung et al. 2002; Caley et al. 2006; Batabyal 2007; Finnoff et al. 2007; Keller et al. 2007; Springborn et al. 2010). Others have focused on the design of institutional measures to reduce invasion risk. Perrings et al. (2010) show that the risks of invasive infectious pathogens depend both on factors that influence trade volumes and the SPS measures undertaken by trading partners. Horan and Lupi (2005) develop a model of tradable risk permits for invasive species. They show that tradable risk permit systems potentially have a greater risk reducing affect than uniform quotas or taxes do to the heterogeneous risks that different sources provide. McAusland and Costello (2004) analyze the effectiveness of potential policies such as tariffs and inspection and interception to combat the potential risk of invasive infectious pathogens introduction. They conclude that tariffs do not always safeguard against the introduction of invasive infectious pathogens. Kohn and Capen (2002) show that institutional policies discouraging international trade may increase environmental damage by invasive infectious pathogens if change in the composition and volume of international trade unexpectedly creates new opportunities for invasive infectious pathogens.

There is relatively little work on the effect of direct risk-reducing measures such as inspection and interception on the structure of trade. Inspection and interception changes the cost of importing good, and any change in the cost of imports will induce a response on the part of importers. Ameden et al. (2007) present a model of strategic firm behavior where importers respond to inspection regulations. Their model suggests that importing firms may decrease imports and engage in avoidance behavior (e.g., smuggling or port-shopping – the process of importing through ports with less stringent regulation). Many third-party logistics providers maintain databases to help identify least cost and least time ports, attributes importers might uses as proxies for regulations. These data are intended to identify the most efficient shipping routes from the firm's perspective, which likely means avoiding more stringent regulations. Ameden et al. (2007) also suggest that firms may engage in lower protection investments with more stringent inspection because the expected profit from importing goods is reduced by the expect inspection costs. Empirical work also confirms that firms respond to different border inspection effort by choosing alternative ports with less border inspection (Ameden et al. 2009). Alternatively, importers with nimble supply chains may respond by sourcing substitute commodities from elsewhere, which will affect the risk of importing an animal disease. Trade diversion affects the structure of risks and since the risks from invasive infectious pathogens depend on the origin of the traded commodities, such trade diversions affect the efficiency of inspection and interception measures adopted by importing countries.

We fill a gap in the literature by considering how inspection and interception regimes induce both supply and demand responses for the commodities affected (Fig. 7.1). We consider the impact of these responses on disease risks, and outline the importance of incorporating market responses into the choice of inspection and interception regimes. We build on the work of Ameden et al. (2007) and specifically show the need to consider the importer's response to border inspection regimes.

Infectious Disease Risks Are an Externality of Trade

Trade creates private benefits for consumers and importing firms. However, at the same time trade may introduce infectious pathogens that cause damage both to the local economy and the natural environment – a public risk. The private nature of

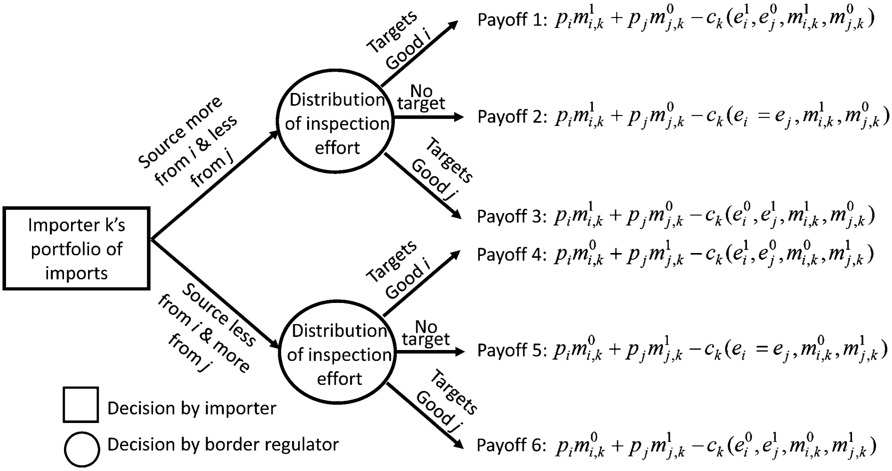

Fig. 7.1 A decision tree illustrating importing firm k's decision: p_i is the market price of good i, $m_{i,k}$ is the import volume of good i by firm k, superscripts indicate more (1) or less (0). The term c is firm k's private costs of importing, where e_i and e_j are costs associated with the inspection. The importer's decision is illustrate with the *box*, and the importer generally takes the border regulator's decision (*circle*) as a stochastic event with a given distribution (though in the long-run the importer may attempt to influence the regulator) and forms expectations over e_i and e_j. The firm chooses the import level to maximize the payoff conditional on its own cost structure and its expectation of inspection. If the regulator recognizes this structure, and if the goal is to minimize total social costs, then the regulator takes the firm behavior as endogenous when solving for its inspection effort program. If the regulator never targets, then the firm only considers payoffs 2 and 5, and the import portfolio is determined by market conditions. When the regulator differentially targets goods (or sources) i and j, then trade diversion will occur and the firm compares the expectation of payoff 1 and 3 with the expectation of payoff 4 and 6 and chooses the allocation that leads to a greater expected payoff

the benefits and public nature of the costs implies that the infectious disease risks of trade will be excessive from a social perspective – the risk is an externality. Private consumers and importers will not generally consider the public risks that their private activities produce.

