Economic Considerations in Designing Emergency Management Institutions and Policies for Transboundary Disasters

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ECONOMIC CONSIDERATIONS IN DESIGNING EMERGENCY MANAGEMENT INSTITUTIONS AND POLICIES FOR TRANSBOUNDARY DISASTERS

Adam Rose and Tyler Kustra

Abstract

An increasing number of disasters are generating consequences that extend beyond political boundaries. This article provides an economic framework for designing transboundary emergency management institutions and policies to address these transboundary crises. It emphasizes the importance of economic considerations in two ways. First, we disaggregate economic losses into direct and indirect components, which vary in terms of their transboundary potential. Second, we apply economic principles such as scale economies, externalities and public goods in analysing European cooperation in emergency management. The article concludes by identifying the type of consequences that might best be addressed by a wider geographic and political authority.

Key words
Transboundary crises, emergency management institutions, economic consequence analysis

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INTRODUCTION

The number of disasters that have transboundary consequences appears to be on the rise. These disasters stem from increasingly powerful natural forces (Icelandic volcanic ash and the 2004 Asian tsunami), expanded use of imperfect technology (Chernobyl and the nuclear reactor failure following the recent Japanese Tsunami) and the increased interdependence of the world economy (mad cow disease and Severe Acute Respiratory Syndrome).

The economic consequences of transboundary disasters consist of several different but interconnected types of direct and indirect impacts. One example is the estimate that the largest single component of the business interruption (BI) losses associated with 9/11 attack was the nearly 2-year reduction in world airline travel and related tourism because of a ‘fear factor’ (Rose et al., 2009). Another one is the set of impacts stemming from the geographically far-reaching radiological contamination caused by the Chernobyl explosion.

The contribution of this article is to present an economic framework for designing emergency management institutions and policies to address transboundary disasters. Transboundary crises can be defined in terms of three dimensions: (1) cross-political, (2) cross-functional (with respect to systems) and (3) time scales (Ansell et al., 2010). In this article, we focus primarily on the political dimension. We begin by identifying the several categories of economic consequences from disasters and illustrate their relative size for a range of disasters. We subsequently specify which of the categories are most likely to transcend political boundaries, thereby providing a finer delineation of the potential benefits of the development of appropriate emergency management institutions and policies.

We present a set of economic principles that are especially well suited in providing a basis for cross-jurisdictional cooperation. This includes a discussion of how desirable policy and institutional design are affected by economies of scale, externalities and public goods, so as to better match policies with needs. The framework is illustrated by applying it to a terrorist attack using chlorine gas and to cooperative emergency management, with a special emphasis on the European Union.

ECONOMIC CONSEQUENCE ANALYSIS

The measurement of economic consequences of disasters is a critical input into policy decisions. The avoidance of various categories of direct and indirect economic impacts, multiplied by their probability of occurrence, represents the benefits of risk reduction. Moreover, the implementation of these policies also has direct and indirect economic costs that should be considered.

A broad conceptual framework for estimating economic consequences of terrorist attacks and natural disasters has recently been formulated to take all of these factors into consideration and is depicted in Figure 1 (Rose, 2009a). The methodology provides insight into how the various factors interact and indicate the breadth and some of the details of
economic consequence analysis. These distinctions also provide input for designing emergency response policies and creating institutions, including transboundary ones.

Until recently, economic consequence analysis focused almost entirely on standard target-specific effects in the form of ordinary economic impacts, such as direct BI and casualties. They also included ordinary indirect effects, referred to as multiplier, general equilibrium or macroeconomic impacts. The major expansions of the framework are the addition of resilience and extended linkages, which greatly affect economic consequences. Resilience adjustments refer to actions that mute the initial shock and that hasten recovery. Resilience can be quite effective in standard cases, potentially reducing losses by as much as 90 per cent (Rose et al., 2007, 2009). They have the effect of lowering direct BI, a major category of target-specific economic impacts. Extended linkages refer to extreme behavioural reactions (such as fear of going to work or shopping in a high-risk area) or cascading system failures (mainly through interdependent infrastructure). They have the effect of significantly increasing the impacts.

Behavioural linkages can increase direct losses by more than an order of magnitude (Giesecke et al., 2012). Direct remediation costs should be inserted into the analysis at an early stage, in part, because they, along with the two more standard features, are subject to indirect effects. The sum of all these positive and negative components yields a thorough bottom-line estimate of total economic consequences.

