International Trade in Agricultural Products – Economic Aspects of Exposure to Risk for Infections

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Report no. 160

1999

TITLE: International Trade in Agricultural Products –
Economic Aspects of Exposure to Risk for Infections

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PUBLICATION: Report no. 160, 1999

ISBN-NO: 82-7401-124-4

FINANCIAL SUPPORT: The Norwegian Royal Ministry of Agriculture

PROJECT CODE: 98078

HEAD OF PROJECT: Lars Håkonsen

START OF PROJECT: April 1999

END OF PROJECT PERIOD: August 1999

ABSTRACT:

This report studies welfare and policy aspects of exposure to risk for infections and diseases related to increased imports of agricultural products to Norway. With no market failures, an importing country will have gains from trade whenever the price of imported goods is below the domestic market price. However, the expected costs associated with such a risk for imported infections and diseases constitutes a negative externality. This calls for a corrective tax on the imported goods, i.e., a tariff.

The use of the price mechanism alone is in most cases not the most efficient policy. Control measures may be employed to reduce the risk of importing infected goods. The gains from a reduction in the risk, must be balanced against the control costs. Unless the marginal cost of control is an increasing function of the number of controlled units, it is better to control all imported units than to control only a share of the imported goods.

The first best optimal import policy requires a combination of control measures and a tariff. With control measures in place, the optimal tariff includes *the cost associated with the remaining risk after control plus the control costs*. Thus the price of the imported goods should include both the marginal control costs and the expected marginal costs associated with the after-control risk. Then, the resulting import volume will maximise the gains from trade. Such a trade optimum involves a trade off between gains (reduced domestic price, increase in consumer surplus) and costs (expected cost of infections/diseases, control costs). This applies if we assume risk neutrality. With risk aversion, a risk premium must be added to the expected marginal external cost in order to sustain the efficient import volume.

SUMMARY	*DATE*	*NUMBER OF PAGES*	*PRICE*
No	26 August 1999	44	NOK 120

KEYWORDS

Imports of agricultural goods, risk for infections, external costs, optimal tariffs,

control measures

PUBLISHER

Telemark Research Institute-Bø
N-3800 Bø, Norway
Phone +47 35 06 15 00 Fax +47 35 06 15 01

ORDER FROM: Publisher

PREFACE

This work represents the final report of the project “International Trade in Agricultural Products – Economic Aspects of Exposure to Risk for Infections”, financed by the Norwegian Royal Ministry of Agriculture. My colleague Knut Løyland and participants at two seminars held in the Ministry of Agriculture are thanked for valuable comments and suggestions. All views and any remaining errors are my own.

Bø, August 26, 1999

Lars Håkonsen

1 INTRODUCTION

This report studies welfare and policy aspects of exposure to risk for infections and diseases related to increased imports of agricultural products to Norway. It is well documented that Norway has a relatively favourable situation with respect to plant, animal, and human diseases stemming from agricultural products. A status of the Norwegian plant and animal health situation, and an assessment of the risk associated with increased international trade in agricultural products, have been worked out in two reports from The National Veterinary Institute and The Norwegian Crop Research Institute, Plant Protection Centre. This reports follows up these assessments, and analyses the economics of trade-related infections and diseases with potentially harmful consequences for plant, animal or human health.

It is fairly obvious that imports of agricultural products to Norway may cause higher exposure to a range of infections and diseases. Imports of particular goods from particular countries may cause outbreaks of new diseases – or cause a higher frequency of existing ones. Both these events may be regarded as an external cost; a cost for society which is related to the imported quantity of agricultural products, but which is not reflected in the price of the imported goods. The main theme of this report is to analyse the structure of this problem, and to relate it to the theories on trade-, tax-, and environmental policy.

We start in section 2 by giving a brief summary of the prospects of gains and losses from increased trade in situations with and without negative externalities. Section 3 proceeds by drawing a distinction between public goods or external effect as the main sources of market failures related to imported goods. Sections 4 and 5 studies how we may model a risky event – imports with some probability for each unit being infected – in order to compare gains and costs from increased trade, and define an optimal import volume. In section 5, special emphasis is placed on the implications of attitudes towards risk/varying degrees of risk aversion. In section 6, we discuss whether unregulated markets can be capable of obtaining an efficient outcome, i.e., whether the negative effects may be internalised into each decision maker's objective function without government intervention. Section 7 follows up section 6 by discussing how legislation may help the process of internalising the costs related to infections and diseases into the private importers' or exporters' objective functions. Section 8 analyses control measures which aims at detecting infected units before they pass across the border, and extends the analyses of optimal import volumes and tariffs to a case where the authorities can adopt both control measures and tariffs simultaneously. Finally, section 9 recapitulates some major points and concludes.

2 ON GAINS AND LOSSES FROM TRADE

It is a well known and undisputed fact that countries may gain from international trade. The theory of comparative advantage made clear a long time ago that in a perfectly competitive economy, the only prerequisite for gains from trade is that countries differ with respect to relative prices. Thus, if the relative price on agricultural products is higher in Norway than in some other country, both Norway and the other country will realise a gain if Norway imports agricultural products in exchange for products with the opposite relative price pattern.

The theory of comparative advantage explains inter-industry trade patterns[1]. Such trade only accounts for a limited share of the world's total trade activities, however. Partly as a response to this empirical fact, the

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[1] With inter-industry trade, different countries with different relative domestic prices engage in trade with each other, and each traded commodity-variety only goes in one direction. For example, England exports textiles to

last couple of decades has brought important contributions for explaining intra-industry trade patterns[2]. These explanations focus mainly on economies of scale, product-differentiation, and imperfect competition. Gains from trade then occurs because it becomes possible to specialise end exploit scale-economies, and at the same time avoid (or at least reduce) the problems of market power and too little product variety. There problems would be severe obstacles for economic development, especially in small countries, in the absence of trade.

Trade in agricultural products may be of both kinds – intra- and inter-industry trade. However, for the bulk of this trade, perfect competition and differences in relative costs are presumably the more relevant assumptions. In this report, we shall mostly make use of simple partial equilibrium diagrams (demand and supply curves) in order to analyse gains (and costs) from trade. In a situation with no market imperfections, a partial equilibrium diagram makes clear that there will be gains from trade if the domestic absolute price level is lower than the price level in a potential exporting country (or the international price level if there is a world market for the product in question). It should be noted that this is not at odds with the theory of comparative advantage and relative price differences. The shift of focus from relative to absolute prices, is simply due to the simplification introduced when we only consider one market at a time. The traditional analysis of the gains for an importing country is illustrated in Figure 1. In the Figure, we have assumed that Norway faces a horizontal international supply-curve, i.e., Norway is so small that increased Norwegian imports does not press the world market price, P^{WM}, upwards. This "small-country-assumption" seems reasonable for imports of most agricultural products into Norway. Domestic supply and demand are denoted S and D respectively, and the domestic price without trade (autarky) is P^D.

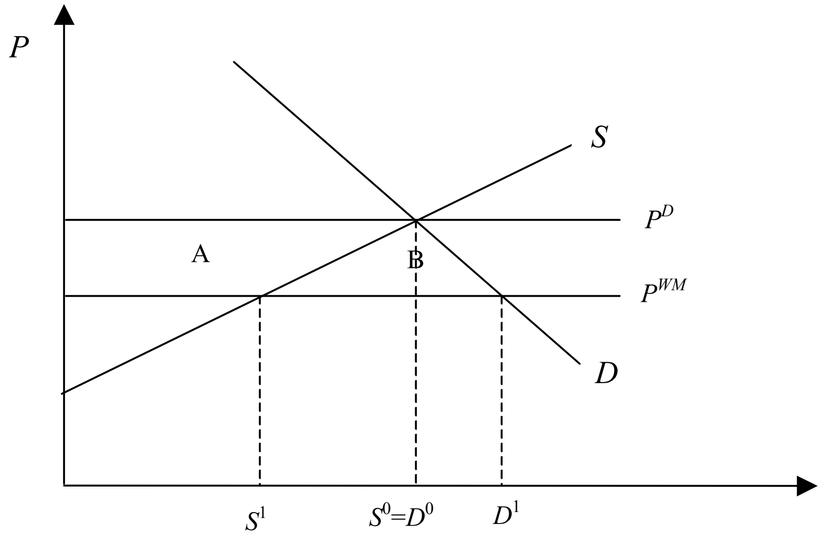

Figure 1. Gains from trade

A simple cost-benefits analysis based on the areas shown in the figure tells us that:

- the consumers gain the area A (increase in consumer's surplus[3])

Portugal and Portugal exports wine to England (Ricardo's famous example from the early 19th century), and there are no exports of wine from England to Portugal, or exports of textiles from Portugal to England.

[2] Inta-industry trade means that similar countries simultaneously import and export similar products. An example could be that Finland exports Nokia telephones to Sweden and imports Ericson from Sweden – and vice versa.

[3] The consumer's surplus is not an accurate measure of the money metric gain in utility for the consumers when one or several prices change; the equivalent or compensating variation (based on compensated rather than

- the producers' profits decline with the amount B
- the net change in social surplus equals A-B = C

The fundamental idea behind the gains from trade shown in Figure 1 is very simple: The international price is the relevant marginal cost if importing the commodity, while the domestic supply-schedule represents the marginal cost if producing the good in Norway. Whenever it is possible to import something which the domestic consumers demand at a lower cost than that of domestic production, Norway will save productive resources which have a higher value in alternative use, i.e., a higher opportunity cost. By importing, and shifting the productive resources into a sector or industry which does not have a cost disadvantage, Norway will increase the national product and realise a welfare gain.

The potential for welfare losses from international trade

The above analysis was based on the assumption that the import price was the only relevant marginal cost component when importing a commodity to Norway. If there exists market failures, however, it is in principle possible that a gain is turned into a loss. Such a situation is depicted in Figure 2, in which it is assumed that the imported goods create a negative marginal external cost.

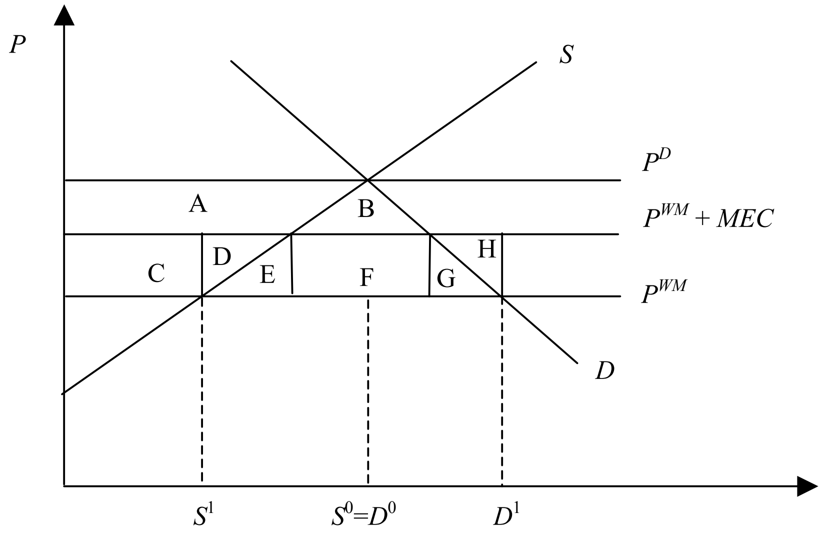

Figure 2. Costs and gains from trade with negative external costs related to imported goods.

In Figure 2, the cost-benefit accounts from going from the autarky-equilibrium $S^0 = D^0$ to the trade equilibrium S^1, D^1 becomes as follows

- Change in consumer's surplus: A+B+C+D+E+F+G
- Change in profits: –(A+C+D)
- Change in external costs: –(D+E+F+G+H)

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uncompensated demand curves) are the theoretically correct measures of consumer welfare change. However, the measurement error associated with using the traditional consumer's surplus measure is in most cases

- Net change in social surplus: +B –(D+H)

In this particular example, we have that trade at the world market price affects national welfare (social surplus) negatively, compared to the autarky-situation (since B is smaller than (D+H)). Of course, no generality is claimed for this result; a lower marginal external cost schedule would imply that free trade at the world market price would still be better than autarky.

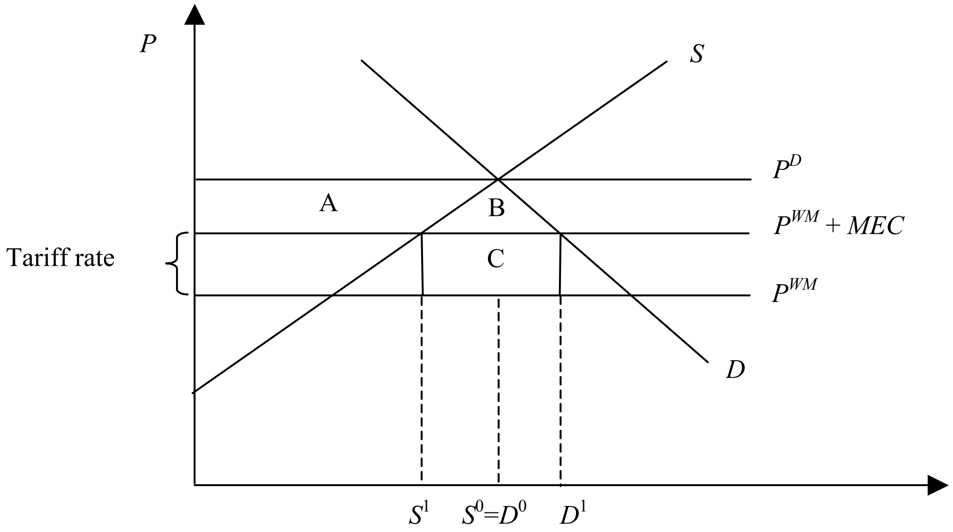

Figure 3. Optimal import volume achieved by a tariff rate equal to the marginal external cost.