An importer's choice of supply sources depends on the expected costs of importing (supply costs) – including the costs associated with inspection and interception. Demand for substitute commodities depends on the relative prices of those commodities and the elasticity of substitution between pairs of commodities, which is dependent on consumer preferences. Market interactions drive what ultimately gets imported – including the pathogens that accompany traded goods.

Risk is the product of the probability and consequences of a stochastic event. Risk can be reduced by reducing either the probability of the event or the costs it is expected to impose. Public border protection agencies engage in inspection and interception activities to reduce the probability of pathogen introduction – a risk mitigation strategy (Perrings 2005). Post invasion control or adaptation strategies are often left to other governmental agencies. However, if a public border inspection agency is to balance the social benefits (e.g., consumer and producer surplus) from trade with the public risk of a novel infectious animal disease, then the agency must account both for the actions of other agencies and decentralized importer and consumer behavior. The border inspection agency does not directly control the quantity of goods imported, the price of those goods, or the management response to a pathogen introduction. The border agency can, however, consider the importing firms' incentives. Firms' choices with respect to trade volume, source, and commodity affect the risk of pathogen introduction directly, but the border inspection agency can influence this decision by adjusting inspection effort and hence the cost of various goods or goods from various trading partners.

Springborn et al. (2010) discuss two potential inspection strategies for managing the risks posed by potentially invasive infectious pathogens. The first involves focusing inspection effort on known high-risk imports. There are two potential problems with this strategy. First, it ignores the risk posed by new commodities or new trade routes – the problem of fundamental uncertainty. Second, it is not clear a priori whether inspection is best allocated to low probability but high potential cost imports or to imports for which the cost of inspection is low. Springborn et al.'s second strategy is to allocate a fraction of prevention effort on unknown risky imports, and use a Bayesian updating process to information future allocation of inspection effort. In practice, this second strategy implies a broader inspection effort where learning is explicitly part of the management objective. The second strategy is essentially an adaptive management strategy (Walters 1986). Neither of Springborn et al.'s strategies explicitly account for substitution and trade diversion effects, though both could be adapted to do so. A reasonable hypothesis is that targeted inspection regimes would have greater affect on the structure of trade creating a moving target.

Following Springborn et al. (2010) and Ameden et al. (2007), we explore the case where the border inspection agency's objective is to minimize the social cost of an introduced disease that results from imports of either particular commodities or from particular countries. The social costs comprise the expected damage costs of an introduced pathogen including expected control costs, the direct cost of border inspections, and the expected indirect costs to consumers and importers of the inspected goods in terms of lost surplus. Inspection has two effects on risk. The intended effect is that inspection directly reduces the probability that a novel pathogen will be imported. This constitutes a direct benefit. A secondary effect follows from the fact that the direct cost of border inspection functions like a tax on imports. Importing firms incur additional costs due to inspection (e.g., inspection fees, time delays, and the risk that some goods will test positive and will be rejected). This "tax" affects the market clearing price of the inspected good. This in turn affects the quantity demanded of the inspected good and the quantity demanded of substitute goods. The substitution effect influences trade composition and volume and has implications for the expected damages of associated with substitute commodities or substitute suppliers in the resulting supply and demand shifts generate indirect benefits and costs.

A Model of Risk Substitution

We develop a simple model to illustrate the potential for risk substitution to show how substitution between goods can affect both the cost of inspection regimes, and the risks faced by the importing country. We consider a country that imports goods from two sources (i.e., there are two exporting countries, country $i \in \{1, 2\}$, $j \neq i$ each supplying a single good) to simplify analysis. We assume that importers operate in a competitive market that clears, but neglect the social costs of disease risk. Furthermore, we assume that the goods imported from countries 1 and 2 are substitutes, that countries 1 and 2 have different characteristics θ_i, and that these characteristics affect the probability that the country is the source of an infectious pathogen. The risk to the importing country depends on trade volumes, m_i, inspection effort, e_i, and country-specific factors such as bio-climatic conditions. If the border inspection agency in the importing country had perfect information about the probability that a specific exporter would introduce a pathogen, then the inspection service might be expected to target inspection by exporter – i.e., adopt the first strategy identified by Springborn et al. (2010). However, for the inspection program to be efficient, the inspection regime should account for substitution effects on the volume of imports from other countries. This should affect the distribution of inspection effect across risk sources.