Actual estimation of the full slate of consequences is difficult. The problem is complicated by the fact that not only do a broad range of impacts need to be evaluated, but, in a full risk analysis, the consequence estimation should be done for a probability distribution of magnitudes and likelihood of success of a given threat, meaning that an extensive array of consequence analyses may need to be performed.
Table 1 presents the results of simulations for six different targets of potential bio-
terrorist attacks (Lee et al., 2008; Rose, 2008). The table illustrates the wide variability
in the values of the various types of economic consequences within and across cases.
Similar sizeable variations are likely to hold across attack modes (such as ordinary bomb
blast and radiological or chemical attacks).

While the component estimates in Table 1 may at first appear random, some
patterns do emerge. Several of the causes of variation are technical in nature, but
several others are highly dependent on public policy and private sector decisions before
and after an attack. The explanations can be summarized in the following categories:

- Lethalness of the biological agent
- Concentration of people and their ability to escape
- Vulnerability/security of the target
- Duration of the event
- Fear of replication on this or related targets
- Perceived ability to mitigate future attacks
- Extent of resilience.

## CONSEQUENCES OF A TERRORIST ATTACK: AN ILLUSTRATION

An example of the diverse consequences of a terrorist attack can prove useful. Consider
a chlorine bomb attack at an industrial site (Giesecke et al., 2010). The aggregate
impact estimate is an indication of the potential severity of the event. However, it is the
decomposition of the estimates in relation to the causal factors that will be useful in fine-tuning the appropriate planning and policy response.

Let us assume that such an incident takes place in a large city on the border between two countries. The gas plume from the event would extend into the neighbouring countries and kill or injure many people on the spot. The general lack of experience with such terrorist agents and the high levels of uncertainty surrounding the event’s impact and control are likely to generate significant amounts of fear. Researchers have divided these into two major time-related categories. In the short run, media attention and rumours lead to a social amplification of risk that exacerbates fear (Kasperson et al., 1988). In the long run, the area is likely to suffer from a stigma effect (Slovic, 2004). Altered risk perceptions manifest themselves into behavioural changes, which can have severe economic consequences (Burns et al., 2010).

The translation of these effects into losses stems from reactions of individuals, such as requiring higher pay for workers and higher rates of returns for investors in the affected area, as well as requiring discounts for shoppers and tourists to frequent restaurants and purchase goods and other services in the area. This increased cost of doing business leads to direct price increases, which rob residents of their purchasing power, while also reducing demand for products in the area. Further problems arise from property owners walking away from their mortgages. This can lead to a real estate meltdown. A downward spiral can then ensue creating a situation of mass exodus. For the chlorine attack scenario, Giesecke et al. (2010) found that BI losses could exceed normal direct and indirect resource loss by almost three-fold (see Table 2).

ECONOMIC PRINCIPLES AND TRANSBOUNDARY SOLUTIONS

Several major economic principles are pertinent to the formulation of appropriate policies and institutions to address transboundary consequences of disasters. The effect

<table>
<thead>
<tr>
<th>Economic consequence category</th>
<th>Loss/ratio (in millions of 2008 dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total short-term (S-T) resource loss</td>
<td>67.5</td>
</tr>
<tr>
<td>Total S-T behavioural loss</td>
<td>62.8</td>
</tr>
<tr>
<td>Total S-T loss</td>
<td>130.3</td>
</tr>
<tr>
<td>Total medium-term (M-T) behavioural loss*</td>
<td>119.8</td>
</tr>
<tr>
<td>Total behavioural loss</td>
<td>182.6</td>
</tr>
<tr>
<td>S-T behavioural/S-T resource</td>
<td>0.93</td>
</tr>
<tr>
<td>M-T behavioural/S-T resource</td>
<td>1.77</td>
</tr>
<tr>
<td>Total behavioural/S-T resource</td>
<td>2.71</td>
</tr>
</tbody>
</table>

*Discounted at 5 per cent.
of each of the principles discussed below depends, to a great extent, on how disaster costs are distributed across jurisdictions. The framework presented above can help to estimate these costs.