The general lesson from Figure 2, however, is that free trade *at the world market price* P^{WM} is not the optimal policy if there are negative externalities. Whenever negative externalities come as a by-product of the trade activities, it is optimal to restrict the import volume to the point where the demand curve crosses P^{WM} plus *MEC*. This may be achieved by use of a tariff equal to the size of *MEC* at the optimum. Such an optimal tariff is shown in Figure 3. Again the areas in the figure show the changes by going from the autarky-equilibrium $S^0 = D^0$ into the trade equilibrium given the tariff rate t^*.

The optimal import volume shown in the figure, $(D^1\text{-}S^1)$, yields the following costs and benefits:

- Change in consumer's surplus:	+(A+B)
- Change in profits:	–A
- Change in external costs:	–C
- Change in tariff revenue	+C
- Net change in social surplus: +B	

Figure 3 may be seen as an application of the "polluter-pays-principle" (PPP), which states that the costs of a negative externality should be borne by its originator – in this case the imported goods. Thus, the correct import price is the full marginal cost – the price inclusive the marginal external cost. This is obtained by levying a tariff

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sufficiently small to yield a reasonable estimate of the welfare effect of a price change.

of the same size as the marginal external cost. Then, the decentralised actions of the market participants will realise the optimal outcome.

It is theoretically possible that the optimal tariff rate is prohibitive, i.e., for a sufficiently high external cost, such that $P^{WM} + MEC > P^{D}$, it is optimal to have zero imports and remain in the autarky equilibrium. However, whenever $P^{WM} + MEC$ is below the domestic price, the optimal tariff will not be prohibitive, and Norway will then be able to obtain a gain from trade.

The analyses and figures in this section have been based on a setting where the commodity in question is a final consumption good. However, the results will be equally valid for production factors/intermediate inputs. In such settings, the demand schedule is not represented by the consumers' willingness to pay, but rather by the producers' marginal value product of the input in question. As before, the domestic supply schedule will be represented by the domestic producers' marginal costs; the only difference is that it is intermediate and not final goods which are produced and supplied domestically. The same basic idea remains in this alternative setting: The good or factor in question will be imported as long as the import price is lower than the price of domestically supplied inputs. In the remainder of this report, the major part of the analyses will consider final consumption goods, but the reader should keep in mind that the input markets may be analysed in the same way[4].

3 PUBLIC GOODS VS. EXTERNALITIES

The agricultural policy in Norway as well as in other counties, is often motivated with reference to the existence of public goods which is provided as a by-product of agricultural production. In such a situation, an unregulated market will typically not provide the optimal supply of the public goods; there will be a *market failure*. The public goods which have been associated with agricultural production in Norway is mostly the provision of a diversified cultural landscape (agricultural landscape), food security, and maintenance of population in remote areas (Brunstad et. al. 1995). Food security is a term with several dimensions, see e.g. Bredahl et. al. (1999), including a sufficient production volume in cases of emergency. The term may also be taken to include the dimensions under consideration in this report; safety in the form of a low risk for being exposed to contaminated food. The existence of such public goods implies that there is a positive willingness to pay among Norwegian citizens for the provision of these goods. In the context of the partial equilibrium models in the previous section, this can be captured by subtracting the willingness to pay (WTP) for the public goods from the domestic supply schedule.

The outcome then becomes that the optimal volume of domestic production increases, and that the optimal import volume decreases, cf. Figure 4.

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[4] Imports of agricultural products as intermediate inputs may occur in a range of industries. E.g. in the agricultural sector itself, feed, livestock, etc. is traded internationally. Also, the food manufacturing industry would in an unregulated international market purchase a whole range of agricultural products internationally instead of at home, due to large differences between Norwegian and international price levels.

In Figure 4, the optimal level of domestic production is achieved by introducing a production subsidy equal to the marginal willingness to pay for the public good, such that the perceived marginal cost in domestic production becomes *S-WTP*, and domestic production rises from S^0 to S^{opt}. The same effect on domestic production could have been achieved by introducing a tariff of the same size as the production subsidy. However, the tariff would have the additional effect of raising the consumer price and reducing the consumed quantity below the optimal level D^{opt}. Thus, a tariff does not represent an efficient policy-instrument in a situation where domestic production creates public goods. Subsidising the source of the public good is more directly targeted towards correcting the market failure than the tariff: The production subsidy boosts domestic production and reduces the import volume, but leaves the consumed quantity unaffected at D^0=D^{opt}.

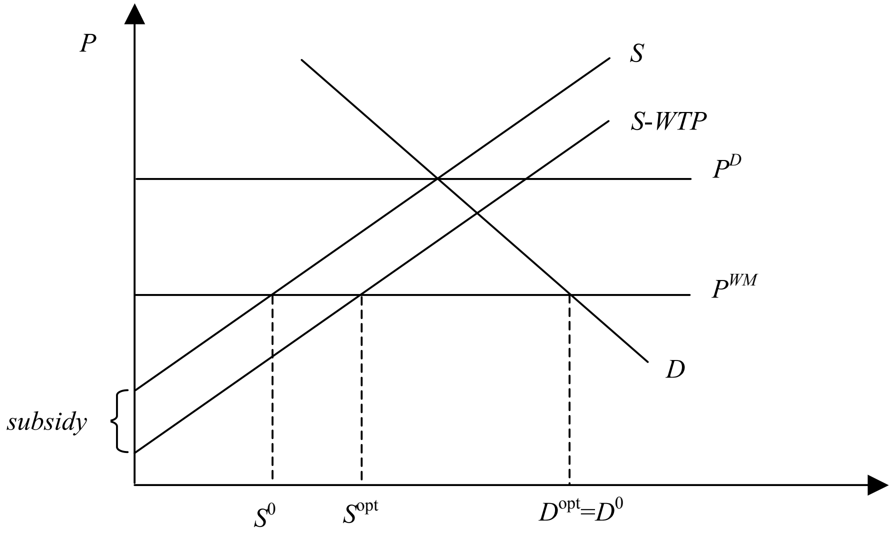

Figure 4. Optimal import volume when domestic production yields a public good.

The existence of "clean" food (i.e., a low risk for being exposed to contaminated food) may be categorised as a public good; the consumers may have a positive willingness to pay for avoiding an increase in such a risk. Whenever imports contributes to increasing that risk, imports may be said to reduce the supply of the public good "clean and safe agricultural products". However, in such a situation, the framework of a negative externality is in our view the most relevant one. It is the import activity as such which creates a cost – higher risk for exposure to contaminated food. The distinction between imports inflicting an external cost or deteriorating the supply of a public good, is perhaps more of a semantic character. Our main point is that the deterioration of the supply of public goods in such a case is linked to the import activity, implying that the real or true cost of imports is above the world market price. We therefore find the framework of a negative externality the most appropriate, and will use that terminology for the remainder of the report. As discussed above, this has the implication that the optimal policy is *not* to stimulate to a higher domestic production level by means of subsidies, but rather to adopt measures which are directly oriented towards the import activities. This conclusion only applies for the specific issue of higher exposure to contaminated imports of agricultural products. Production subsidies may certainly constitute a part of an optimal agricultural policy towards *other kinds* of market failures or political goals (e.g., preserving cultural landscapes).

4 A CLOSER LOOK AT POTENTIALLY NEGATIVE EFFECTS OF HIGHER IMPORTS

Until now, we have simply postulated that imports of agricultural products inflicts a marginal external cost due to higher exposure to contamination of various kinds. In section 2, this was modelled by introducing a marginal external cost which was added to the import price. In this section we shall take a closer look at how such a marginal external cost schedule may be derived from models of risk analysis, see e.g. Vose (1997) and Paisley (1999).

In models of risk analysis, one often starts by identifying a pathway of events which may lead to the importation of an infected product. Of course, this pathway of events will be highly dependent on the product and the disease or organism in question. After the pathway of events and the probabilities at each uncertain step in the chain have been determined, we end up with a certain probability distribution for the number of infected imported products. We may then compute the expected number of infections, and finally compute an expected cost schedule.

For welfare comparisons, uncertainty requires that we have a welfare measure which is defined over the uncertain events, i.e., an expected utility function. Only if we assume risk neutrality, we may take the expected value of the uncertain event and compare this figure directly to certain costs or gains. If we assume risk aversion, the *certainty equivalent* of an expected cost figure will be higher than the expected cost. We shall mostly focus on expected total and marginal costs in our analysis, but will return to the issue of the degree of risk aversion and certainty equivalents in section 5.

4.1 Two examples of cost types and probability distributions

Vose (1997) analyses a series of steps which eventually leads to the importation of a contaminated product. We briefly repeat his example, in which the issue is imports of turkeys, and the risky event is that contaminated meat finds its way to the final consumers in the supermarket. The probability of the described outcome at each step is given in parentheses[5].

- Source flock (in exporting country) is infected with disease X (p_1)
- Consignment taken from flock is infected (p_2)
- Infection in consignment is not detected during pre-slaughter testing (p_3)
- Infection is not detected during inspection at slaughterhouse (p_4)

⇒ Contaminated meat

In order to obtain analytical transparency, let us simplify such a chain of events into only one "aggregated" uncertain event. This single uncertain event may be thought of as the "end product" of a risk analysis model. This shortcut is done in order to focus on how expected total and marginal cost schedules may be derived under alternative assumptions about the probability distribution and the type of cost involved if the costly outcome occurs.

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[5] Each probability along the chain (except for p_1) is a conditional probability, i.e., the probability given that all the previous events have occured.

In many situations relating to imports, the relevant stochastic process will be the binomial. With a binomial process, there is a definable number, n, of trials (imported units), a probability of infection for each trial, p, and a resulting number of infected imported units, y. The basic assumption underlying the binomial process is that each trial has the same probability of infection as the previous one no matter what the outcome of the previous trials has been. Let $f(y;n,p)$ denote the probability density function for having y out of n goods infected – when each trial has a probability of p, and let $F(y;n,p)$ denote the corresponding cumulative probability for the number of infected imported goods belonging to the interval
$[0, \ldots, y]$.

We use two extreme assumptions about the consequences of infections in order to illustrate the some possibilities for the shape of the expected total and marginal external cost schedules.

4.2 Cases where each infected unit results in the same cost

We first consider a case where the external cost is a linearly increasing function of the *number of infected units*. An example of such a case can perhaps be that each case of salmonella-infected food inflicts the same cost for the consumers. The expected total cost is then simply the cost per case of infection times the expected number of infected units. With a binomial process with probability p for each unit being infected, the expected number of infected units (y) is given by

$$E(y) = \sum_{y=1}^{n} yf(y;n,p) = np, \tag{1}$$

i.e., the expected number of infected imported units is simply the number of imported units (n) times the probability of each unit being infected (p). If we denote the cost per case of infection c, we have that the expected total and "marginal" costs, $E(TC)$ and $E(MC)$, as functions of the import volume become

$$E(TC) = cpn \quad \text{and} \quad E(MC) = cp. \tag{2}$$

The graphs of $E(TC)$ and $E(MC)$ thus have the form as indicated below:

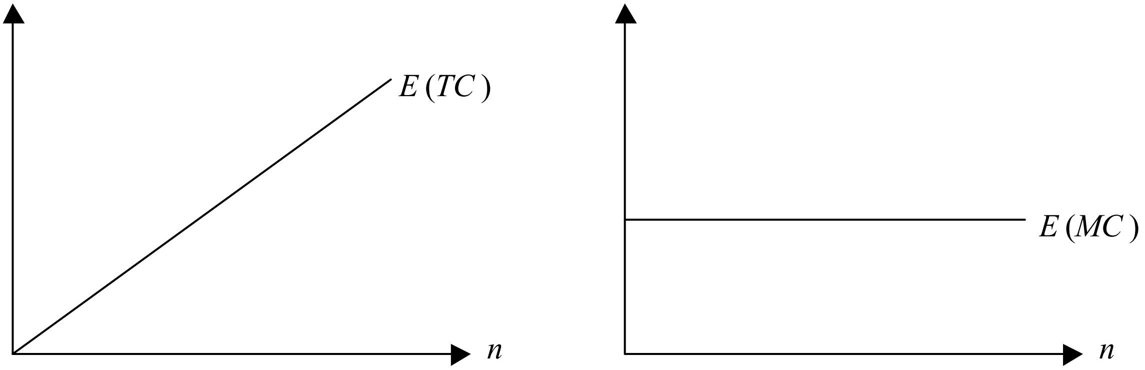

Figure 5. The shape of *E*(*TC*) and *E*(*MC*) when the damage per infected unit is constant.