A border inspection agency chooses a vector of inspection efforts, $\mathbf{e}$ for the vector of imported good $\mathbf{m}$ (where $\mathbf{e} = \{e_i, e_j\}, \mathbf{m} = \{m_i, m_j\}$) to minimize the sum of three cost components, C: the direct costs of border inspection and interception; $W(\mathbf{e})$: the forgone producer and consumer surplus from the tax effect of the inspections; $-S(\mathbf{x})$, where $\mathbf{x}$ is a vector of goods consumed, $\mathbf{x} = \{x_i, x_j\}$; and the expected cost or the risk of disease introduction $\gamma(\mathbf{e}, \mathbf{m}, \theta)Z$, where γ is the probability that pathogen is introduced conditional on inspection effect, $\mathbf{e}$ is the volume of imports, $\mathbf{m}$ is the exporter specific characteristics, θ and Z is the cost associated with any control program and disease related damages. Formally, the border inspection agencies problem is

$$\underset{\mathbf{e}}{\text{Min}} C = W(\mathbf{e}) - S(\mathbf{x}) + \gamma(\mathbf{e}, \mathbf{m}, \theta)Z. \tag{7.1}$$

We make two general observations before discussing each term in detail. First, the prices paid by consumers for good x_i must adjust so that the market clears and $x_i = m_i$. The quantity x_i denotes goods demanded, and m_i denotes goods supplied. Second, in practice, optimal detection, prevention, and control of an invasive animal pathogen are a dynamic problem. Prior work (reviewed in Horan et al. 2010 and Horan et al. 2011) and chap 6 in this book (Horan et al. 2012) discuss the optimal control of an animal pathogen once it has been introduced and detected. To show the effect of inspection on the substitution between imported goods, however, we assume that damage costs are fixed at Z, and that these reflect the optimal level of control after introduction of infectious pathogens occurs.[1] This enables us to treat the border agency's problem in static framework. Our approach can, however, easily be extended to the dynamic context using the approach of Springborn et al. (2010).

The direct cost of inspection, $W(\mathbf{e})$, depends on the level of inspection effort invested at the border. We assume that more effort leads to higher costs, $W'(\mathbf{e}) > 0$. The border inspection agency must also consider the losses from any reduction of trade or price effects caused by the increased transactions costs associated with boarder inspection. This is the loss of surplus, $-S(x_i, x_j)$, associated with the "tax" effect of the inspections. To simplify the problem, we assume that there is no local production of substitute goods (though an extension to include a local market would be straightforward).

First, consider the effect of border inspection if surplus were only a function of one good, x_i. Assume that good x_i is imported by a competitive group of price-taking importing firms, such that the marginal firm earns zero economic profit. Inspection regimes may directly charge importers for goods inspected or may impose additional storage costs and longer transit times. This shifts the supply curve for the good upwards and reduces the quantity of good x_i demanded while increasing the price of the good (Fig. 7.2).

In a two good system, the demand for good x_j depends on the prices of the goods i and j. Consumers make decisions about how much of each good to consume as a result of the new prices (Fig. 7.3), the resulting allocation reflecting both income and substitution effects. The income effect results in a loss of surplus; however, the ability of consumers to substitute an alternative good offsets some of the potential utility loss. It follows that, the loss of consumer surplus depends on the elasticity of substitution between the goods. If the goods are perfect substitutes, then only the lower priced good would be consumed, and when the price of good x_i increases society reduces consumption of good x_i up to the point where good x_j becomes the lower priced good. After which good x_i is not consumed and $m_i = 0$. When the elasticity of substitution is finite, the consumption of both goods will change.[2] This change in the demand for good x_j has a feedback effect on the demand for good x_i so there is also a demand shift for good x_i (Fig. 7.4).

The third term in the border inspection agency's problem is the expected damage from introduced pathogens or the risk of disease. The probability of introducing a pathogen from country i is a function of the volume of trade from country i, the characteristics of country i, and inspection effort directed at goods from country i. Let γ_i represent the probability that an infectious pathogen is introduced from country i into the country i, so that $\gamma_i = \gamma_i(m_i, e_i, \theta_i)$, with $\partial\gamma_i/\partial m_i > 0$ and

[1] Even if the likely response were to be suboptimal, the expected damage of the future response that should be determined prior to the inspection effort needs to be determined.

[2] While we focus on substitute goods, if goods and x_i and x_j were complements, then the reduced quantity demanded for x_i would also reduce the demand for x_j potentially creating greater welfare loses, but also potential additional risk reductions.

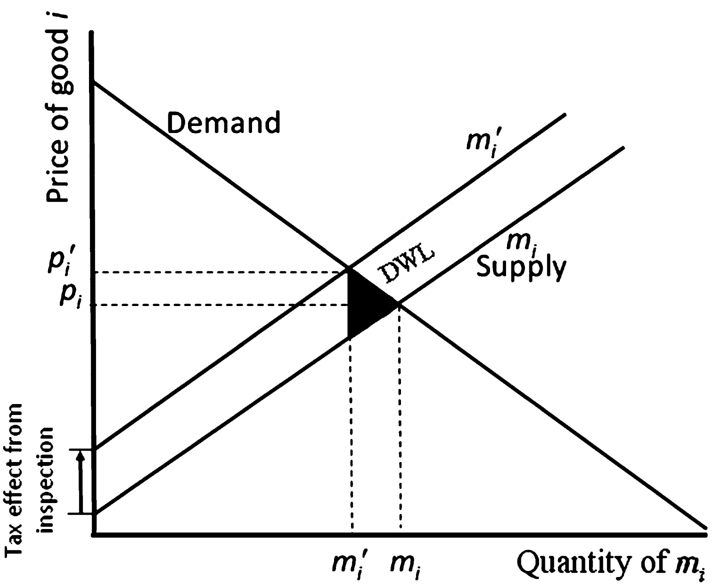

Fig. 7.2 The market for imported good m_i. The line m_i indicates the import quantities and prices of good m_i at an initial level of inspections. The line m_i' indicates the import quantities and prices of good m_i in with a more stringent level of border. With inspections the domestic market price of m_i increases from p to p'. The loss of produced and consumer surplus is illustrated by the *black triangle*