Economies of scale are an obvious consideration. Large facilities and operations can significantly reduce the costs of many activities, in part by reducing unnecessary duplication. At the same time, policy-makers must weigh the trade-off between cost savings from typically centralized operations as opposed to smaller decentralized ones. Centralized emergency management operations may become prime targets and therefore render systems more vulnerable. In addition, decentralized responses are likely to be the norm in resilient actions taken by industrial and household consumers (e.g. use of stockpiles, conservation, use of back-up electricity generators).

A related consideration is the reduction in transactions costs, which is often attained through mergers or consolidation in general. Governments often reduce disaster response costs by sharing rarely used equipment and resources. Mutual assistance agreements presume that disaster probabilities are uncorrelated. So, when one jurisdiction requires the material, its neighbours almost certainly would not. Transboundary disasters, however, affect multiple jurisdictions at once, and thus cause a surge in demand, meaning that governments that would have been willing to lend unused material to their neighbours may find that they need it themselves. As a result, mutual assistance agreements may not be entered into as readily and may lose some of their effectiveness.

In addition, many aspects of emergency management have public goods characteristics (i.e. they can be shared by many entities and without exclusion). This is an advantage in the dissemination of their services because this means that there is no additional marginal cost of service provision to additional users. At the same time, this poses a problem where some countries may not readily agree to cooperative efforts, hoping that other countries will provide the services. The reluctant countries will then be able to partake of these services as ‘free-riders’. Examples include flood control projects and treating victims of an epidemic. The solution here is to improve cooperation among countries in equitably sharing the cost of disaster management.

Yet another consideration is that of externalities or spillover effects. This is, in fact, the essence of a transboundary problem, as some mitigation/interdiction/recovery costs, as well as consequences, cross country boundaries. On the pre-disaster side, many of the expenditures on disaster management can result in positive transboundary multiplier effects. Additionally, consequences can ripple extensively on a geographic basis (Galaz et al., 2011; Van Eeten et al., 2011). Prime examples include ordinary BI from flooding, earthquakes and many of the behavioural effects of terrorist attacks. An attack on an airport or airliner in one country is likely to instil especially heightened fear in others. Here, the solution involves ‘internalizing’ externalities by expanding the cooperation among countries likely to be affected.
EUROPEAN UNION COOPERATION IN THE FACE OF DISASTER

The European Union (EU) was designed to realize the benefits of European integration by reducing transaction costs and promoting gains from trade. Its powers now include areas that have direct and indirect impacts on the prevention of, and response to, natural disasters and terrorism. The EU claims a supporting competence in coordinating disaster relief, allowing member states to make use of these services if they choose so.

Disasters are rare events and pooling resources across multiple jurisdictions result in amortizing their costs over more deployments reducing their per-unit cost. But with twenty-seven member states in the EU, coordinating offers of and requests for assistance can place a great strain on governments already struggling to cope with devastation. Established in 2001, the EU’s Monitoring and Information Centre acts as a clearing house for offers of assistance from thirty European nations to European and non-European countries facing disasters (European Commission on Humanitarian Aid and Civil Protection, 2011). The Centre quickly proved valuable. In the summer of 2002, heavy rains inundated the Czech Republic. A total of 220,000 people were forced to evacuate as 40 per cent of Czech land was affected by flooding. The Czech government contacted the Centre to request floating and submersible pumps as well as portable dryers. By coordinating the actions of dozens of EU members the Centre was able to reduce the cost of emergency response. In so far as efficient emergency response can lower ordinary direct impacts and causalities, the Centre helps to reduce these costs as well. Nonetheless, some governments chose to circumvent the Centre and deal with the Czech officials directly. The German government, concerned that the flood waters would soon flow downhill into its territory, stayed in direct contact with Czech authorities, demonstrating the difficulties national governments have in ceding power to supranational bodies when their own citizens are under threat (Ekengren et al., 2006).

While European integration has brought numerous economic and social benefits, it has also allowed criminals and terrorists to spillover from one country to another. The EU created Europol to facilitate inter-European cooperation on police matters, such as intelligence sharing. In theory, intelligence should be a public good because it is non-rivalrous in consumption. EU countries, therefore, should be willing to share it with their fellow members. The EU initially allowed its members to decide which information to share, on the understanding that the countries that generated the intelligence would be in the best position to decide whether other countries would find it valuable. While this rule was not designed to allow countries to hoard their most valuable intelligence, it quickly had this effect (Bures, 2006).