4.3 “Catastrophic” scenario

Suppose now instead that a disease has the characteristic that very high costs will be the result if the disease first occurs. For example, it may be difficult or impossible to prevent the disease from spreading due to a long incubation period. We could perhaps think of the introduction of BSE (“Mad cow disease”) into Norway as an event falling into this category. The general feature of the case we have in mind, is that a new disease is introduced, and succeeds to establish in the Norwegian population (plant, animal or human). In such a situation, the cost will not be related to the *number* of infected imported units; one infected unit is enough for the costly situation to occur. Let the cost – in case of outbreak of the disease – be C, and zero otherwise. This cost may be constituted both by the damage which the disease causes directly, or indirect costs related to attempts to combat and/or eradicate the disease after successful establishment – or a combination of both these kinds of costs.

In such cases, the expected cost as a function of the number of imported units, n, is given by $C[1-f(0; n, p)]$, i.e., C times the probability for a non-zero number of imported infected units. The most relevant assumption is presumably a low probability in each trial. If not, the expected costs would soon become far greater than the gains from trade without taking the risk for infections/diseases into consideration. Choosing $p= 0.01$ and $p = 0.001$ (one percent and one tenth percent, respectively) yields the following graphs for $[1-f(0;n,p)]$:

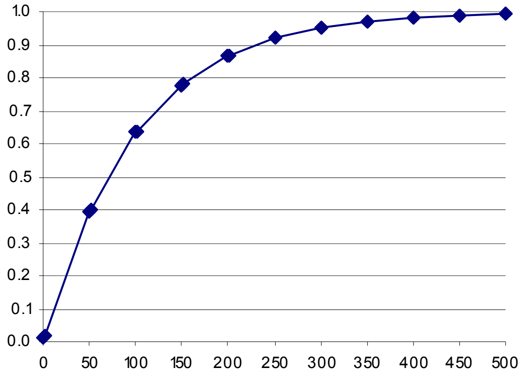

Figure 6a. 1-$f(0;n,0.01)$

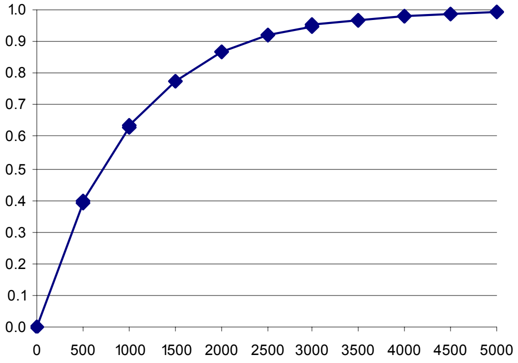

Figure 6b. 1- $f(0;n,0.001)$

The only difference between the two graphs is the scale of the n. The general picture which emerges from these examples, is that the probability for having at least one infected unit is more than 99% if n times p is 5 or more. The corresponding expected total cost schedule is obtained simply by multiplying the probabilities in the above graphs by C.

Since the binomial process is defined over discrete numbers, the density and cumulative distribution functions are not differentiable. The relevant construction – the discrete analogue of the derivative – is then the increment in probability when increasing n by one unit. By reference to figures 6a and b, the incremental probability, $[1-f(0,n+1,p)]$ –
$[1-f(0,n,p)] = f(0,n,p)- f(0,n+1,p)$), for having at least one infected unit starts at a high level and falls asymptotically towards zero. Figure 7 shows the incremental probability for the a case where p=0.01.

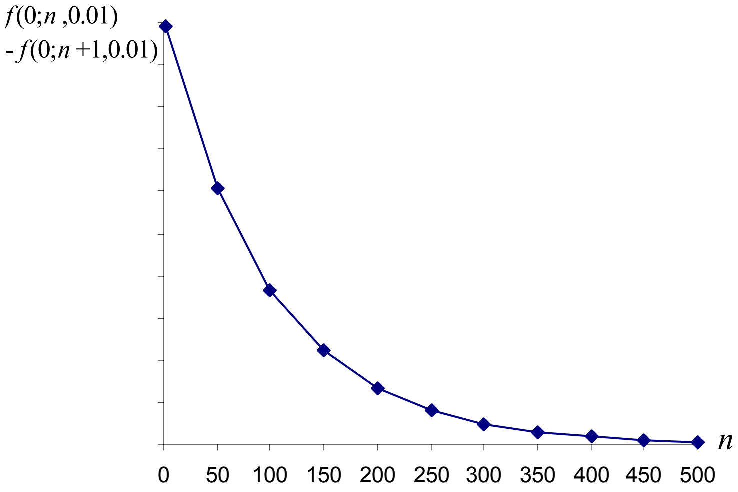

Figure 7. The incremental probability $f(0;n,p) - f(0;n+1,p)$ for at least one infected unit as function of n when $p = 0.01$

Thus, contrary to the case we saw in figure 5, the structure studied in this subsection will typically have falling marginal (incremental) cost schedules. The corresponding expected marginal (incremental) cost schedule is found by multiplying the incremental probability by the total cost *C*. For the remainder of the report, we shall for convenience refer to marginal costs instead of incremental costs, although we strictly speaking have non-differentiability of the probability density functions[6].

5 ATTITUDES TOWARDS RISK

In order to get an idea of the consequences of attitudes towards risk, let us continue by studying a simple, stylised example. By means of this example, we will study the implications of risk aversion in situations with external cost schedules having a similar structure as those in sections 4.2 and 4.3. Of special interest is how large an error we would make if we employ the expected cost figures directly in a cost benefit framework similar to the examples in section 2. We shall that this critically depends on both the degree of risk aversion and the nature of the cost schedules.

Let us assume the following demand, supply, and world market supply curves:
$P(x) = 100-x$, $S(x) = x$, $P^{WM}(x) = 25$. This yields the price-quantity diagram below:

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[6] It is of course standard to assume differentiability in most analytical problems in economics, i.e., to assume that quantity is a continuous and differentiable variable, although many goods only are sold as dicrete numbers.

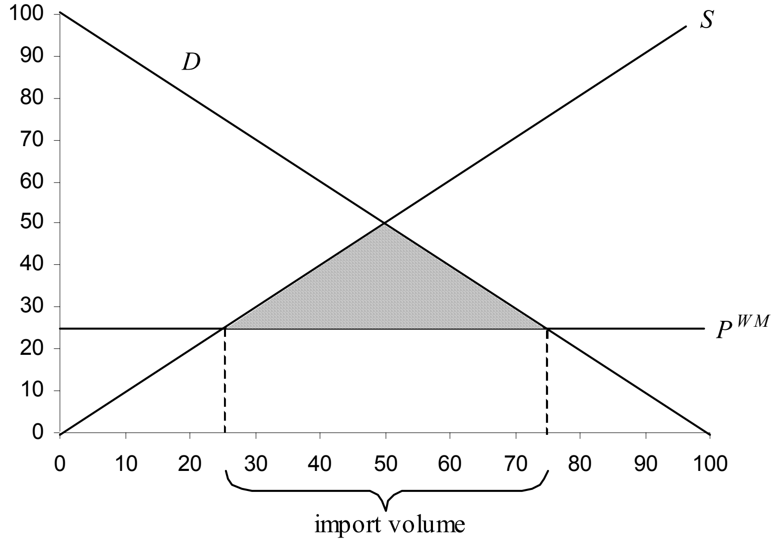

Figure 8. Demand, domestic supply, and world market price

In the absence of external effects, the gain by going from autarky to free trade would in this example be 625 (the shaded area), which represents the increase in social surplus, see also Figure 1. The domestic production would drop from 50 to 25, the demand would increase from 50 to 75, and the import volume would be 50.

A convenient way of expressing the gains from trade when introducing external effects, is by use of the *import demand curve*. This is found as the horizontal difference between the domestic demand and supply curves. The import demand curve in our example becomes $P^{IMP}(n) = 50\text{-}n/2$, i.e., at the autarky price 50, the import is zero, and at the world market price of 25, the import volume is 50. The same gross benefits from trade as shown in figure 8 may now be found as the shaded area located between the y-axis and the $P^{IMP}(n)$- and P^{WM}-curves, see figure 9.

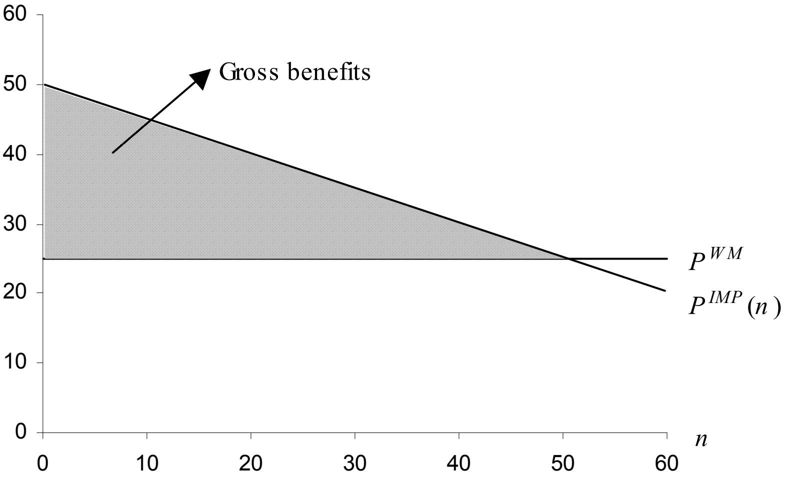

Figure 9. Import demand curve and world market price

In technical terms, the gross benefits of importing *n* units is given by

$$GB(n) = \int_{\tilde{n}=0}^{n} \left(P^{IMP}(\tilde{n}) - P^{WM} \right) d\tilde{n} = 25n - 0.25n^2, \qquad (3)$$

i.e., the definite integral of the import demand curve from zero to *n* imported units, minus *n* times the world market (import) price.

We are now ready to introduce negative externalities relating to imports in addition to the gross benefits measure in (3). In section 5.1, we study a case with the same structure as in section 4.1, while section 5.2 consider the catastrophic scenario of section 4.2. The examples are not meant to be taken literally, but instead to be thought of as "devices" which illustrates the underlying, general principles. This is done since it is felt that it may be easier to see the main principles from the worked examples, than by use of an analytical formulation.

5.1 Constant damage per infected unit

In order to get cost figures of a size comparable with the gross benefits described above, we assume that each infected unit gives a unit cost of $c = 100$. We furthermore assume that the probability of each imported unit being infected is 0.1, i.e., the number of infected units (y) as a function of the import volume (n) is represented by the binomial distribution, $f(y;n,0.1)$. If allowing for free trade at the world market price, the expected number of infected units would then be $np = 5$, causing an expected total external cost of 500. Thus, there will be an expected net benefit of 625-500 = 125 if trade takes place at the world market price. In this particular example, the critical number of infected units is 6, i.e., if seven or more units are infected, there will be a net loss. The density function for the number of infected units and the net benefits if 50 units are imported are shown in figure 10a and 10b. The net benefits, *NB*, is a function of import volume and the number of infected units, $NB(n,y) = GB(n) - 100y$. When $n = 50$, *NB* varies from 625 to –4375 as the number of infected units varies from zero to 50.

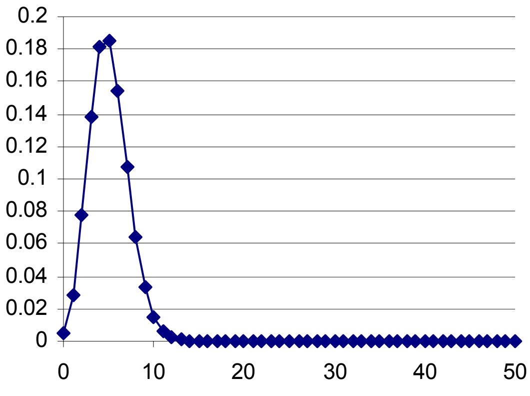

Figure 10a. Probability density, $f(y;n,p)$, for the number of infected units (y) if $n = 50$ and $p = 0.1$.

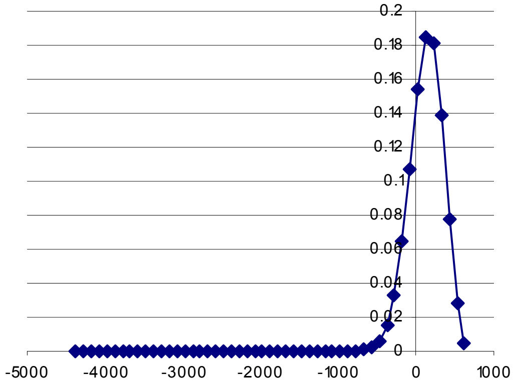

Figure 10b. Probability density for the net benefits, $NB(n,y)$, $n = 50$, $p = 0.1$.

These figures provides a useful overview of the "structure" of problems of these kinds: There is a prospect for realising gains if the number of infected units is not too high. In our example the *expected net benefit* of free trade at the world market price is positive. However, there is a small but positive probability for having a net loss. In principle, the loss could be large, e.g. if 40 out of 50 imported units are infected, but the probability for such an outcome is extremely small.

Optimal imports using the expected marginal cost

Let us first define the optimal import volume if we compute the expected marginal external cost, and compare that cost figure with the certain benefits directly. The expected marginal external cost in this example is simply $cp = 10$. We add the expected marginal external cost to the world market price to find the "full" price of imported goods. The import volume which maximises the expected *net* benefits – social surplus including expected marginal external costs – may then be read out of figure 11.

