Opinion TRENDS in Ecology and Evolution Vol.20 No.5 May 2005

How to manage biological invasions under globalization

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Protecting national borders against biological invasions is becoming increasingly difficult because those whose actions result in invasions seldom bear legal responsibility for those actions. Invasion costs are often an externality (an unintended side effect) of international trade. Externalities are best dealt with by internalizing them; that is, by getting those who harm society to meet the cost. This is the 'polluter pays principle', which, under current trade rules, is difficult to implement. Tariffs could, however, be used to confront exporters with the costs of their actions, and the right to do this should be embedded in trade agreements. At the same time, international aid could be used to protect donor societies against the inability of some other countries to take appropriate biosecurity measures. The impact of invasions can thus be reduced by tackling their economic externalities.

The invasion externalities of trade

When plants and animals are traded across borders, a price is paid by the importer to the exporter. This price covers the costs to the exporter of production and transport, but no costs that would result should the plant or animal become invasive. These side effects of trade are called 'externalities' (see Glossary). Whereas many trade specialists argue that side effects of this sort should not get in the way of trade liberalization, environmental economists claim that they have to be internalized if we are to contain the already substantial and rapidly rising costs of invasions [1].

One of the most striking consequences of globalization is the increase in the problem of invasive species. The growth and development of the world trade system has resulted in a sharp increase in the number of new species being introduced to ecosystems and the frequency with which such introductions are made [2–4]. The opening of new markets or trade routes often brings new species along with the traded goods. The growth in the volume of trade along these routes increases the frequency with which introductions are repeated. In some cases, the introduced species are themselves the object of trade, whereas, in others, they are 'passengers' on traded goods, packaging or the vehicles of trade. Although only a small proportion of introduced species turn out to be harmful, those that are have historically caused substantial damage and control costs [1].

If intentionally or unintentionally introduced species establish, spread and have an impact, the resulting costs are said to be externalities of trade. They indicate what economists call a 'market failure'; that is, the market prices of the goods and services implicated in the introduction, establishment and spread of potentially invasive species do not reflect the damage that those species might cause to human, animal or plant health, amenity or cultural value, or the costs involved in their eradication or control. Estimates of these external costs have risen sharply over the past few years [1,5].

Evidence for the effects of trade on species introductions takes three forms. First, several studies relate individual species introductions to the development of markets and trade routes. For example, Cassey *et al.* [6] find that the probability of successful invasion of parrot species is positively correlated with the development of the international pet trade. Semmens *et al.* [7] show a similar relationship for non-native marine fishes and the volume of imports for the aquarium trade. Second, there is some evidence for a link between the volume of all trade and general invasion risks. Dalmazzone [8] and Vilà and Pujadas [9], for example, show a positive correlation between the relative abundances of invasive species in different countries and the volume and composition of imports, while Levine and D'Antonio [10] find a positive relationship between the rate of establishment of unintentionally introduced alien species and import volumes in the USA. Third, evidence of unintentionally introduced species tends to be pathway specific, and much is now

Glossary

Biosecurity: the protection of a country from biological impacts.
Economic incentive: a scheme to induce people to act in a particular way because it is to their financial advantage.
Externality: a cost not reflected in the market price.
GEF: Global Environmental Facility. A United Nations body that funds biodiversity conservation schemes in developing countries, allied to but distinct from UNEP, the United Nations Environmental Programme.
Internalize: to shift a cost so that it is included in the price paid by the user.
Market failure: when free markets fail to capture the full economic costs of an action.
Public good: a good that benefits the public at large, and from which the public cannot be excluded.
Quarantine regulation: a regulation that allows the inspection for, retention of and/or destruction of undesirable biological material.
Tariff: a tax applied to imports.

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Available online 10 March 2005

 0169-5347/$ - see front matter doi:10.1016/j.tree.2005.02.011

known about the specific introduction risks associated with ballast water, wood packaging and so on [11].

The best solution to the problem of externalities is to internalize the costs, to ensure that those whose actions harm others face the costs themselves. Yet little has been done in this regard. The main impediment to progress is that the World Trade Organization (WTO, http://www.wto.org/) and the international agreement regulating international trade [the General Agreement on Tariffs and Trade (GATT, http://www.wto.org/english/tratop_e/gatt_e/gatt_e.htm)] have no effective mechanisms by which to internalize the invasion externalities of international trade. At present, negotiations over trade are largely uncoupled from health and environmental issues. Responsibility for environmental protection lies with national governments and takes the form of trade restrictions: black and white lists, quarantine regulations and so on. These restrictions are permitted under GATT and do offer some protection against invasive species, but they do not internalize the external invasion costs of trade. Exporters and importers of potentially invasive species are not, in general, legally liable for the consequences of their actions and are not required to pay the expected costs of those actions. Moreover, national governments are not required to compensate others for weaknesses in their national biosecurity, monitoring and control policies.