The Schengen Agreement was designed to make European travel easier by eliminating border controls between signatory states. While the agreement was successful, allowing tourists and business travellers to journey throughout most of Europe without
passports, it also allowed fugitives to flee across the continent. Once arrested, suspects had the right to fight extradition, resulting in costly and time-consuming judicial proceedings. To address this concern, the EU now has a European Arrest Warrant, which compels member states to extradite suspects within 90 days. Reaching an agreement on the warrant was time-consuming, however. The treaty creating the warrant was not finalized until 2001 and member states did not finish altering their legislation to permit the warrants until 2005 (Bures, 2006).

Even in areas where the EU’s jurisdiction is clear and the danger is immediate, members have attempted to block and succeeded in stalling EU actions to protect the common good when these actions threatened national interests. After the British government announced that beef from cows infected with Bovine Spongiform Encephalitis (BSE, or colloquially ‘mad cow’ disease) could lead to Creutzfeldt–Jakob disease in humans, the EU instituted a ban on British beef exports. The UK government ceased cooperating with the EU in retaliation for the embargo. Understanding the importance of British cooperation in handling the crisis and the difficulties in forcing them to comply the EU agreed to relax restrictions on low-risk exports. In return, the British agreed to resume cooperating with the EU response, thereby showing that, while the EU may have the authority to undertake actions, the cost of enforcing this authority on a recalcitrant member is often prohibitive (Lezaun and Groenleer, 2006).

MODIFYING EUROPEAN COOPERATION TO ACHIEVE EFFICIENCY

There are two organizational forms within which individuals may interact to produce goods: firms and markets (Coase, 1937). Markets may be divided into ones where a Leviathan enforces contracts and ones that operates under anarchy (Dixit, 2004). Firms address spillover effects through centralized management that takes into account the effect of one unit’s actions on the other parts of the organization. Markets address spillover effects through side-payments between the affected parties. The organizational structure that minimizes the production and transaction costs is considered efficient.

Making the EU directly responsible for disaster response would be analogous to using a firm structure (although with some key differences discussed shortly). International agreements enforced by the EU would be the equivalent of a market structure with government enforcement, while international agreements without EU or other third-party enforcement would be similar to market transactions under anarchy.

Placing the EU in control of disaster response could, in theory, be the most efficient way to respond to transboundary disasters within the Union. It could result in significant economies of scale and allow the Union to take a holistic view of its actions. Sandler and Siqueira (2006) note that a significant portion of anti-terrorism spending is for measures that do not decrease the number of attacks or the damage done, but merely cause terrorists to shift from one target to another. This spending is individually
rational but socially wasteful. Unilateral reductions would be politically difficult to achieve, while a coordinated decrease would be not be possible because the benefits of defecting from the agreement would be too high. For instance, if anti-terrorism policy became the responsibility of the EU, it would have the incentive to take into account the externality created by deterrence measures.

A federation may not act in the best interests of all its members, crafting its policies to appeal to the politically powerful at the expense of efficiency. Researchers have found evidence of this problem with American disaster assistance spending. An American president is more likely to declare a flood a natural disaster, making the affected state eligible for federal aid, in years when he is running for re-election (Downton and Pielke, 2001). Battleground states receive twice as many disaster declarations as uncompetitive ones (Reeves, 2011).

Placing the EU in charge of disaster response would raise significant sovereignty concerns (Bossong, 2008). The EU is reticent to force its members to comply with its directives in the areas it is already the supreme authority, even when non-compliance may prove devastating. The Europol and mad-cow examples mentioned above are two examples. Another one is the European currency union. Under the Maastricht Treaty, countries that wish to use the Euro must have deficits lower than 3 per cent of GDP and a debt to GDP ratio of less than 60 per cent, so that they will not have an incentive to default on their debt. These requirements were widely disregarded for over a decade resulting in the European financial crisis of 2011–12.

If, on the other hand, the EU shared responsibility for disaster response with its members, this could lead to a moral hazard problem, where its members put themselves at undue risk because they will not bear the full consequences of their actions. This has been the case in other parts of the world, such as the United States, where local governments have used federal funds to promote post-disaster reconstruction on sites that are likely to fall victim to catastrophe again (Daniels et al., 2006).

According to the Coase theorem, externalities can be eliminated and efficiency achieved if individuals are able to bargain with one another using complete information and transaction costs (the costs of making and enforcing contracts) are negligible (Coase, 1960). For instance, a country could negotiate with its neighbours to provide assistance in its time of need, share information or abate a problematic spillover. These agreements could be enforced by a third party, an international organization like the EU, or their fulfilment could rest on the goodwill of the contractors.