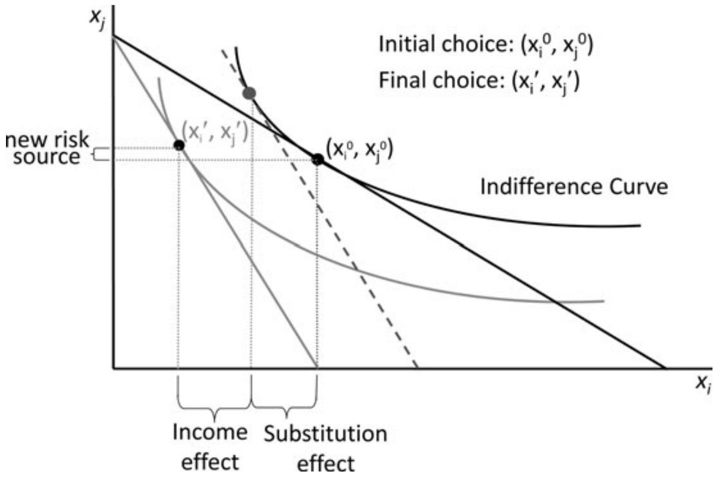

Fig. 7.3 How a representative consumer substitutes between goods. Summing over consumers can lead to increases in import volume of other goods. (x_i^0, x_j^0) are a representative customer's initial preferences of trade goods from country *i* and *j*. (x_i', x_j') are the final preference choices of good *i* and *j* after a price increase due to higher inspection cost. This preference change includes substitution effect and income effect. Trade reduction from country *i*, x_i will lower the risk of pathogen introduction; while at the same time, trade increase from country *j*, x_j may cause new risk of pathogen introduction

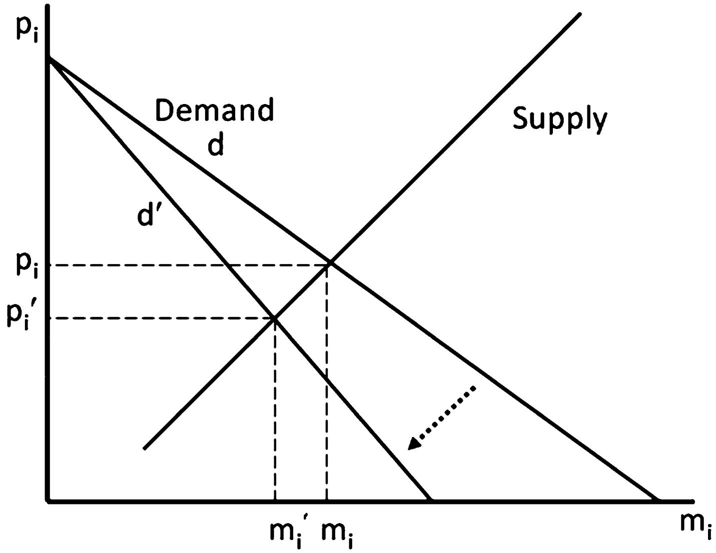

Fig. 7.4 The market for demand good m_i. When inspection on good from country i increase, market price of good i increase too. This leads to customer to look for substitutable goods. And hence demand for x_i shifts from d to d'; correspondingly, trade volume decrease from m_i to m_i'

$\partial \gamma_i / \partial e_i < 0$. We note, however, that $m_i = m_i(\mathbf{e}, \mathbf{m}_{-i}, d(x_i))$ where $\mathbf{m}_{-i}$ is the vector of all goods except i.

If the probability of pathogen introduction by countries i and j is statistically independent, then

$$\gamma(\mathbf{e}, \mathbf{m}, \theta) = \gamma_i + \gamma_j - \gamma_i \gamma_j. \tag{7.2}$$

Since the cost of infection is not dependent of the source, (7.2) indicates that the risk of infection is jointly determined by the volume of trade in and inspection of goods from all sources.

In much of the animal health and invasive species literature, risk is assumed to be independent of human prevention activities or exogenous (e.g., Leighton 2002; Caley et al. 2006; Gubbins et al. 2008). Therefore, if the surplus effects are ignored (i.e., $S(\mathbf{x}) = 0$), then one might reason that the marginal cost of increased inspection, $W'(e_i)$ should be set equal to the marginal benefits from reducing risk, $\partial \gamma / \partial e_i$ for all countries independently. However, the same forces that change demand and supply resulting from the costs imposed by border inspections, also drive changes in $\mathbf{m}$. Assuming market clearing conditions, $\mathbf{m} = \mathbf{x}$, importing firms and consumers cause the market to reach a new equilibrium in terms of quantities, $\mathbf{x}$, and prices, given a level of inspection effort. Therefore, the inspection agency's choice of $\mathbf{e}$ affects both the cost of inspection and consumer surplus, S, and has both a direct and an indirect effect on the probability of pathogen introduction through γ.