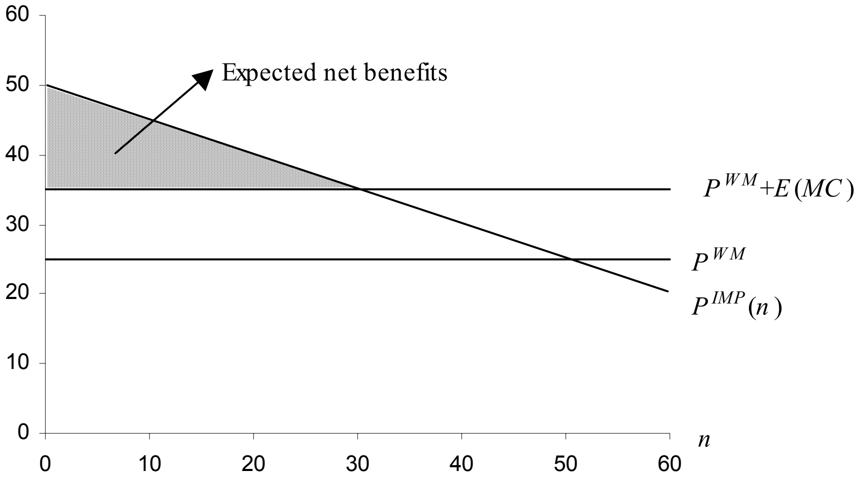

Figure 11. Optimal imports according to expected marginal external costs

The maximum expected net benefits is realised if importing 30 units, i.e., the optimal policy is to reduce imports from 50 (the free trade import volume at the world market price) to 30 units. The expected net benefits then rise from 125 (with 50 imported units) to 225. This may be achieved by use of a tariff equal to the expected marginal external cost, such that the after-tariff import price (and thus the domestic price) becomes 35.

Maximum expected utility

The above analysis is valid only if we assume risk neutrality, such that the expected value of uncertain events may be compared with certain cost and gains directly. The general framework for dealing with uncertainty, however, is to formulate a welfare or utility function defined over the risky outcomes, and compute the expected utility. We recollect that the net benefits from importing n units if y units are infected is denoted $NB(n,y)$, and that $NB(n,y) = GB(n) - cy$. In our example, $NB(n,y)$ is the gross benefits (increase in the sum of consumer's surplus and producer profits) minus the cost associated with the realised number of infected units. The gross benefits thus is given by the area between the import demand curve and the world market price, while the cost if y units are infected is $100y$. Thus, net benefits are given by

$$NB(n,y) = \int_{\tilde{n}=0}^{n} \left(P^{IMP}(\tilde{n}) - P^{WM}\right) d\tilde{n} - 100y. \tag{4}$$

The utility associated with each level of net benefit is given by the utility function *v*(*NB*). The *expected utility*, *U*, as a function of the import volume then becomes

$$E\left[U(n)\right]=\sum_{y=0}^{n}v\left(NB(n,y)\right)f(y;n,p)\,, \tag{5}$$

i.e., the probability-weighted sum of the utility in all possible states (all possible number of infected units, *y*). For more details concerning expected utility functions and their properties, see e.g. Hirshleifer and Riley (1992).

The degree of risk aversion will be reflected in the degree of concavity of the utility function *v*(*NB*). In the example we have used throughout this section, the net benefits may be both positive and negative. If there is risk aversion, the negative outcomes will get a higher weight in terms of utility than the positive ones. We show two examples of utility functions below, one with risk neutrality and one with risk aversion, computed for the optimal import volume in the risk-neutrality case (n=30). In the risk-neutrality case, the utility is simply the net benefit, $v(NB) = NB$, while utility in the case with risk-aversion is modelled as $v(NB) = NB - 0.0005|NB|^2$. We also show the density function associated with each net benefit level.

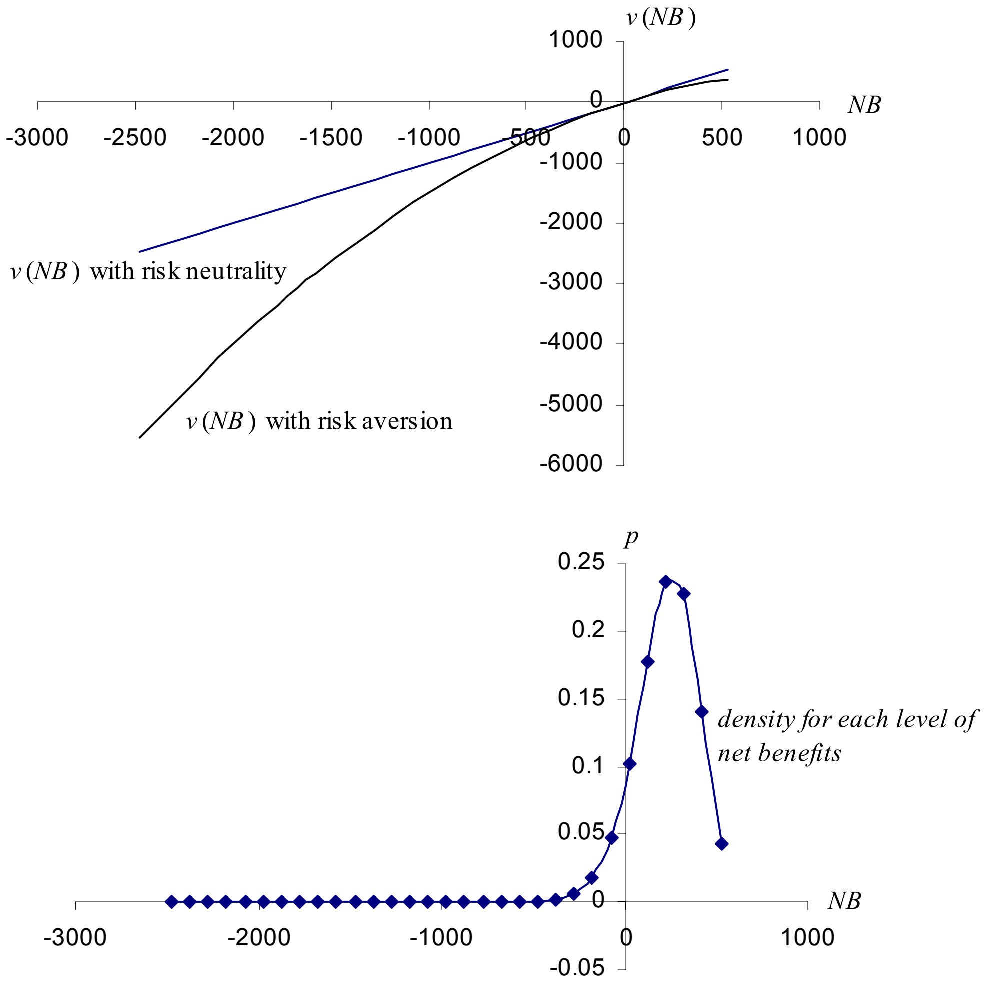

Figure 12. Utility and prob. density as functions of net benefits

In the case of risk neutrality, we find that expected utility is maximised when importing 30 units. The same conclusion was derived on basis of figure 11 in the previous section; with risk neutrality it must necessarily be the case that we get the same conclusion regardless of whether we compute the certain gross benefits and subtract the expected external costs, or compute the utility level for each possible outcome, and then compute the expected utility.

When introducing risk aversion of the degree shown in the above figure, we find that the import volume which maximises expected utility (cf. formula (5)) falls from 30 to 29. The reason for the small change is that although the loss of *utility* is much higher than the negative net benefit figures if negative net benefits occur, the probability for, say, $y = 20$ is extremely small. It is important to keep in mind that the small sensitivity of the optimal import volume with respect to the degree of risk aversion derived here is not a general result – in the next section we shall see an example of the opposite.

5.2 Cost if a positive (non-zero) number of infected units occurs.

In contrast to the example in the previous subsection, a total cost of C occurs in the event that the number of infected units is *one ore more*. In the example, we assume that $C = 1350$, and that $p = 0.01$. These particular numbers are chosen in order to calibrate the expected marginal cost curve such that the import volume where the world market price plus the expected marginal cost equals the import demand curve, is the same as in the previous case seen in figure 11; $n = 30$, cf. figure 13 below.

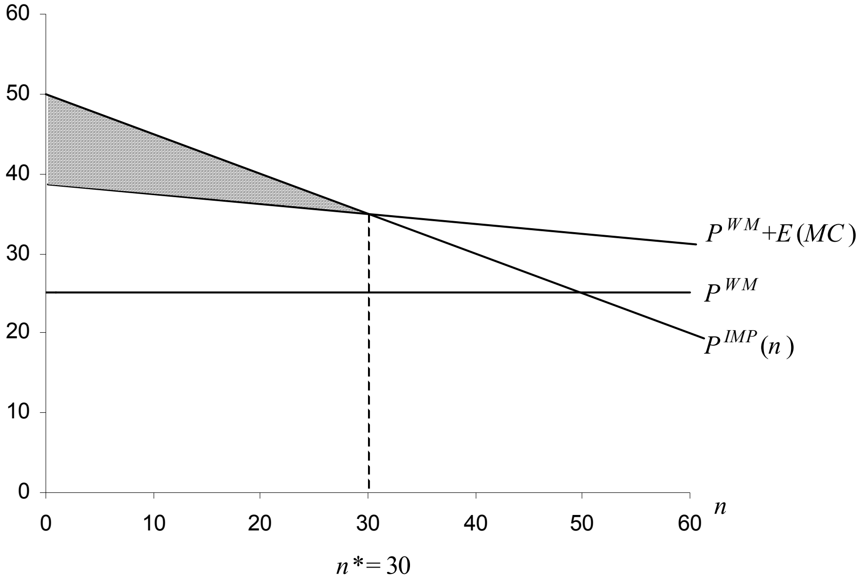

Figure 13. Maximum expected net benefits

The maximum for the expected net benefits in this case is 174. This figure is found from the gross benefits $GB(30) = 525$ minus the expected total external cost of 351, and is also represented by the shaded area in the figure.

Turning to the computation of expected utility, the possible outcome is now very simple; you either do or do not get infected units across the border. The net benefits for each import volume level and the associated probabilities are therefore given as follows:

$$\begin{aligned} NB(n,y) &= GB(n) \quad \text{for } y=0 \ \ (\text{prob.} = f(0,n,p)) \\ NB(n,y) &= GB(n) - C \quad \text{for } y \geq 1 \ \ (\text{prob.} = 1 - f(0,n,p)) \end{aligned} \tag{6}$$

The maximum expected net benefits was found above as 174 when importing 30 units. The expected net benefits can be decomposed according to (6) as net benefits of 525 with probability 0.74 (zero infected units) or net benefits of –825 with probability 0.26.

Expected utility

If we assume the same utility function as in the previous section (the same degree of risk aversion), we obtain the following results for the *expected utility level*: If importing 30 units (the volume which maximises the expected net benefits), the expected utility is -17, i.e., importing 30 units is worse in terms of expected utility than to import nothing and remain at the autarky equilibrium. The import volume which maximises expected utility is $n = 12$. Figure 14 shows the utility level as a function of net benefts, $v(NB)$. We use the same utility function as in figure 12,

$v(NB) = NB - 0.0005|NB|^2$.

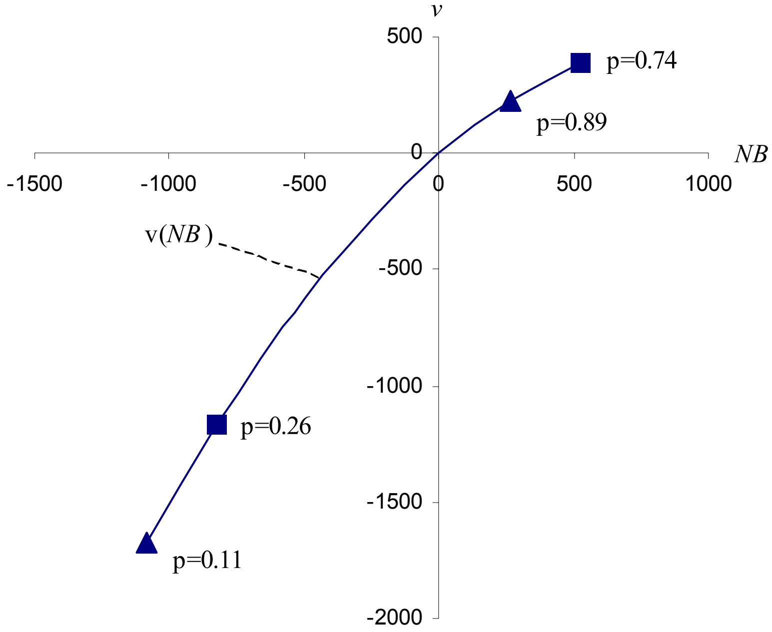

Figure 14. The utility level as a function of net benefits from imports.