Many disaster response policies rely on such agreements. Starting in 1949, the United States government began monitoring the Pacific Ocean for tsunamis. The Soviet Union and Japanese government soon followed suit. Recognizing that accuracy could be improved and costs reduced through cooperation, they, along with twenty other Pacific countries, formed the Pacific Tsunami Warning System in 1965 to share seismographic measurements and alert each other to possible tsunamis. The warnings
and evacuation orders generated by this arrangement have decreased tsunami deaths by 15.3 per cent since the system was put in place (Escaleras and Register, 2008).

Electric utilities in North America use mutual assistance agreements to provide one another with additional line crews during emergencies. These agreements have proved useful in many instances, including when the Red River, which follows north along the North Dakota/Minnesota state border, experienced a 100-year flood in April 1997. At the same time, an ice storm had knocked out electricity to 50,000 homes and businesses in the two states. These structures were protected with emergency dikes and relied on electric pumps to bail out any water that managed to seep in. However, without electricity, the pumps were useless, and Minnkota Power (the local electric utility) did not have enough line crews to restore power before the buildings were flooded. Manitoba Hydro loaned Minnkota Power over 100 employees to help to quickly restore power, thereby preventing billions of dollars of flood damage (Wachtendorf, 2000).

In these cases, however, all parties had incentives to keep to their agreements. With the Tsunami Warning System, cooperation was possible in large part because the information gathered was non-rivalous: its use by one nation did not diminish its value to others. Manitoba Hydro also had significant incentives to help Minnkota Power. The American utility purchases electricity from Manitoba Hydro and resells it to its customers, and under its mutual aid agreement with Manitoba Hydro it pays Hydro for the use of Manitoban line crews.

When the costs to their own interests are small, EU members are quite willing to cooperate. For instance, member states not directly affected by the Czech floods were willing to contribute and coordinate through the Monitoring and Information Centre. But when the costs are, or could be, substantial, such as with Germany during the Czech flood, members may put their self-interests first. EU members often make bold pledges of mutual cooperation only to retreat from them at the first sign they may entail costs as well as benefits (Boin and Rhinard, 2008). This behaviour extends to EU security and defence spending. As the costs of contributing to a mission decrease, smaller EU states are more likely to contribute to it and argue that, in return, they should not have to contribute to more costly activities (Dorussen et al., 2009).

Increasing sanctions for opportunistic behaviour could be effective (Dixit, 2004). However, the EU is loath to impose punishments. Dixit suggests that individuals shun those who have behaved opportunistically in the past, but his model focuses on medieval fairs, where dissatisfied customers could choose to do business with different merchants in the future. While European nations could attempt to extract additional concessions in future negotiations from countries that have behaved opportunistically in the past, it would be quite difficult and expensive for one EU member to shun another. The following sections of this article provide critical first steps in this direction. The analytical framework presented at the outset of this article for estimating the location and magnitude of disaster impacts can be used to understand which countries will bear
what costs. The economic principles outlined in the previous two sections can then help to understand how countries will attempt to shift these costs onto others, either through strategically crafting international agreements or by refusing to honour agreements.

ALLOCATING EMERGENCY RESPONSIBILITIES

We now turn to post-event emergency management and recovery operations. Losses that can be reduced by these actions include BI, economic productivity losses due to death and injury, costs of medical care and losses from behavioural overreactions. The examples below pertain primarily to the chlorine attack case discussed above but many of them are more generally applicable.

For many years, the focus of disaster management was mitigating against property damage and loss of life. There is growing awareness that BI losses can rival those of property damage (Rose and Blomberg, 2010). In contrast to property damage, which takes place during the event, BI just begins at that point and continues until some recovery target is achieved. The comparison of resource loss and behavioural loss effects offers yet another perspective. Our analysis divides the losses into the eight components listed in the first column of Table 3. In the third column, next to each loss type is a loss reduction action (either emergency response or recovery). The fourth column presents an assessment of the cooperation that might be warranted.