It follows that the choice of **e** has three effects on risk. First, an increase in inspection effort directly reduces that probability that an infectious agent makes it into the country. This reduces the risk of infection. Second, an increase in e_i increases the price of x_i decreasing the quantity of x_i demanded, and therefore the volume of good i imported (m_i). This decrease in m_i is expected to reduce risk, all else equal. This implies that a given level of risk reduction may require less inspection effort when the price effects of the inspection program are considered. Third, assuming that goods i and j are substitutes, then an increase in the price of good i will increase the demand for good j from country j. If country j's specific characteristics are such that country j has a significantly higher probability of introducing a pathogen conditional trade volume than country i, then it is possible that increases in e_i could actually increase γ through γ_j, consistent with the finding of Kohn and Capen (2002). The opposite is also true if country j is considerably less risky, since ignoring the substitution effect would result in over-investment in inspection. Therefore, in addition to country specific characteristics, the elasticity of substitution among goods is important for devising efficient border inspection programs.

Formally, it is possible to find the optimal inspection effort directed at good i by differentiating (7.1) with respect to e_i.

$$\frac{\partial C}{\partial e_i} = \frac{\partial W}{\partial e_i} - \frac{\partial S}{\partial \mathbf{x}}\frac{\partial \mathbf{x}}{\partial e_i} + Z\frac{\partial \gamma}{\partial e_i} + Z\frac{\partial \gamma}{\partial \mathbf{m}}\frac{\partial \mathbf{m}}{\partial e_i} = 0. \tag{7.3}$$

The first right-hand-side (RHS) term is the marginal direct cost of increasing inspection effort. The second RHS term is the indirect cost associated with a loss of producer and consumer surplus as a result of the costs imposed on the market by the inspection program. The third RHS term is the direct marginal risk reduction associated with an increased probability of intercepting a pathogen with increased effort – a benefit. The final RHS term is the indirect effect on risk of the shifts in market supply and demand as a result of the inspection effort. This term includes own price effects that reduce risk, and cross-price effects that have an ambiguous effect on risk.

Now consider what happens as the number of source countries and goods gets large. If a country has a large number of trading partners and imports a large number of goods, then it is likely that there will be a close substitute for inspected goods. If the highest probability goods are targeted, then we may expect inspections to induce substitution, i.e., inspections reduce the probability that a pathogen crosses the border and the substitution effect reduces the volume of trade in the risky good. If this were the only effect, then we would expect little welfare loss because a large number of substitutes increases the probability of finding a close substitute. However, as the number of trading partners increases, the differences among the θ_i's likely decrease. This implies that the substitute good becomes more likely to also introduce a pathogen (though perhaps a different pathogen). Spillover effects of inspection efforts increase, and targeting risk becomes more complicated with a large number of trading partners and commodities.

Case Studies

To provide a preliminary test of the strength of substitution effects on disease risks we consider three cases. The first of these is bovine tuberculosis in the U.S. Wolf et al. (2008) analyze effect of different levels of bovine tuberculosis inspection on cattle imports from Mexico to the U.S. Bovine tuberculosis is endemic in Mexico, but only occurs in isolated areas in the U.S. that are close to the Mexican border or associated with a wildlife reservoir (e.g., in Michigan where bovine tuberculosis is endemic in wild deer). Wolf et al. showed that more prevention effort leads to an increase of the price of cattle in U.S. markets and changes the quantity demanded of cattle and other goods. They considered multiple levels of border inspection intensity, including a ban on all Mexican cattle. Their analysis showed that a ban on importing Mexico cattle would increase U.S. prices for beef and live steers. A ban lasting 5 years would increase the retail price of live steers by $6.02 per cwt and the retail price for beef by $8.78 per cwt. Supply and consumption of beef were projected to decline by 3,135 million pounds. Wolf et al. considered an alternative strategy that allowed imported Mexican cattle subject to increased testing for bovine tuberculosis at the border. This increased the cost of each animal imported, the cost of additional inspection being estimated to be 2.4% of the value of the animal (Federal Register, Vol. 69, No. 138).

A second case is bovine spongiform encephalopathy (BSE). Most U.S. cattle imports come from Mexico and Canada. It is a reasonable hypothesis that a ban on cattle from Mexico would increase demand for Canadian cattle. In December 2003, a cow in the U.S. tested positive for BSE. This cow had been imported from Canada (CDC 2010), which – as of February 2010 – had reported 18 additional cases of BSE (CDC 2010). The detection of a BSE positive cow in the U.S. induced trade restrictions on U.S. cattle that resulted in significant trade losses as well as domestic adaptation costs; these losses were not “disastrous” due to a combination of unique market conditions (Mathews et al. 2006). Nevertheless, it seems feasible that in addition to the costs of additional inspection of Mexican cattle reported by Wolf et al., there is also the potential for increased disease risk from cattle from other sources.