The two alternative import volumes $n = 30$ and $n = 12$ are represented by the quadrangles and triangles, respectively, with the associated probabilities at each data point. The reason why the import volume which maximises the expected net benefits, $n = 30$, yields negative expected utility, is simply that the probability for a net benefit of -825 is relatively large, $p = 0.26$, and that the assumed concavity means that the loss in terms of utility associated with negative net benefits is relative large compared to the gains from positive net benefits. Therefore, the expected utility rises as we reduce the import volume down to $n = 12$. The two possible outcomes at $n = 12$ are a net benefit of 264 with probability 0.89 (zero infected units) and a net benefit of -1086 with probability 0.11 (one ore more infected units). Thus, *the expected net benefits* fall from 174 to 111 when reducing imports from 30 to 12, but *the expected utility* rises from -17 to +13.[7]

5.3 Is there scope for reconciliation?

It is certainly an easier and more straightforward task to use expected costs directly in a traditional cost-benefit framework, than to compute the expected utility (the probability-weighted utility of all possible outcomes). Thus, if using expected costs may yield a reasonably accurate conclusion regarding the optimal policy also in cases where we assume risk aversion (by adding a risk premium), this procedure would be welcome due to its analytical convenience.

If we assume risk neutrality, we have seen that we are free to choose between either of the two approaches. The more relevant assumption is presumably that there is some degree of risk aversion relating to uncertain events like those studied here. In principle, it is then possible to define a risk-premium which can be added to the expected marginal cost schedules in order to reproduce the outcome if maximising expected utility. The problem, however, is that such a procedure only can be recommended if there is a clear relation between the degree of risk aversion[8] and the risk premium. The above two examples make clear that we hardly can expect this to be the case. In sections 5.1 and 5.2, we constructed the examples such that the expected marginal cost was the same, $E(MC) = 10$, at the optimal import volume of 30 units. We also assumed the same utility function $v(NB)$.

In the example in section 5.1, expected utility was maximised with an import volume of 29. The same optimum would be found by increasing $E(MC)$ in figure 11 from 10 to 10.5, i.e., by adding a risk premium of 5% to the expected marginal cost. The example in section 5.2 resulted in an optimal import volume of $n = 12$ according to maximum expected utility. If the same optimum should follow from adding a risk premium to the expected marginal cost schedule in figure 13, we would need a risk premium of 19%. We therefore conclude that there is no easy way from a particular degree of risk aversion to a corresponding size of a risk premium which should be added to expected cost schedule. It is therefore clear that the degree of risk aversion ought to be incorporated explicitly into an expected utility framework. There seems to be little scope for a "rough and ready" incorporation of expected costs into the traditional analysis of costs and gains from trade based on consumer's and producer surplus in cases where the relevant assumption is that there is risk aversion.

For the remainder of this report, however, we shall mostly assume risk neutrality. This is simply done for analytical convenience, and not because this assumption is regarded as the most relevant one. It is outside the scope of this report to derive a "correct" degree of risk aversion in analyses of this kind. We might therefore as well assume risk neutrality as any "arbitrary" degree of risk aversion. The analyses in the above sections have made clear the *qualitative* effects of instead assuming risk aversion: the higher the degree of risk aversion, the lower is the optimal import volume.

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[7] Since the utility numbers ("utils") have no physical interpretation, the absolute levels of expected utility at the two import volumes considered are arbitrary. In technical terms, the utility function $v(NB)$ is only defined up to a positive affine transformation, i.e., $v(NB)$ is a cardinal utility function with a certain degree of concavity, but the absolute utility level is arbitrary.

[8] The degree of risk aversion is often expressed by means of the elasticity of the marginal utility of income. In our setting, the corresponding measure would be the elasticity of the marginal utility of the net benefits, $(dv(NB)/dNB)(NB/v(NB))$.

6 CAN UNREGULATED MARKETS OBTAIN EFFICIENCY?

In the analyses so far, it has been assumed that the domestically produced units and the imported units are identical, and sell at the same price in the domestic market. While this assumption may be the relevant one in some circumstances, it is also possible to take an alternative view, viz. that the market participants regard domestic and imported goods as sufficiently different for the price on otherwise equal commodities (apart from the country of origin) to differ. In this section, we shall briefly discuss whether such a market response may be sufficient to obtain efficiency, i.e., that government intervention may be superfluous.

As a starting point, it is important to have in mind that the presence of risk as such represents no violation of the assumptions for an unregulated market to obtain efficiency, cf. Hirschleifer and Riley (1992). However, in the presence of uncertainty, new potential sources for market failures are introduced. First of all, the relevant information may be unevenly spread among the potential buyers and sellers in the markets involved, such that problems of information asymmetries arise. Second, in our setting there may also arise problems if the market participants do not face the full cost associated with the uncertain events. In this section, we shall first discuss an example where it seems reasonable to assume that the risk for infections may be internalised without government intervention, and then discuss some situations which seem less promising with respect to the market's capabilities to achieve efficiency.

6.1 A case for efficient markets

Suppose now that the only cost involved if infected units are imported, is a cost for each final consumer who happens to buys an infected unit. An example could be that a consumer gets temporarily ill if an infected unit is consumed. Let us further assume that the "personal" cost associated with this illness is the same for each consumer, and given by c. We finally assume that domestically produced goods are risk free with respect to infections, but otherwise identical to the imported good. Then, each consumer will face a problem with a similar structure as the examples in section 5.1. The only requirement for a rational consumer to internalise the costs associated with infections into his/her decision problem, is then that imported and domestically produced goods are labelled[9], and that each consumer is correctly informed about both the probability of infections (p) and the consequences (cost) if an infected unit is chosen (c). If each consumer is risk neutral, the market demand for imported goods will shift down by the expected cost. Using the same example as in Figure 11, we then get the following result:

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[9] In order to communicate the correct probabilities to all potential buyers, the authorities' best estimate of the probability would have to be visible. E.g.: "This product is imported from country X, and has an estimated probability of containing Salmonella of 5%".

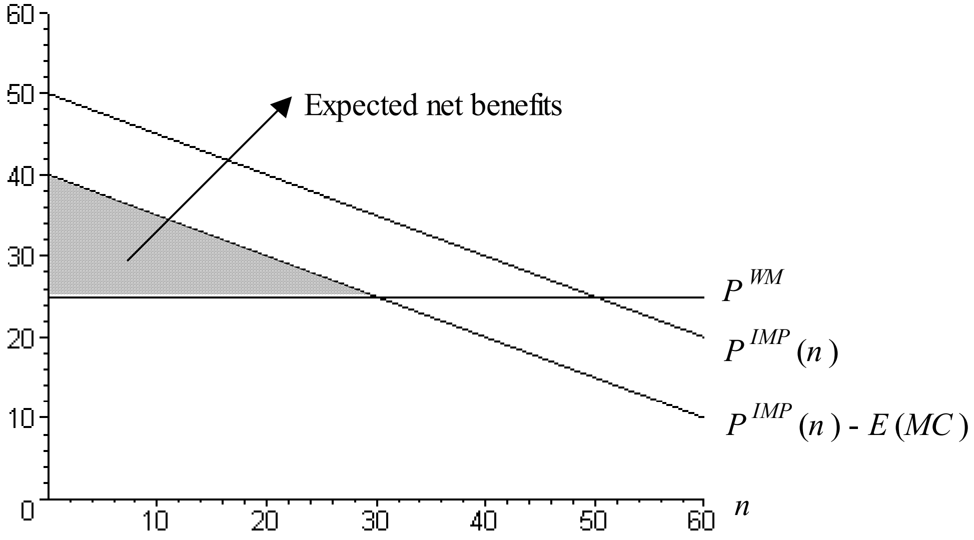

Figure 15. Downwards shift in import demand due to internalisation of "external costs".

Figure 15 makes clear that if the consumers corrects for the expected costs of infections by adjusting the import demand (reducing the willingness to pay for imported goods), we obtain the same outcome (the same import level and expected net benefits) as if the consumers did not internalise the costs and the government instead imposed a tariff equal to the expected cost. This result applies if we assume risk neutrality. If all consumers are risk averse, they would reduce the demand by more than the expected cost. Again, the outcome would be efficient, given the existing probabilities and risk attitudes. The introduction of a tariff would in this situation be harmful – it would cause a movement away from an efficient to an inefficient allocation.

In this example, we have assumed that the final consumers are the ones who are subject to the costs associated with infections. However, the result would pertain also if we instead assumed a setting where each producer used imported goods as intermediate inputs, and carried the cost associated with infected units themselves.

6.2 Problems with the market solution

Section 6.1 have made clear that it is *possible* to achieve efficiency without government intervention. The mechanism behind this result is that if each decision maker is perfectly informed, and bears the full burden of the negative impacts of the infection themselves, they will correctly incorporate the risk for infections into their decisions. However, it is not hard to think of counterexamples. A feature of infections and diseases of most kinds is of course that they hardly can be expected to be confined to the units of food or animals which was infected in the first place. Rather, the infections will in most cases be able to spread if they first are introduced some place in the food chain – at least until the infection is discovered and counter measures are introduced. If so, the imported units which happen to be infected on arrival to the importing country will infect further units – both other imported goods and domestically produced goods. Examples may be cases where infected meat is introduced into a slaughterhouse or a food-producing factory. The same mechanism applies to cases where live animals are imported. There may then be a huge risk that the bacteria, virus or organism in question spreads from the first place of introduction. Such cases seems to have the character of "genuine" externalities, i.e., effects that goes outside the market – from consumer to consumer, from producer to producer, from producer to consumer, or even from consumer to producer. The incorporation of expected "private" costs relating to infection for each agent is then of limited help for obtaining efficiency.

6.3 Tentative conclusion

It is a fundamental assumption in economic theory that both producers and consumers behave rationally, in the sense that they choose from the set of available actions, the one which gives them the best outcome (highest profits or utility). Uncertainty – for example relating to the possibility for infections – does in principle not represent a problem which the consumers or producers are unable of resolving rationally. If the consumers and producers incorporate the costs associated with infections into their demand or supply decisions, it should be no need for government intervention due to external effects. However, infections and diseases of various kinds will often constitute "genuine" externalities – they are hard to isolate among the market participants. If infections spread from commodity to commodity, from factory to factory, from farm to farm, or from consumer to consumer, it seems hard to imagine that all costs related to infections which *originally* stems from imported goods may be internalised such that the unregulated market transactions obtain efficiency. In such cases, it is believed that various control measures, legal/institutional arrangements, and internalisation via taxes or tariffs are called for. We should keep in mind, however, that each time we apply an argumentation based on external costs, we ought to check carefully whether the "externality" is a genuine one, or is of a type that in fact may be internalised without intervention. The next section discusses some institutional arrangements which may "help" the market participants to internalise costs that otherwise would be external to the markets.

7 LEGISLATIVE INTERNALISATION

The fundamental source for externalities is a lack of property rights for the good in question. A classical example is the demand for unpolluted air. Since nobody "owns" the air, no private agent is able to charge polluters with the correct price whenever they emit polluting substances. Thus, the market fails, and government action is called for in order to correct for this market failure. In our context, a parallel to the example with emissions to air would be that nobody is legally responsible for the cost associated with infections related to imported goods. In principle, it may be possible to make an economic agent economically responsible for such costs. The most natural candidates are, presumably, the importers or the exporters.

We start our discussion by assuming that the exporter must carry the costs associated with infections and diseases which stems from the goods he or she exports. Using the same notation as in chapter 2, 4, and 5, the exporter is able to export the goods in question at the world market price P^{WM}. If we assume that each infected good results in a cost of c, and that the probability for infections is p, the expected cost per imported unit becomes $E(MC) = pc$. If the exporter shall break even in the long run[10], the minimum price per exported unit must therefore be $P^{WM} + pc$. Thus, the market solution will resemble the outcome depicted in figures 3 and 11:

The domestic price of imported good becomes the world market price plus the expected marginal cost, cf. figure 16.

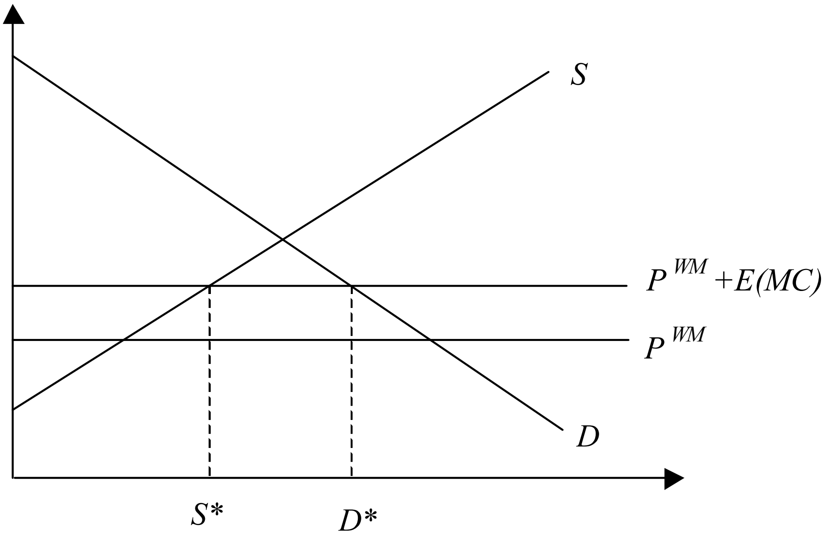

Figure 16. Internalisation of damage cost in export price by means of making the exporter legally responsible for the cost of infections.