The second column provides a qualitative assessment of the potential for each consequence component to have transboundary effects. Terrorist attacks like the chlorine event are likely to be localized; a gas plume, however, broadens the potential of the direct BI, hence the ‘low/medium’ (L/M) designation of transboundary potential. Most natural disasters cause direct property damage within country borders; floods are a major exception, as many rivers serve as country boundaries. The ‘direct impact on the surrounding area’ is primarily related to a buffer or safety zone that might be designated in advance of an event for the purpose of evacuation. This zone will extend beyond the ‘target’ area, so it has also been designated to have low/medium potential.

Indirect BI primarily refers to ‘multiplier’ or general equilibrium effects that readily transcend country boundaries through commodity trade, hence the ‘high’ designation. Deaths and injuries are designated as ‘L/M’ likelihood for transboundary effects for reasons similar to the direct BI at the site. Medical expenditures are given a ‘medium’ designation because cases involving chemical, biological or radiological attacks or accidents are also likely to involve a buffer/safety zone.

The behavioural effects relate to costs stemming from fear. Workers are likely to require a premium to return to an area that has been struck by disaster out of concern over repeat events or the safety of the site (e.g. lingering chemical contamination or structural instability of buildings). However, the workforce will typically come from a
broader geographic area than the disaster centre, hence a higher transboundary designation. Moreover, the zone of fear is likely to include the buffer zone as well, further moving the transboundary likelihood indicator up another half notch to ‘medium’. Investors are likely to require a higher rate of return as well, but since investors are likely to come from an even much broader area, this component receives an even higher transboundary designation of ‘medium/high’ (M/H). Price discounts to attract shoppers back to the affected area will also have negative economic consequences, but are considered to have the same geographic pool as the workforce. The exception would be tourist destinations, which would command a higher score. Note also that the behavioural effects have multiplier effects of their own, which would have as widespread effects as those associated with the direct BI listed in the first row of the table.

Key ways to reduce BI losses in this situation are to improve the effectiveness of decontamination and to improve risk communication. Improved risk communication is likely to represent a rather small investment compared to the massive size of the losses.

### Table 3: Linking loss reduction actions to economic impact components

<table>
<thead>
<tr>
<th>Economic consequence component</th>
<th>Transboundary potential</th>
<th>Example loss reduction action</th>
<th>Interjurisdictional cooperation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource loss effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct BI at site of attack</td>
<td>Low</td>
<td>Prompt and effective decontamination</td>
<td>Attacked country with mutual aid</td>
</tr>
<tr>
<td>Direct impact on surrounding area</td>
<td>L/M</td>
<td>Careful delineation of evacuation area</td>
<td>Attacked country with mutual aid</td>
</tr>
<tr>
<td>Indirect BI</td>
<td>High</td>
<td>Information clearinghouse for chlorine supplies</td>
<td>Many countries potentially affected</td>
</tr>
<tr>
<td>Deaths</td>
<td>L/M</td>
<td>Rapid emergency management response</td>
<td>Attacked country with mutual aid</td>
</tr>
<tr>
<td>Injuries</td>
<td>L/M</td>
<td>Effective critical care facilities</td>
<td>Attacked country with mutual aid</td>
</tr>
<tr>
<td>Medical expenditures</td>
<td>Medium</td>
<td>Effective use of medical resources</td>
<td>Many countries potentially affected</td>
</tr>
</tbody>
</table>

| Behavioural effects            |                         |                               |                                |
| Investor rate of return premium | M/H                   | Effective decontamination; risk communication | Attacked country; all affected |
| Wage rate premium              | Medium                  | Effective medical screening; worker protection | All countries potentially affected |
| Customer price discounts       | Medium                  | Effective decontamination; risk communication | Attacked country; all affected |
In terms of transboundary considerations, risk communication has significant sensitivities to language and nuance. While a multi-lateral and cooperative approach among governments is to be considered, it must, at the same time, be fine-tuned to the needs of different populations including a diversity of ethnic, language and cultural groups within a city or region.

There are, of course, other complications that need to be addressed. One is the joint product benefits of several of the actions. For example, effective risk communication can reduce fear and thereby reduce the necessary wage and rate of return premia and customer discounts needed to attract people to the area. Synergies between the actions present another complication. For example, the reduction in injuries also reduces medical expenditures. More difficult to address is the issue of tradeoffs between actions. Death and injury can be prevented by evacuation, but, at the same time, evacuation increases BI. Moreover, unless the designated area is carefully selected it may lead to a stigma effect on a broader area than is necessary. Rapid decontamination will reduce BI in the short term, but scepticism of rapid clean-up may cause people to have doubts about its effectiveness, which leads to heightened fear and hence longer-term behavioural losses.