The detection of a single infected cow in the U.S. led almost 15 countries to ban U.S. beef and cattle products. In 2004, U.S. beef export declined dramatically (Fig. 7.5). However, the world beef export volume continued to increase (Fig. 7.5), which suggests that countries substituted beef and cattle products from other sources. Three of the four largest importers of U.S. beef (Japan, South Korea, and Mexico) increased imports from Australia, New Zealand, and South America to substitute for U.S. beef and beef products (Mathews et al. 2006) and total exports from these countries increased (Fig. 7.6). Interestingly, New Zealand has suffered from ongoing bovine tuberculosis infections and South America has suffered from ongoing foot and mouth infection (OIE Handistatus database II, http://www.oie.int/hs2/report.asp?lang=en). Therefore, these changes in sourcing beef and cattle products may have increased the overall exposure of these countries to reinfection from these pathogens. This is particularly true for Mexico, which had experienced

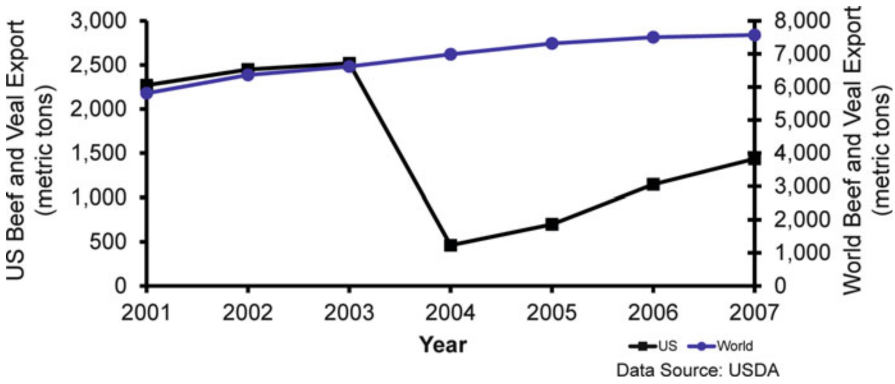

Fig. 7.5 U.S. and World beef and veal exports from 2001 to 2007. Though U.S. beef and veal exports declines dramatically in 2004, world exports increased instead

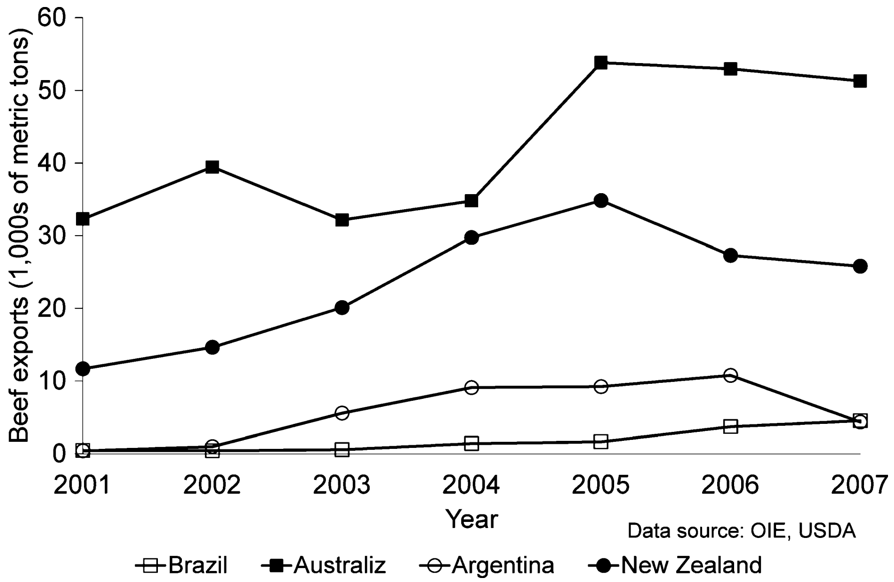

Fig. 7.6 Cattle exports from Brazil, Australia, Argentina, and New Zealand from 2001 to 2007. These are BSE free countries during these years. All export volumes increased after 2004, after the U.S. detected BSE

its last FMD outbreak in 1954 (OIE Handistatus database II, http://www.oie.int/hs2/report.asp?lang=en).

BSE affected trade within Europe (Mathews et al. 2003). Outbreaks of BSE in the U.K. caused importing countries to ban the imports of live cattle form the U.K.

and increased expenditures for BSE inspection and interception. Data show that after outbreaks of BSE in U.K. in 1996, the export of beef and live cattle from U.K. dramatically declined. However, data also show that world beef imports remained stable in that period. This implies that beef imports were resourced. Following the ban on U.K. cattle, the range of the livestock disease bluetongue expanded into northwestern Europe. This range expansion is generally attributed to climate change (Purse et al. 2008). However, Jones et al. (2008) found little evidence for climate related shifts in vector-borne pathogens such as blue tongue, and shifts in trade patterns cannot be ruled out.

Conclusion

To establish inspection policies that aim to minimize the sum of expected costs and damage, it is important to consider the market response to any inspection program. Prior work has largely focused on the direct costs and direct expected benefits associated with increases in expected inspection efforts and disease risk mitigation. Inspection programs have the potential to cause indirect effects through changes in importer behavior (see Ameden et al. 2007 for other types of firm response then those discussed here). The incentives that inspection efforts provide for importers to re-source goods or change import volumes have received less attention. To date, there appears to be two distinct literatures. The first literature largely focuses on how to balance the marginal cost of inspection effort with the marginal risk reductions from increased probability of mitigating against pathogen introduction. The second literature focuses on the use of market-based policy instruments that provide incentives for individual agents to internalize and reduce risk. Yet, inspection programs likely do both. In this chapter, we have laid out how inspection programs may also provide incentives for importing agents to alter their importing behavior. We also show that if these incentives are not considered, there is the possibility that additional inspection effort could increase risk.