Since the exporter must include the expected marginal cost of infections in the export price in order to cover the full long-run cost, we see that the optimal import level D^*-S^* (assuming risk neutrality) will be realised. Thus, there is no need for tariffs in this scenario. Exactly the same solution would materialise if we instead made the importer legally responsible for the costs of infections. The importer would then import the costs at the price P^{WM}, but would need to include the expected marginal cost $E(MC)$ before selling the goods at the domestic market. The arrangement outlined here implies that the importer or exporter carries all the risk associated with the possibility for infections. If they are risk averse, they will not be willing to undertake this risk without a risk premium. With a risk premium, the domestic price will be higher than $P^{WM} + E(MC)$. In section 5, we concluded that the optimal price indeed is higher than $P^{WM} + E(MC)$ if the importing country as a whole is risk averse with respect to the resulting net benefits from imports. If we assume risk aversion, the optimal import volume may only be expected to materialise if the degree of risk aversion is the same for the private firms which are legally responsible for the costs, and the importing country as a whole.

A central question is of course whether a strategy of making the exporter or importer legally responsible for the costs of infections and diseases is feasible in practice. First of all, such arrangements will be very demanding with respect to information: The number of infections and the costs associated with each of them must be verifiable in a court of law, such that the exporter or importer may be charged to pay for them. Second, the arrangement may imply violations of international trade agreements. The last problem is perhaps most pronounced if foreign agents (the exporters) are made responsible for the costs, but the first problem will remain in either case. Seen on this background, the idea of using legislation to internalise damage costs into the import price may seem a bit farfetched. However, the idea still deserves to be mentioned in this report, since the discussion in this section have made clear that the crucial thing from an efficiency point of view is not *how*

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[10] In the long run (when exporting a large volume), the number of infections will approximately be given by the probability times the number of exported goods, such that the expected number of infected goods will

internalisation of damage costs takes place. More specifically, it is not a central issue whether the government imposes tariffs or another mechanism works to internalise the costs[11].

8 CONTROL MEASURES AS SUPPLEMENTS AND/OR ALTERNATIVES TO THE PRICE MECHANISM

The analyses in the previous sections have primarily focused on how to define the optimal import volume in cases where imports of agricultural products represents a risky event – a certain probability for importing infected units of various kinds. The only policy instruments we have considered so far, are the use of tariffs and various other ways of using the price mechanism to account for the costs relating to infections and diseases. Of course, the use of tariffs is the natural "prescription" whenever there are negative externalities related to imported goods. Tariffs may then be seen as a direct implication of the polluter pays principle, since the costs of the negative externality is added to the imported goods – the originator of the externality. It is of special importance to note that such a tariff is not a tariff in the traditional sense. Rather, it is a Pigouvian tax which happens to apply to imported goods, since these are assumed to be the source for the negative externalities. There are certainly alternatives to the use of prices, however. First of all, the price mechanism represents a fairly remote or indirect way of addressing exposure to risk for infections. Control measures are available and indeed fairly widespread in most countries today – both for imported and domestically produced agricultural products. Such measures include pre- and/or post-shipment quarantine, diagnostic testing, vaccination programmes, and various processing and treatment measures, e.g., heat treatment for a specified time and temperature. Needless to say, the remaining risk for outbreak of a disease may be greatly reduced by performing such activities. However, all such measures have a cost, such that there will in principle be an "optimum" level of the frequency, regularity, quality and so on. Such a "control-optimum" will basically involve a trade-off between reducing the risk and the incurred control costs. However, international trade agreements may imply restrictions on the type and intensity of control measures specifically oriented towards imports. We shall mostly abstract from such restrictions, and treat the control measures as a freely chosen policy variable in order to analyse a "first-best" response to risky imports when both prices and control measures may interact in order to obtain the best possible outcome.

8.1 Modelling of control measures

In this chapter we shall attempt to introduce control measures into the stylised framework we have been using in the previous sections. In the context of our model, the control measures we shall consider are represented as follows: The probability for an arbitrarily drawn imported unit being infected is now denoted p^1. This is the same probability as the one we have called p in the previous sections. If a unit is controlled, we assume that the *test*

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materialise.

[11] This conclusion is only valid in a first best setting. When we consider the full range of government policy issues – including the use of taxes in order to finance public expenditures – it will be the case that internalisation via tariffs is superior to e.g. legislation. This is because raising government revenue by means of taxes leads to a deadweight loss. Therefore, when a Pigouvian tax (or tariff) raises tax revenue, other distortionary finance may be reduced, and this opportunity implies that revenue raising policy instruments (taxes/tariffs) are superior to other ways of internalising the damage. See e.g. Goulder et al. (1999).

sensitivity – the conditional probability for detecting an infected unit given that the unit is controlled – is represented by p^2. Further, we denote the share of imported units which are controlled by $x \in [0, 1]$. Also, we assume that the stochastic processes underlying p^1 and p^2 are independent. If an infected unit is detected, we assume that it is stopped (not introduced into the domestic market). Then, the probability for an infected, imported unit to be introduced in the domestic marked, conditional upon the control share x, becomes

$$p^3 = (1-x)p^1 + xp^1(1-p^2)\,. \tag{7}$$

The following figure explains how we end up with the conditional probability p^3 in (7).

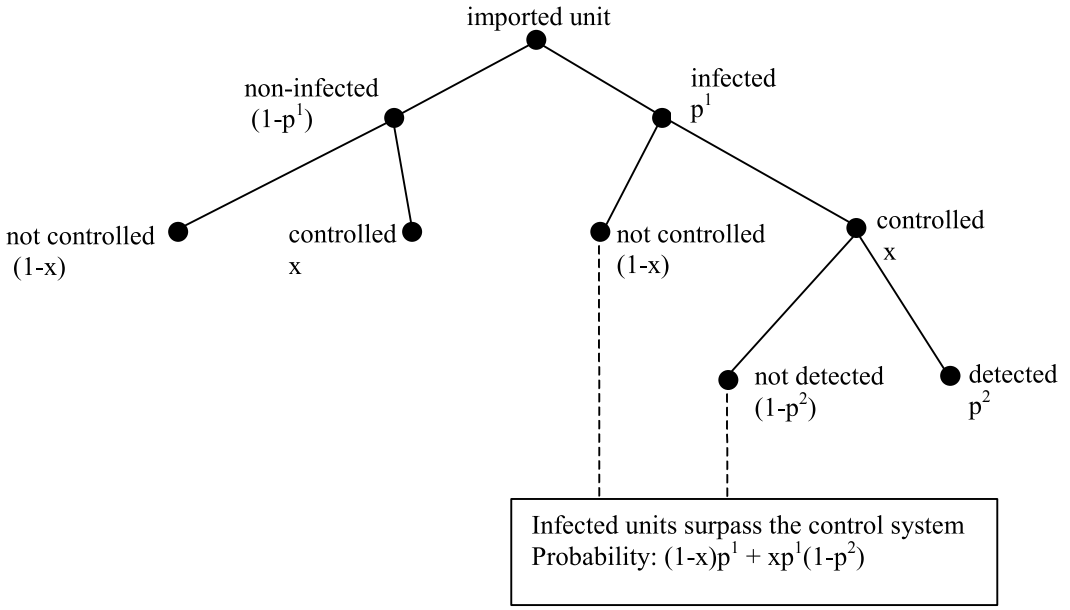

Figure 17. Probability tree for the conditional probability of introducing an infected unit into the domestic market.

Of course, the quality of the control – the test sensitivity – varies considerably from species to species and from disease to disease. In the examples below, we choose a test sensitivity $p^2 = 0.9$, i.e., 90% of the infected units are detected if they are controlled.

The policy issues we shall analyse is whether to control at all, and how large a share of the import volume to control – if we choose to control. The decisive variable for this question will be the control cost per unit, denoted by q, relative to the expected marginal damage cost relating to infections. The analytical details of this optimisation problem will not be derived, as it is expected to be too technical for most of our readers. Rather, we continue to work with the examples we used earlier in section 5.

8.2 Constant damage per infected unit

Before we introduce the control measures, let us briefly recapitulate the assumptions and definitions used in section 5. We assumed that the world market price was $P^{WM} = 25$, and that the import demand curve was $P^{IMP}(n) = 50 - n/2$ (where n as before is the import volume). We further had a cost per infected unit of $c = 100$, and a probability for infection (for an uncontrolled unit) of $p^1 = 0.1$. Thus, the expected marginal cost was $p^1c = 10$. We defined the gross benefit from an import volume of n as $GB(n) = 25n - 0.25n$. This is the benefit from imports if no units are infected. Finally, we had the net benefits $NB(n,y) = GB(n) - cy$, where y represented the number of infected units (varying between zero and n).

If we choose to control a share, x, of the imported units, the formula for the net benefits becomes

$$NB(n,y,x) = GB(n) - cy - qxn, \tag{8}$$

where q denotes the control cost per controlled unit[12]. Equation (8) makes clear the trade off involved when deciding to control the imports: we spend control costs equal to qxn, and the gains from doing so is due to the reduction of the probability for infections from p^1 to p^3, cf. equation (7) and figure 17. Given this set-up, the expected value of the objective function (8) is linear in the choice variable x. This has the implication that there will be no interior solution for x, i.e., the optimal policy is either to control all units or no units. If the test sensitivity is $p_2 = 0.9$, it turns out that the critical level for the control costs per unit, q, is 9. This result is easily understood in terms of figure 18.

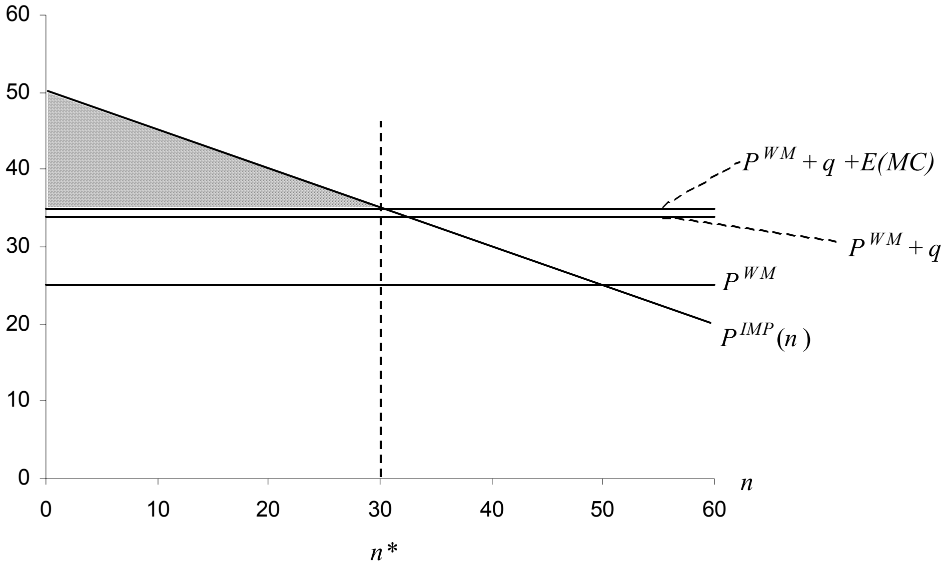

Figure 18. Optimal import volume when control costs break even compared to the situation without control measures.

When the test sensitivity (p^2) is 0.9, and when controlling all units (x=1), the probability for any arbitrarily drawn imported unit being infected becomes $p^3 = 0.01$, i.e., it is reduced to one tenth of the probability in the no-control case. Thus, the expected marginal cost is reduced from 10 to 1. However, the control cost q is as high as 9, such that the total cost of importing a unit is a certain cost of $P^{WM} + q = 34$, plus an expected marginal cost of 1.

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[12] One simplifying assumtion is made in relation to the formula for net benefits: We assume that if an infected unit is detected, it is replaced by a non-infected unit. This implies that we neglect the fact that the extra unit used to replace the detected unit also will be infected with the same probability as the originally imported units. Thus, the net benefits measure will be slightly too high.

Thus, the total expected marginal cost of imported goods is the same as without control measures (cf. figure 11), and the same goes for the optimal import volume and the net social surplus[13]. Thus, the same tariff rate of 10 will be required in order to obtain the optimal import volume as in the case of no controls.

Any level of control cost which is higher than 9 in this example, will imply that control becomes too expensive, i.e., it is better to drop control altogether. Of course, this applies only for the assumed test sensitivity of 0.9. The general rule for the critical cost level is that the unit cost q must not exceed the reduction in the expected marginal cost. Since the expected marginal cost is p^1c without control and p^3c with control of all units, this rule becomes that $q < (p^1\text{-}p^3)c$ if introducing controls to increase welfare (net benefits). Since $p^3 = p^1(1\text{-}p^2)$ when all units are controlled, the rule may alternatively be written as $q < p^1p^2c$.

Let us now turn to a more realistic case; that the control costs are small enough for control measures to be beneficial. Suppose for example that the control cost per unit is one, $q = 1$, such that the control cost constitutes 4% of the world market price. This seems like a more reasonable level for the control costs; we would expect that control costs for the most part are considerably lower than the world market price, although this necessarily varies a lot from commodity to commodity[14]. We still assume a test sensitivity of 90% ($p^2 = 0.9$). Figure 19 shows the results from these assumptions.