Horticulture: an example

To illustrate the nature of the general problem, consider a particular case: the trade in ornamental plants. The economic importance of ornamental plants has been increasing in many countries as demand for 'exotics' has expanded [12]. In the UK, this market is based on $>73\,000$ plants species and cultivars [13], to which the native flora ($\sim$1500 species [14]) make a negligible contribution. Globally, this trade has been a major source of invasive species [15,16]. In the Czech Republic, Pyšek *et al.* [17] find that 53% of naturalized invasive plants were first brought in as ornamental plants and, in Australia, 65% of plant species naturalizing between 1971 and 1995 had been introduced as ornamentals [18].

The invasiveness of introduced ornamental plants is partly due to the fact that importers select some plants based on characteristics that might also promote a successful invasion, such as climatic suitability or easy propagation. In addition, repeated introductions and secondary releases through cultivation foster naturalization of non-native species [19,20]. Contamination of traded plants with other plants and/or seeds offers another pathway for the distribution of non-native plants [21]. The horticultural trade is also a source of accidental introductions of non-native pests and pathogens. In the USA, 68% of insect interceptions in commodities shipped by air cargo in recent years were associated with cut flowers [22] and 75% of interceptions at the USA–Mexico border involve ornamental palms [22]. The proportion of shipments affected can also be high. In Switzerland, for example, 13% of cuttings and almost 5% of samples of plant material imported during the early 1990s were infested by a pest insect [23]. Western flower thrips *Frankliniella occidentalis* was found in 20.5% of cuttings and 12% of the plants [23] (Box 1). A recent example of a plant pathogen distributed across countries by trade in ornamental plants is the fungus *Phytophtera ramorum*, known as Sudden Oak Death (SOD) [24,25], the origin of which is unclear. There are genetic differences between the fungus found in the USA and in Europe, and SOD can travel attached to many species, although some (e.g. rhododendrons) can be especially susceptible.

So why are the risks so high? The international trade in ornamental plants (similar to many commodities) is subject to a set of international agreements governing: (i) relations between the trading partners; and (ii) the environmental and health consequences of trade. Although GATT does contain provisions to restrict trade where environmental or human health is threatened, the main source of protection is a separate Agreement on the Application of Sanitary and Phytosanitary Measures (SPS, http://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm) and the International Plant Protection Convention (IPPC; an international agreement relating to plant health, https://www.ippc.int). These try to curtail the introduction and spread of pests, and enable the regulation of invasive plants [26]. However, as already indicated, the main thrust of these agreements is to authorize countries to take defensive measures to protect themselves against the potentially harmful effects of imported pests of plants or plant products (Box 2). Specifically, these agreements permit actions to restrict or regulate imports, providing that the actions are scientifically justified and are not designed to confer trading advantage. Although this is helpful, it does not do enough to dissuade exporters from putting others at risk.

Box 1. Horticultural trade as pathway for pests: the example of *Frankliniella occidentalis*

The western flower thrips *Frankliniella occidentalis* is a highly polyphagous insect that causes considerable damage to a wide range of horticultural and ornamental crops. It mainly affects glasshouse crops, although outdoor populations can also be found during the summer [33], and in countries with hot climates. In southern Italy, for example, the thrips colonizes many of the wild plants that grow around field crops and glasshouses [34].

Until the 1960s, the distribution of the western flower thrips was concentrated on the western side of North America, and Mexico. Since then, it has spread not only within North America, but also to Europe, northern Africa, Australia, New Zealand, Japan, South Korea, Malaysia, Cameron, African countries, and Central and South America, mainly through the movement abroad of horticultural and ornamental material. In each region, it has established and spread rapidly [35]. In Europe, the primary focus is believed to be the Netherlands, where it arrived during the first half of the 1980s. The Netherlands is one of the world's leading suppliers of ornamental plants, and also re-exports a large proportion of its imported flowers [36]. A recent analysis of first records across Europe shows an outward spread of thrips from this primary focus, and that trade between adjacent countries has a major role [35]. By 1986, western flower thrips was reported in Sweden and Denmark and, by 1987, it had reached France and Spain. Since then, it has been reported from most European countries [37].

Box 2. International rights to protect against plant pests

With the aim of preventing the introduction of pests of plants and plant products into their territories, Article 7 of the IPPC allows contracting parties the authority to regulate the entry of plants and plant products and other regulated articles. They may:
(i) 'prescribe and adopt phytosanitary measures concerning the importation of plants, plant products and other regulated articles, including, for example, inspection, prohibition on importation, and treatment;
(ii) refuse entry or detain, or require treatment, destruction or removal from the territory of the contracting party, of plants, plant products and other regulated articles or consignments thereof that do not comply with the phytosanitary measures prescribed or adopted under subparagraph (i);
(iii) prohibit or restrict the movement of regulated pests into their territories;
(iv) prohibit or restrict the movement of biological control agents and other organisms of phytosanitary concern claimed to be beneficial into their territories.'