The various loss reduction actions take place in different time frames. This should make it easier than if they all had to be implemented simultaneously, and allows for learning and adaptation to the situation. Also, there is greater potential to make adjustments if the scenario unfolds slowly or if the emergency response period is lengthy. Of course, there is greater uncertainty regarding effectiveness with regard to those impacts that are further out in time. Also, the uncertainties related to stigma effects are much greater.

Many types of resilience are implicit in the analysis. Resilience refers to the ability to mute BI losses by using remaining resources more efficiently and recovering more rapidly (Rose et al., 2007; Rose, 2009b). Resilience extends beyond government actions to include the actions by businesses, households and other organizations. This can shift the burden of response and is potentially much more cost-effective. For example, as opposed to a major mitigation expense of a redundant system (e.g. a parallel water line in case of emergency) or maintaining an expensive inventory (e.g. storing a spare electricity transformer), disruption of lifeline services can be more cost-effectively addressed by customer conservation or substitution. Such actions can be empowering to the point where individual citizens can be major partners in reducing post-disaster losses (Flynn, 2008).

Finally, although we have not performed a formal cost-effective analysis, we can reasonably conjecture that one of the most cost-effective disaster response actions is risk communication (Casman and Fischhoff, 2008). Quelling fears does not necessarily require the massive costs of mitigation and reconstruction but has the potential to reduce behavioural losses. Risk communication also has the potential to reduce fatalities and injuries through increased public understanding and compliance with emergency
managers’ orders for actions such as evacuation or sheltering-in-place (Sorensen et al., 2004) or by educating the public on how to independently respond to chemical releases and other hazards without waiting for official orders after such incidents (Davis et al., 2003). In the case of transboundary crises, it may behove emergency management officials in several countries to coordinate their communication efforts to put forth a consistent message, while at the same time accounting for cultural differences among the intended audiences.

Overall, all of the post-disaster loss reduction actions listed in the second column of Table 3 can be more effectively implemented by various types of cooperation among countries, while keeping in mind the desire of countries to shift costly responsibilities and outcomes onto their neighbours. More limited joint efforts are warranted in the case of direct effects, because these are concentrated in a smaller area than the other forms of losses. However, in the case of a transboundary crisis, all other seven types of losses warrant extensive cooperation for the various reasons pointed out earlier in this article. Indirect economic losses resulting from quantity multiplier effects or trade effects call for the largest geographic expanse of cooperation.

From an overall institutional perspective, extra effort must be made to deal with special characteristics of disaster mitigation and recovery. For example, individual governments are inclined only to take into account the benefits to their own country when regulating plant safety and deterring terrorism, leading to inefficient outcomes at the level of the broader community of nations. Similarly, improving risk communication in the wake of an attack is a public good and its non-rival nature means that it may be more efficient for a central transboundary agency to provide it. Government compensation and reconstruction efforts also have significant spillover effects onto neighbouring economies, meaning that they too may be under-provided.

**CONCLUSION**

This article represents an attempt at providing an economic framework for understanding the economic consequences of, and responses to, transboundary disasters. We explained some key economic principles that are operative in transboundary disaster management. We decomposed the consequences of disasters into various sub-categories for the express purpose of identifying those that are especially prone to transcend jurisdictional boundaries. This also provides a basis for estimating the relative magnitudes of various types of losses for the sake of prioritization of loss reduction actions. The article described major ways to reduce these consequences with an eye towards cooperative solutions among countries.

We conclude that transboundary problems are best addressed by transboundary solutions at different scales geared towards specific types of losses from disasters. Caveats are offered with respect to the need to account for cultural differences in
such aspects as risk communication and warning. Also, cooperative efforts typically increase centralization, which may have some downsides in terms of increased vulnerabilities of emergency management centres and of the speed of response. In addition, ways need to be found to harness the decentralized nature of resilience of the general citizenry through individual motivation to contribute to recovery. This is a valuable, but often overlooked, complement to government efforts.

The article focuses on BI following a disaster in part because this is an oft-neglected area. We identify numerous opportunities to reduce the various types of BI losses through transboundary cooperation. By analysing economic interdependence and spatial connections, the article should be useful to businesses of any size and governments at all levels in seeking cooperative solutions to an ever-growing problem.

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