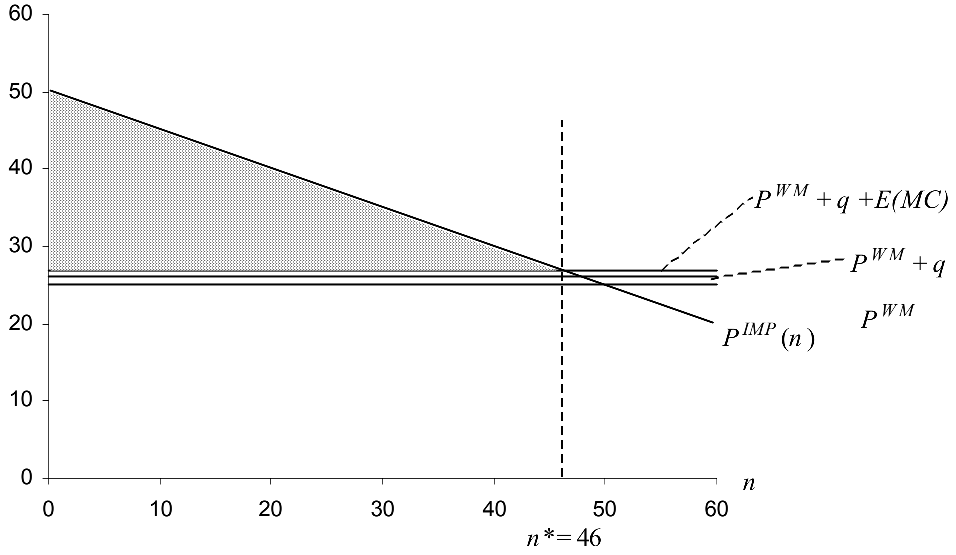

Figure 19. Optimal imports with relatively small control costs (q=1)

When the control costs are relatively small, we are able to greatly reduce the risk for infections by controlling all imported units at a modest cost. The full expected marginal cost of imported goods is as before the world market price plus the control costs and the expected marginal cost of infections. In figure 19 this becomes 25 + 1 +1 = 27, and the optimal import volume rises from 30 in the no-control case to 46. Thus, we approach the no-

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[13] This applies if we are risk neutral. If we assume risk aversion, the conversion of nine tenth of the uncertain cost into a certain cost will imply a gain. Thus, the critical level of control costs is higher if we assume risk aversion.

[14] For example, the control cost in per cent of the world market price will obviously be related to how the product in question is measured, counted and packed. For some highly pre-processed products (finished meals

intervention import volume of 50, and realise most of the gains from trade we would have had without the negative externalities; the shaded area in figure 19 represents 85% of the gains from trade when there is no risk for infections. However, we still need a tariff, although small, in order to implement the social optimum. In this case the optimal tariff is 2, which represents 8% of the world market price.

The general lesson from this exercise is simply that if the control cost per unit is not too great, the control measures will greatly improve national welfare, since they reduce the risk considerably, and thus implies a higher optimal import volume and a lower domestic price level. The losers are of course the domestic producers, who experience both a price and quantity reduction. As always in models of imports, however, the consumers gain more than the producers lose, such that the net social surplus increases.

We should finally note that the analyses points out that the "correct" price of imports includes not only the costs relating to infections, but also the cost of controlling the imports. Thus, the optimal import price is $P^{WM} + q + E(MC)$. This implies that a tariff equal to $q + E(MC)$ will implement the optimal solution, and that this increase in the import price may be regarded as a Pigouvian tax, i.e., a tax which internalises the external costs. With control costs, therefore, we have that the "polluter pays principle" means that the import price should reflect both the remaining probability for infection after the control have taken place *and the cost associated with these control measures*.

Ban on tariff protection

In the examples which figures 18 and 19 were based on, we assumed that the government freely could choose both the intensity of the control measures (the control share x) and a tariff level in order to implement the optimal import policy. Suppose now instead that the future WTO-negotiations implies an effective ban on using the price level as a protection device altogether[15], but that border controls still are allowed. In such a case, the import volume will always be decided by the world market price. In terms of our example, this means that n will be locked at 50, with no scope for government policy affecting the import volume[16]. Will such a situation change the profitability of introducing control measures? And will the critical level of the cost per controlled unit change when control measures are the only remaining policy instruments? It turns out that the answers to both these questions are no – at least in the stylised framework adopted in this section. The reason is that the argument outlined in figure 18 is independent of the import volume. More precisely, both the expected marginal cost and the control cost per unit are constants, such that that the trade off between reducing the risk and paying for the cost of control remains unaffected by the import volume. The optimal control policy is therefore still to control all units ($x = 1$) as long as the reduction in expected marginal costs is higher than the control cost q, and to control zero units otherwise. We recall from above that the requirement for a welfare increase from introducing control was that $q < (p^1 - p^3)c$.

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etc.), the volumes and prices per unit will be quite small, while the opposite obviously is the case for e.g. live cattle or wholesale slaughted animals.

[15] Such an extreme solution can not be expected to occure in the short run, but the forthcoming negotiations will in any case aim at reducing the maximum tariffs considerably. For simplicity, we analyse the extreme case of no tariffs. The consequences of an "intermediate" level for the allowed tariffs – between the freely chosen optimum and zero – should in principle be clear by "interpolation" of the results for the two polar cases shown here.

[16] This presupposes that subsidies to domestic producers also are excluded from the feasible policy instruments.

8.3 Costs if a non-zero number of infected units is introduced

We now turn to the polar case regarding the consequences of importing infected units, i.e., not a constant cost c per unit, but rather a relatively high total cost $C = 1350$ if *one or more* imported units are infected. We furthermore assume a binomical distribution with probability $p = 0.01$. These assumptions are the same as the one used in section 5.2. We recall that the particular numbers $C = 1350$ and $p = 0.01$ was chosen such that the expected marginal cost was 10 and the optimum number of imports was $n = 30$ in the absence of control measures.

We choose the same assumptions regarding the test sensitivity as in the previous section; $p^2 = 0.9$. We should recollect from (7) that the after-test probability for an arbitrary imported unit being infected – conditional on a control share x – is $p^3 = (1\text{-}x)p^1 + xp^1(1\text{-}p^2)$.

In section 8.2 (constant damage per infected unit) we found that the critical level for the control cost per controlled unit was $q = 9$. This was due to the simple fact that when the cost per infected unit is 100, and when the probability for infections fell from $p^1 = 0.1$ to $p^3 = 0.01$, the expected marginal cost fell from 10 to 1. For this to be beneficial, the control cost cannot exceed the reduction in the expected cost of 9.

When we face a cost C whenever one or more units are infected, however, it turns out that control measures will be beneficial even tough the control costs are higher than 9. A per unit control cost of $q = 10.5$ is now the critical level for the control costs. The reason is that the expected marginal cost is not independent on the import volume, cf. figure 13 in section 5.2. At the critical level for the control cost ($q = 10.5$), the optimal import volume is $n = 26$. This case is shown in figure 20.

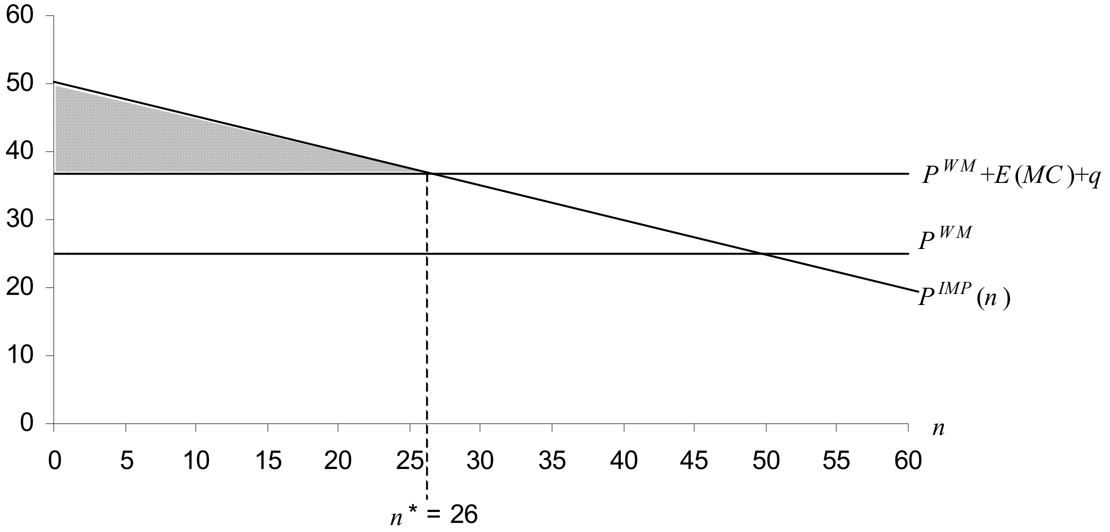

Figure 20. Optimal imports with control measures at the critical level of control costs

The expected net benefits is now given by the triangular shaded area below $P^{IMP}(n)$ and above the full marginal costs given by $P^{WM} + E(MC) + q$. The *size* of this area is exactly the same – 174 – as the net benefits in the corresponding no-control case shown in figure 13, although the *shape* of the area is somewhat different.

Table 1 provides the results of alternative levels of the control costs q on the optimal import volume, tariff level, and net benefits. We have computed the optimal policy from the critical level $q = 10.5$ in steps down to $q = 0$. For $q = 8.5$ we find the same optimal import level as in the no-control case shown earlier in figure 13, i.e., 30 units. The optimal control share is one (all imported units controlled) for all levels of q under the critical level.

Thus, the determination of how large a share to control follows the same simple rule as in section 8.2: If control is not too expensive, we should control, and then we should control *all imported units*.

Table 1. Effects of alternative control costs per unit

	Optimal imports	Optimal tariff	Net Benefits
No control measures (q> 10.5)	30	10	174
q = 10.5	26	12	174
q = 10	27	11.5	187
q = 8.5	30	10	230
q = 5	37	6.5	349
q = 1	45	2.5	514
q = 0	48	1	561

An interesting qualitative feature of this case, is the non-monotone relationship between the control cost q and the optimal import volume and tariff. Although welfare (net benefits) is higher than with no controls for any q below 10.5, the optimal import volume is *lower* and the optimal tariff is *higher* than with no controls for q between 10.5 and 8.5. Thus, contrary to what one would expect, it is theoretically possible that the introduction of control measures implies higher and not lower optimal tariffs. However, the control cost levels which bring this outcome, are most likely too high to be of much relevance for most real life cases. For more moderate levels for the control costs, the effect is the one most people would expect – that introducing control measures implies a higher optimal import level and a lower tariff compared to the no-control case.

Another interesting feature of this case, is that introducing *some* control (e.g. controlling half the imports) may reduce welfare, although controlling *all units* increases welfare. Such a pattern was not a possibility in the case where we assumed that there is a constant damage per infected unit. The following figure illustrates a case where we assume that the control cost per unit equals 10.

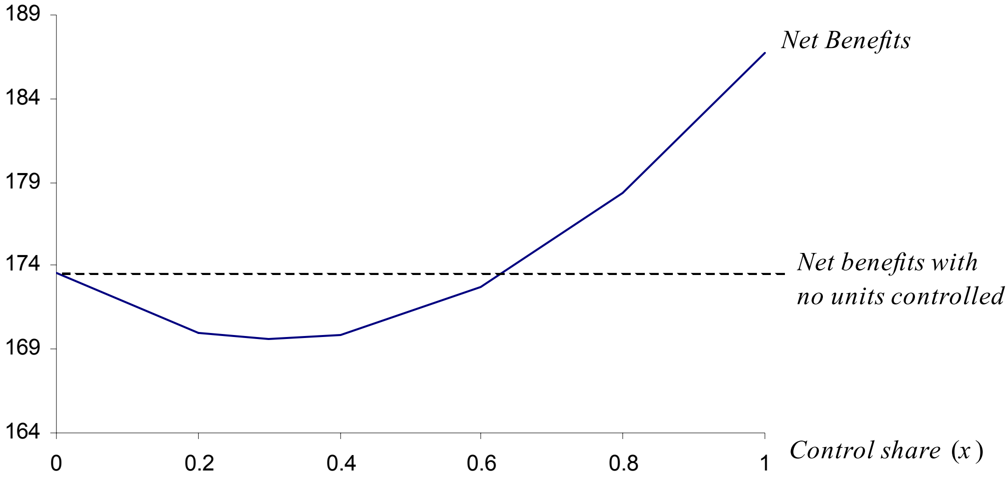

Figure 21. Relationship between control share and expected net benefits (when q =10)

We see that if we start with no control measures (x=0) and introduce a control regime where e.g. 30% of the imports is controlled, welfare (net benefits) will be reduced. However, if we already control 30% of the imported units, welfare will start to rise when increasing the control share, and eventually becomes higher than without control measures when the control share reaches approximately 65%. It should be noted that the figure has been constructed such that we have computed the optimal import volume for each level of the control share. For $x = 0$, the optimal import volume is $n = 30$, gradually falling to $n = 27$ as x rises to 1. The explanation for the pattern shown in figure 21 is related to the properties of the cumulative probability function. Table 2 provides more details into the opposing forces which together gives the results seen in figure 21.

Table 2. Explanation of the result seen in figure 21

Control share	Optimal import volume	Prob. for $y > 0$	Expected disease-related cost	Control cost	Gross benefits	Expected net benefits
0	30	.2603	351.4	0	525	173.59
0.2	28	.2059	277.97	56	504	170.03
0.4	27	.1592	214.87	108	492.75	169.88
0.6	27	.117	158.02	162	492.75	172.73
0.8	27	.0729	98.43	216	492.75	178.32
1	27	.0267	35.98	270	492.75	186.77

If no units are controlled, the probability for one or more units being infected is 0.26. This gives an expected cost related to imported diseases of 351.4. As we start to control a share of the imports, the probability for infections and thus the expected costs fall, but at the same time we are confronted with control costs and a fall in the gross benefits since the optimal import volume goes down. The gains from controls are smaller than the costs until the control percent reaches appr. 40, when it goes the other way around. The expected net benefits in the table is given by gross benefits minus control costs and expected disease-related costs.