Article 5.7 of the SPS allows that, 'in cases where relevant scientific evidence is insufficient, a Member may provisionally adopt sanitary or phytosanitary measures on the basis of available pertinent information, including that from the relevant international organizations as well as from sanitary or phytosanitary measures applied by other Members. In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk and review the sanitary or phytosanitary measure accordingly within a reasonable period of time.'

Box 3. General solutions to invasion externalities

- Regulations and standards: the imposition of standards or regulatory limits that are accompanied by measures such as risk assessments, inspections, export certificates and quarantine actions, and could also involve the imposition of penalties on those parties who are not in compliance. Examples include the black and white (or red, green and amber) lists in widespread use around the world. A black list includes species whose importation is prohibited, whereas a white list contains species demonstrated to be low risk, and whose importation is allowed in general.
- Taxes and charges: mechanisms that are designed to induce socially responsible behaviour through the use of taxes, subsidies, administrative charges and so on. Corrective taxes are known as Pigouvian taxes, and are consistent with the polluter pays principle. Knowler and Barbier [38] have investigated the use of taxes to regulate the nursery industry.
- Tradable pollution rights: this mixed mechanism involves the creation of a market for pollution rights within the protection of a total allowable level of pollution. Permits are allocated and then made tradable. Horan and Lupi [39] have explored the use of this instrument in the context of invasive species problem.

Policy options and conclusions

What is needed are measures to confront exporters with the costs of their actions. In economists' language, these measures internalize the invasion externalities of trade. There are several options available (Box 3) but we consider just one: an invasion risk-related tariff. Costello and McAusland [27] have explored the use of tariffs on imports to reduce the damage costs from accidental introductions. Their model shows that import tariffs will always reduce import volumes of risky species. They also note that determining the risks might be difficult [28,29], and that tariffs could have potentially adverse effects if they alter the composition of imports, which might lead to land-use changes in such a way as to make ecosystems more vulnerable [27]. But the central point is clear.

The same researchers have explored the efficiency of mixed instruments; for example, port inspections combined with tariffs on imported goods [30]. Costello and McAusland show that the importer should, in this case, apply a tariff that covers inspection costs plus the potential damage costs from outbreaks of pests undetected during inspections. The optimal level of tariffs in each case depends on the risk of invasion and any resulting damage. Setting an optimal tariff is currently difficult given the non-discriminatory policies embedded in the GATT [31,32], but it remains the only effective way of internalizing the invasion externalities of trade.

Some might argue that tariffs could hurt export revenues in low-income countries, and so might weaken biosecurity measures in those countries. There is currently some international support for biodiversity conservation measures in low-income countries, where those measures also confer a benefit worldwide. The Global Environmental Facility (GEF) is the mechanism by which the North invests in those biodiversity conservation activities in the South that have a global payoff (see http://www.gefweb.org/ for examples). This mechanism has not been used to enhance the biosecurity measures of low-income exporters and, in spite of their best defensive efforts, every country is still at risk from unintentional introductions so long as exporting countries pay little attention to the pests or pathogens that accompany their exports. This is seen intuitively in the case of infectious human diseases, but it is also the case for many plant or animal pathogens [4]. For example, in the horticultural trade, the source of reintroductions of many plant pests and pathogens has changed over time. *Frankliniella occidentalis* originally from the USA, was introduced to the UK from the Netherlands, and is currently reintroduced from several tertiary sources, such as Kenya (Box 1).

Article 8 of the IPPC states that contracting parties shall 'cooperate in the exchange of information on plant pests, particularly the reporting of the occurrence, outbreak or spread of pests that may be of immediate or potential danger…; participate, in so far as is practicable, in any special campaigns for combating pests that may seriously threaten crop production and need international action to meet the emergencies; and cooperate, to the extent practicable, in providing technical and biological information necessary for pest risk analysis.' But what is 'practicable' in a high-income country is different from what is practicable in a low-income country. This problem needs to be addressed through the GEF.

A combination of invasion risk-related tariffs and support for biosecurity-enhancing measures in exporting countries would tackle the fundamental causes of the invasive species risks of globalization. Neither exporters nor importers have a strong incentive to avoid these risks, and many countries do not have the resources to monitor and control the flow of potentially invasive species. Tariffs would confront those who are the source of risk with the full social costs of their behaviour. GEF biosecurity investments would provide the means to identify and respond to risk in countries whose inaction affects the rest of the global community. In short, internalizing the

environmental externalities of international trade is the only sure way of containing the invasive species threat posed by globalization.

Acknowledgements

We thank D. Chapman and C. West for their comments on the article. K.D.S. and J.T. are funded by a Leverhulme Trust grant to the University of York.

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