Costello et al. (2007) provide evidence that biogeographic similarity and trade volume is important for identifying the probability that a trading partner will introduce an invasive species. Perrings et al. (2010) find similar results for invasive animal pathogens. The ability to identify such probabilities through easily observed proxies has lead to many recommendations for invasive species inspection programs (e.g., Caley et al. 2006; Keller et al. 2007). Although extremely useful, this information is insufficient to design an efficient inspection and interception program. It is important to account for the alternative goods that will arrive as a result of trade diversions from the increased cost of importing goods that are perceived to be more risky. Not considering these effects likely results in too much effort being spent on some goods or some sources and not enough on others. For this reason, we believe that it is important to build substitution and trade diversion effects into the design of inspection programs.

References

Ameden, H. A., S. B. Cash, and D. Zilberman (2007) Border enforcement and firm response in the management of invasive species. Journal of Agricultural and Applied Economics 39:35–46.

Ameden, H. A., P. C. Boxall, S. B. Cash, and D. A. Vickers (2009) An agent-based model of border enforcement for invasive species management. Canadian Journal of Agricultural Economics 57:481–496.

Batabyal A.A. (2007) International aspects of invasive species management: a research agenda. Stochastic Environmental Research and Risk Assessment 21:717–727.

Caley P, W.M. Lonsdale, and P.C. Pheloung (2006) Quantifying uncertainty in predictions of invasiveness. Biological Invasions 8:277–286.

Cassey P. et al. (2004) Influences on the transport and establishment of exotic bird species: an analysis of the parrots (Psittaciformes) of the world. Glob. Change Biol. 10, 417–426.

CDC (Centers for Disease Control). BSE (Bovien Spongiform Encephalopathy, or Mad Cow Disease). http://www.cdc.gov/ncidod/dvrd/bse/. Downloaded 6/8/2010.

Cleaveland, S., M. K. Laurenson, and L. H. Taylor (2001) Diseases of humans and their domestic mammals: pathogen characteristics, host range and the risk of emergence. Philosophical Transactions of the Royal Society of London B 356:991–999.

Collins, J. P. and A. Storfer (2003) Global amphibian declines: sorting the hypotheses. Diversity and Distributions. Vol 9(2): 89–98.

Costello C, M. Springborn, C. McAusland, and A. Solow (2007) Unintended biological invasions: Does risk vary by trading partner? Journal of Environmental Economics and Management 52: 262–276.

Dalmazzone, S. (2000) Economic Factors affecting vulnerability to biological invasions, in C. Perrings, M. Williamson and S. Dalmazzone (eds) The Economics of Biological Invasions, Cheltenham, Edward Elgar: 17–30.

Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare (1999) Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases. Vol 5: 735–748.

Economic cost of foot and mouth disease in the U.K. (2002) A report to Department for Environment, Food and Rural Affairs.

Finnoff, D., J.F. Shorgren, B. Leung, et al. (2007) Take a risk: Preferring prevention over control of biological invaders. Ecological Economics. Vol 62(2): 216–222.

Guan, Y., B. J. Zheng, Y. Q. He, et al. (2003) Isolation and characterization of viruses related to the SARS coronavirus from animals in Southern China. Science. 302:276–278.

Gubbins S, S. Carpenter, M. Baylis, J.L.N. Wood, and P.S. Mellor (2008) Assessing the risk of bluetongue to U.K. livestock: uncertainty and sensitivity analyses of a temperature-dependent model for the basic reproduction number. Journal of the Royal Society Interface 5: 363–371.

Gurevitch, J. and D. K. Padilla (2004) Are invasive species a major cause of extinctions? Trends in Ecology and Evolution. Vol 19(9): 470–474.

Horan, R. D., E.P. Fenichel, C.A. Wolf, and B.M. Gramig (2010) Managing infectious animal disease systems. Annual Review of Resource Economics. Vol 2: 101–124, doi:10.1146/annurev.resource.012809.103859.

Horan, R. D., E. P. Fenichel, and R. T. Melstrom, (2011) Wildlife disease bioeconomics. International Review of Environmental and Resource Economics. Vol 5: 23–61, doi.org/10.1561/101.00000038.

Horan, R. D, and F. Lupi (2005) Tradeable risk permits to prevent future introductions of invasive alien species into the Great Lakes. Ecological Economics 52:289–304.

Horan, R. D., and C. A. Wolf (2005) The economics of managing infectious wildlife disease. American Journal of Agricultural Economics 87:537–551.

Horan, R. D., C. A. Wolf, and E. P. Fenichel, (2012) Dynamic Perspectives on the Control of Animal Disease: Merging Epidemiology and Economics. In Zilberman, O. Joachim,

D. Roland-Host, D. Pfeiffer (eds.) Health and Animal Agriculture in Developing Countries, Springer, 135–143.

Jones, K. E., N. G. Patel, M. A. Levy, A. Storeygard, D. Balk, J. L. Gittleman, and P. Daszak. (2008) Global trends in emerging infectious diseases. Nature 451:990–994.