The non-monotone relationship between the control share and net benefits seen in figure 21 and table 2 is not a general property. If we reduce the control cost per unit from 10 to e.g. 5, we find that net benefits measure starts to rise immediately, and continues to rise throughout until the control share equals one. In other words, when the control costs are not too high, introducing *some* control is better than *no* control, but controlling all units is better still.

Ban on tariff protection

When we assumed a constant damage per infected unit (in section 8.2), we found that the critical level of control costs was independent of the quantity of imports. Thus, whether the government was able to set an optimal tariff or not, did not affect the critical level of the control cost parameter. This result does not carry over to the case studied in this section. When the government is able to implement an optimal tariff, we have seen that any q smaller than 10.5 will imply that introducing control measures boosts welfare. If tariff protection is not feasible, however, we find that the critical level for the control cost is reduced from 10.5 to 10. Also in this case, the optimal control strategy is to control all units ($x = 1$). The reduction in the break even level for the control cost is not great, but should all the same be mentioned, since the result is qualitatively different from the constant damage per unit case discussed in section 8.2.

8.4 Neglected issues

Hopefully, the above two sections have given us a number of interesting and relevant results regarding the effects of introducing control measures. There are lots of issues which have *not* been treated explicitly, however.

First of all, we have only used one, more or less arbitrary, level for the test sensitivity ($p^2 = 0.9$) in the examples. However, the *qualitative* effects of alternative test sensitivity-levels is straightforward: A higher test sensitivity will – other things being equal – imply that both the net benefits and optimal import volume rise. Also, the critical level of the control cost becomes higher. In the limiting case where all infected units are detected if they are controlled (i.e., a test sensitivity of one), we will be able to get rid of any risk whatsoever – if we find that paying the price of controlling all units is worthwhile. However, such a "perfect" control technology will in most cases be unavailable.

Another potentially interesting issue, is that the veterinary authorities in some cases may choose from a menu of alternative control measures; each with different quality (test sensitivity) and control cost. One might then "invest" in a higher quality of control by paying the price of higher control costs per unit. A relevant assumption may then perhaps be that the control costs rises more than proportionally as we try to push the test sensitivity towards one. In technical terms, the control cost would then be a function of the test sensitivity, $q = f(p^2)$ with $f' > 0$ and $f'' > 0$. It is believed, however, that adding such features will not distort the basic economic logic captured by the more simple cases studied in the previous sections. This economic logic seems solid enough, and implies simply that the benefits from introducing control measures (the reduced probability for importing infected units) must be balanced against the control costs.

A related issue is our assumption of a constant control cost per unit – for some level of the test sensitivity. A more general formulation would be to assume that the unit cost is determined by the cost function $q = g(xn)$, such that varying the number of controlled units[17] may increase or decrease the unit cost. There are two opposing forces for such a functional relationship. If there are fixed costs, we will typically have falling unit costs for low numbers of controlled units. On the other hand, if we have a capacity limit, the unit costs will rise as we approach the capacity limit from below. The combination of fixed costs and capacity limits then suggests a U-shaped unit and marginal cost curve. If we have falling unit and marginal costs, the effects found in our analyses will only be strengthened, i.e., the argument for controlling all imported units will be even stronger. On the other hand, if we have capacity problems and rising marginal and unit costs, we would expect that the *optimal control share will be less than one*. However, capacity problems are only short run phenomena. In the long run, we may invest in a higher capacity, and then our assumption of constant unit costs seems more reasonable.

Another simplifying assumption has been that all imported units represents the same risk. In practice, one particular agricultural product may be imported from both different countries and different exporters within the same country. In most cases, each source will not represent the same risk. This simple fact is bound to have several interesting implications. For example, if a range of potential exporters offer the same commodity at the same price, the importing country will obviously be best off by buying from the exporter with the lowest risk for infections. In some cases, we will be able to find export sources which implies zero or close to zero risk. Then, the SPS agreement opens for the possibility that if it may be documented that some pest or disease does not exist in Norway, we may require that imports are restricted only to come from *other disease-free areas*. In any case, an orientation of the control measures towards export sources which have proved to represent higher risk will be a natural element of the control regime. An example may be to construct a "track record" which shows the past performance of the various exporting agents, and to make future control intensity dependent on this track record. This may represent a way of transferring some of the costs associated with infections to the exporter. If the past record has been sufficiently good, the imports may pass uncontrolled (treated as if the probability for infections is zero). Once infected products are introduced, however, stricter controls will be introduced – and possibly including a temporary ban on imports from that source (like e.g. British beef after the outbreak of BSE). It will then undoubtedly be in the exporter's best interest to maintain a good record in order to stay in business. Such a "flexible" control regime fits nicely into the general framework in sections 8.2 and 8.3. If the track record is sufficiently good, the probability for infections will be very low. Then, the gains by introducing control measures will be correspondingly small, and may not defend the control costs, such that it is optimal not to control. If the infection-free track record is broken, however, the probability needs to be updated to a higher level, and the control measures will then defend the cost.

We should finally mention that in some cases, there may be no available, effective control procedure at all. For example, BSE cannot be detected in living animals. Thus, BSE is typically detected only when the incubation period is over, and the symptoms of the disease starts to show up on the infected animals. Other examples of diseases with poor test sensitivity include Bovine Paratuberculosis and Scrapie. The only feasible control mechanism will then – presumably – be to quarantine imported animals as long as the incubation period lasts. If there is an "absolute" upper limit for the incubation period, it may in principle be possible to obtain a 100% safety level by using a sufficiently long quarantine period.

9 CONCLUDING REMARKS

Until now, imports of agricultural products into Norway and many other countries have been subject to quite substantial trade obstacles. These obstacles include both economic protection, e.g., tariffs or subsidies to domestic production, and various non-tariff protection devices. For agricultural products, the most important non-tariff trade-obstacles are represented by various sanitary and phytosanitary measures which are directed towards preventing imports of infected animal, plant or food products.

The WTO agreement is now up to renewal, and it is expected that further liberalisation of the conditions for trade in agricultural products will be the result. Thus, the scope for using tariffs and other explicit trade barriers will probably be diminished in the near future. Countries with an offensive interest – aiming at an improvement of their export opportunities – fear that sanitary and phytosanitary measures may be used as hidden or implicit devices for protecting oneself against fierce foreign competition. As an example, consider the following statement made by the New Zealand Ministry of Agriculture and Forestry (1997).

> "It is now more difficult to use tariff and other barriers as trade protection measures. This means some countries could turn to using health-protection measures to restrict trade. There is potential to misuse restrictions which look as if they are protecting human, animal or plant health, but have the

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[17] The number of controlled units is the control share times the number of imported units, i.e., xn.

> real agenda of restricting imports and protecting local production. Any move to liberalise trade must try and stop this from happening, while still allowing legitimate steps to protect health."

This statement obviously points to a very real problem and a genuine dilemma and conflict of interests. The last sentence points to the need for allowing "legitimate steps" to protect human, animal and plant health. The problem, of course, is to know what is appropriate or legitimate measures for preventing harmful infections and diseases from spreading due to trade activities, and what is protectionism in disguise. As a response to this problem, the Uruguay round incorporated the SPS-agreement, or the "Agreement on the application of sanitary and phytosanitary measures".

The balance to be drawn between "protectionism" and "legitimate protection" is very hard. It is little doubt that completely unregulated and uncontrolled trade in the whole range of agricultural products is not a good idea – and in fact no country seems to argue for such a "veterinary laissez faire" policy. The British BSE experience represents a good example of how serious a threat which *may* be involved. Thus, while there is complete agreement on the need for *some* restrictions in order to prevent uncontrolled spread of pests and diseases, the issue of *what kinds of and how much* restrictions which are appropriate, is bound to be a more controversial issue.

In this report, we have adopted a stylised framework in order to address these issues from the point of view of economics. In our models and examples, the exposure to risk for infections and diseases from imported agricultural products have been determined by i) the volume of imports, and ii) the risk which each imported unit represents. The first channel – the import volume – is determined by the domestic market conditions and the price level of imported goods, while the probability that each unit is infected is determined by the "original" probability at arrival on the border, and by the control measures which are introduced. A first best optimal policy presupposes that *both* the import price *and* the frequency and type of control measures are subject to choice at the national level – they must both be free variables. The national welfare level will thus be as high as possible if both tariff levels and control measures are set optimally, according to the risk and potential cost associated with the infection/disease in question. It is never a first best optimal to only use tariffs or to only use control measures – unless the control measures are too expensive to be chosen freely. In practise, however, restrictions from the international trade environment (WTO, SPS, EU/EFTA) will regulate both the type of control measures which are allowed, and the maximum level of tariffs or economic support for domestic producers. However, it is not certain that such restrictions will be binding, i.e., prevent the first best or freely chosen measures to be implemented. This is particularly so in the short or medium run. For example, the optimal tariffs which have been studied in this report, may be smaller than the maximum tariffs which will be allowed in the next WTO agreement. The national policy will thus only be affected by international agreements in cases where the maximum tariffs set in the WTO agreement is *smaller than the tariffs aimed at internalising the external costs from imported units*. The same goes for control measures; the optimal control measures from Norway's point of view will presumably be constrained by international agreements (notably the SPS agreement and the Veterinary agreement with EU) only in a subset of all the cases they are directed towards. With respect to tariffs, it seems reasonable to believe that the maximum tariff limits must fall considerably from today's level before they start to constrain the optimal national policy. The hard part is of course cases where national policy aiming at preventing introduction of harmful infections and diseases in fact is constrained by international agreements. It is to be hoped that the weight on facilitating freer trade in agricultural product in the upcoming negotiation, is not so high that efficient measures to prevent food-related pests and diseases from spreading become infeasible.

Upon ending this report, it may be useful to recapitulate some major points, and to stress the informational requirement of a policy maker who is supposed to implement an "optimal" national policy. It is well known that taxes represent an efficient way of improving the allocation of resources in cases where there exist negative externalities. This goes also for the special case studied in this report, when the negative externalities stem from imported goods. Then, a tax which aims to internalise the external cost should be placed on the imported goods. Such a tax will typically be thought of as a tariff, but any association with a traditional tariff, aiming at raising revenue or protecting domestic industries, should be avoided. Since the external costs we have been analysing are related to the *possibility* that some of the imported goods are infected, a *control regime* directed towards detecting infected units before domestic introduction should in most cases supplement tariffs. The only exception is cases where the costs of control is greater than the cost avoided due to a reduced number of imported, infected units. When the importing country combines tariffs and control measures, the "correct" price of imported goods should cover both the control costs per unit, and the remaining external cost (the cost associated with the remaining probability for infections after control has taken place). The analyses have shown that it is theoretically possible that introducing control measures may *increase the optimal tariff* and thus reduce the import volume. In most cases (with moderate levels of the control costs), however, the control measures will work to reduce the need for tariffs and to increase the optimal import volume. Another result in our models, is that the optimal control share is either one or zero. That means that if control measures are too expensive, we should drop them altogether. If they are not too expensive, however, it is always better to control *all imported units* than only *some of* the units. Practical considerations or short run capacity problems may imply that controlling all units is regarded as infeasible or too expensive. In that case, controlling some share of the imports will in most cases be beneficial, but our models have also shown cases where controlling *some fraction of the imports* in fact may reduce welfare; although controlling *all units* would imply a welfare improvement.

With regards to informational requirements, a policy maker would first of all need to know the traditional basic economic tools – the market conditions, including the domestic supply and demand schedules, and the supply curve from foreign supply sources – for all relevant commodities. Furthermore, he or she would need a quantitative risk analysis model in order to obtain estimates of the probability for introduction and establishment for each agriculturally related infection and disease. The reports from The National Veterinary Institute (Paisley, 1999) and The Norwegian Crop Research Institute provide a starting point in order to limit the focus of attention to the most important cases. There is still a very demanding job to be done in order to obtain good, *quantitative* probability estimates, however. The next and final step in the list of data-requirements is a large number of costs estimates: the cost associated with the effects of each possible disease – on crops, herds, and the human population; the costs associated with available control measures for each disease; and the costs associated with eradication programs in cases where successful establishment takes place. Only when we know (or at least have reasonable estimates of) all these elements, we will be able to balance the gains from increased trade in agricultural products, against the costs related to higher risk for infections and diseases which may come as a by-product of such trade. This report obviously represents only a limited contribution to this very demanding task. Within the time available, the main efforts have been directed towards developing a relatively general framework which hopefully can be put into use if the necessary data becomes available at a later stage. It is also hoped, however, that the various analyses and results which have been presented, represents interesting contributions in their own right.

Considering the data requirements and the complexity and multidimensionality of the problem at hand, it becomes clear that drawing up a framework for an optimal national – and more importantly, international – policy within this area is far from straightforward. A lot of research, from a lot of disciplines, will undoubtedly be required before all issues relating to optimal management of risk due to increased trade in agricultural products have been satisfactorily resolved.

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