Lanciotti, R. S., J. T. Roehrig, V. Deubel, et al. (1999) Origin of the West Nile virus responsible for an outbreak of Encephalitis in the Northeastern United. Science. Vol 286: 2333–2337.

Lips, K.R., F. Brem, R. Brenes, et al. (2006) Emerging infectious disease and the loss of emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. Proceedings of the national academy of sciences of the United States of America. Vol 103 (9): 3165–3170.

Keller, R. P., D. M. Lodge, and D. Finnoff (2007) Risk assessment for invasive species produces net bioeconomic benefits. Proceedings of the National Academy of Sciences 104(1):203–207.

Kilpatrick, A.M., A.A. Chmura, D.W. Gibbons, R.C. Fleischer, P. P. Marra, P. Daszak, (2006) Predicting the global spread of H5N1 avian influenza. Proceedings of the National Academy of Sciences of the United States of America 103, 19368–19373.

Kohn, R. and P.D. Capen (2002) Optimal volume of environmentally damaging trade. Scottish Journal of Political Economy. 49(1): 22–38. http://papers.ssrn.com/sol3/cf_dev/AbsByAuth.cfm?per_id=27435; http://papers.ssrn.com/sol3/cf_dev/AbsByAuth.cfm?per_id=334786.

Leighton, F. A. (2002) Health risk assessment of the translocation of wild animals. Scientific and Technical Review International Office of Epizootics 21: 187–195.

Leung, B., et al. (2002) An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proceedings of the Royal Society, London B. 269:2407–2413.

Li, W. D., Z. L. Shi, M. Yu, et al. (2005) Bats are natural reservoirs of SARS-like coronaviruses. Science. 310:676–679.

Mathews, K., J. Bernstein, and J. Buzby (2003) International Trade of Meat/Poultry Products and Food Safety Issues In Buzby, J. (eds). International Trade and Food Safety: Economic Theory and Case Studies. Agricultural Economic Report No. 828. U.S. Department of Agriculture, Economic Research Service.

Mathews, Jr. K.H., M. Vandeveer, and R.A. Gustafson (2006) An economic chronology of bovine spongiform encephalopathy in the North America. Electronic outlook report from the Economic Research Service, USDA, LDP-M-143-01.

McAusland, C., and C. Costello (2004) Avoiding invasives: Trade-related policies for controlling unintentional exotic species introductions. Journal of Environmental Economics and Management 48: 954–977.

Otte, J., D. Roland-Holst, and D. Pfeiffer, et al. (2007) Industrial Livestock Production and Global Health Risks. A Living from Livestock. Research Report. 1. RR Nr 07–09; June 2007. Available at http://www.fao.org/AG/AGAINFO/programmes/en/pplpi/docarc/rep-hpai_industrialisationrisks.pdf.

Pavlin, B. I., L.M. Schloegel, and P. Daszak (2009) Risk of importing zoonotic diseases through wildlife trade. United States Emerg Infect Dis. 15(11):1721–1726.

Perrings, C. (2005) Mitigation and adaptation strategies for the control of biological invasions. Ecological Economics 52:315–325.

Perrings, C., E.P. Fenichel, and A.P. Kinzig (2010) Globalization and Invasive Alien Species: Trade, Pests, and Pathogens. In: Perrings C, Mooney H and Williamson M (eds) Bioinvasions and Globalization, pp 42–55, Oxford University Press, Oxford.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. (2000) Environmental and economic costs of nonindigenous species in the United States. Bioscience, 50(1): 53–56.

Pimentel, D. (2002) Biological invasions: economic and environmental costs of alien plant. Boca Raton, Fla.; London: CRC Press.

Pimentel D., R. Zuniga, and D. Morrison. (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52: 273–288.

Purse, B.V., H.E. Brown, L. Harrup, P.P.C. Mertens, and D. J. Rogers (2008) Invasion of bluetongue and other orbivirus infections into Europe: the role of biological and climatic processes. Scientific and Technical Review International Office of Epizootics 27: 427–442.

Simberloff, P. (1996) Impacts of introduced species in the United States. Consequences Vol. 2(2): Achieved from http://www.gcrio.org/CONSEQUENCES/vol2no2/article2.html.

Semmens, B.X. et al. (2004) A hotspot of non-native marine fishes: evidence for the aquarium trade as an invasion pathway. Mar. Ecol. Prog. Ser. 266, 239–244.

Springborn, M., C. Costello, and P. Ferrier (2010) Optimal Random exploration for trade-related nonindigenous species risk. In C. Perrings, H. Mooney and M. Williamson, eds. Bioinvasions and Globalization: Ecology, Economics, Management, and Policy, Oxford University Press, Oxford.

Walters, C. (1986) Adaptive management of renewable resources. MacMillan Publishing, New York.

Wiens, J.J. and C.H. Graham (2005) Niche Conservatism: Integrating evolution, ecology, and conservation biology. Annual review of ecology evolution and systematics. Vol 36: 519–539.

Williamson, M.H. (1996) Biological invasions. Chapman &Hall, London.

Wolf, C., J. Hadrich, R. Horan, P. Paarlberg, and J. Kaneene (2008) Economic analysis of US TB eradication program options. A report to the U.S. Department of Agriculture, Animal and Plant Health Inspection Service.