Chapter 2
Enumeration of Categories of Economic Consequences

2.1 Introduction

The purposes of this chapter are to identify a broad range of categories of economic consequences of major threats and to develop a checklist tool that provides a framework for their examination in subsequent chapters in this report. The Enumeration approach described below intends to improve the accuracy of economic consequence estimation. Many studies delve deeply into the estimation of a narrow set of economic consequence types but compromise accuracy by the exclusion of others. The Enumeration approach is the opposite—it provides approximate estimates for a comprehensive set of consequence categories. We contend that for many threats, this breadth can achieve more accurate overall estimation than the in-depth estimation of a limited number of consequence categories.

We use a checklist of consequence categories for three biothreats to illustrate the methodology. A brief explanation of the qualitative scoring is provided for the Ebola Virus. Quantitative estimates of consequences based on a synthesis of the literature are presented for other threats in the following chapter.

The approach is useful in two ways. It can distinguish categories that are worthy of more precise estimation and those that are relatively minor. We also make use of the full list of categories in our enumeration of scenarios in later chapters to identify impacts that are being used to initiate changes in the CGE model and other categories that are assumed not to be changing.

2.2 Economic Consequence Categories

Table 2.1 identifies 16 categories of direct economic consequences and two general economic consequence categories that are applicable to various biothreats. Ten of the aggregate categories are broken down in further detail. Moreover, the table

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Table 2.1 E-CAT economic consequence enumeration table

Direct impact category[a]	Domestic influenza	Domestic FMD	Domestic ebola
1. Vaccination/inoculation	+/−M/L	+/− L	−VL
2. Evacuation and/or quarantine	−L	−L	−M
3. Clean-up/decontamination		+/− L	+/− M
4. Medical expenditures	+/− M/H		+/− M/H
5. Mortality/morbidity (humans)			
(a) Deaths	−H		−M/H
(b) Injuries/infected	−H		−M
(c) Other (caregivers)	−M/H		−M
6. Risk management			
(a) Information gathering	−L	−VL	−M/L
(b) Administration	−L	−VL	−L
7. Behavioral effects: avoidance			
(a). International travel—foreign visitors	−M/L		−M
(b) International travel—residents abroad	+L		+L
(c) Domestic tourism	−M		−M
(d). Public gatherings/places	−M		−M/H
8. Behavioral effects: aversion			
(a) Public anxiety[c]	−L		VH/H
(b) Wage premiums			−M/L
(c) Rate of return premiums			−M/L
(d) Other (customer discounts)			−L
9. Infrastructure interruption/aversion			
(a) Transportation	−M/L		
(b) Water			−M/H
(c) Natural Gas			
(d) Electricity			
(e) Education	−M		−H/M
(f) Agriculture		−M/L	
10. International Trade Impacts			
(a) Import (e.g., reductions, bans)			
(b) Export (e.g., reductions, bans)		−M/L	
11. Social disruption (non-economic)	−M/L		VH/H
12. Irreversibilities			
(a) Iconic structures and resources			
(b) Eco-systems			
13. Complex effects			
(a) Compound events			
(b) Cascading events			−L
14. International linkages			
(a) Foreign impacts on the U.S.	−L	−L	+/−L
(b) U.S. impacts abroad	−L	−L	−M/L

(continued)

Table 2.1 (continued)

Direct impact category[a]	Domestic influenza	Domestic FMD	Domestic ebola
15. Resilience[d]			
(a) Conservation			
(b) Substitution	+L	+M/L	+L
(c) Inventories			
(d) Relocation or excess capacity	+M/L		+M/L
(e) Production separation			
(f) Production recapture	+M/L		+M/L
(g) Other (ship diversion, export diversion)			
16a. Negative general direct economic disruption	−M	−M/L	−M/H
16b. Net general direct economic disruption	−M/L	−L	−M
17. Property damage			

Source: See Rose et al. (2015)

[a]All impacts have indirect or general equilibrium effects. The multiplier to translate direct impacts to total impacts at the national level is approximately 2.5

[b]Includes leisure (public gatherings)

[c]Refers to either: (i) public anxiety exemplified by panic buying/hoarding and is indicated by a plus sign, or (ii) general public fear, which is not quantified. Public anxiety in the form of aversion behavior is listed under Row 7

[d]Resilience refers to the ability to mute economic losses by using remaining resources more efficiently and recovering more quickly, and is bounded by the maximum level of economic disruption

presents qualitative indicators (Low, Medium, High) of the relative magnitude of the impacts. It also identifies the relevant geographic area (National, Regional, or Local). In the next two chapters, we discuss how these direct impacts are linked to economic modeling in relation to direct and indirect quantity and price effects.

The focus of the analysis is on *flow* losses, typically measured in terms of reductions in employment and GDP, or more generally characterized as business interruption (BI). This is in contrast to *stock* losses associated with destruction of capital assets, typically characterized as property damage. Property damage usually takes place during the short period of time when the threat is actualized (e.g. when the earthquake shaking occurs), but BI just begins at that point and continues until the economy has recovered or has reached a "new normal." As such, BI is more complicated than measuring the consequences of property damage because it is influenced heavily by public policy, institutional decision making, and human behavior (Rose 2009a). Attention to flow measures like GDP and employment have gained increasing attention in recent years on both the professional literature and the popular press, since BI losses exceeded property damage in the cases of 9/11 and Katrina, and nearly rivaled them in disaster simulations such as the Shakeout Catastrophic Earthquake Scenario (Rose et al. 2011).

Another important aspect is the link between mortality and morbidity, both stock measures, in relation to the flow measures (i.e., they pertain to changes in the labor force stock and are later translated into labor flow units like employment workdays). This involves translating these consequence categories into the flow of labor services they represent. Chemical/Biological/Radiologic/Nuclear (CBRN) threats are more likely to have protracted periods of these health-related stock losses than would natural hazards or blast-related events. Biothreats, more so than other CBRN threats because they typically cause relatively more deaths and injuries, are also likely to have a higher proportion of BI instigated from reduction of labor flows than from the reduced flow of services from buildings and infrastructure.

Key for enumeration letter values*

Letter	Description	Dollar value range	Deaths	Illness/Injuries
L	Low	<$100M	<100	<1000
M/L	Medium/Low	$100M–1B	100–1000	1000–10,000
M	Medium	$1–10B	1000–10,000	10,000–100,000
M/H	Medium/High	$10–100B	10,000–100,000	100,000–1,000,000
H	High	>$100B	>100,000	>1,000,000

*These values pertain to all bounds

All impacts have indirect or general equilibrium effects (not explicitly differentiated in Table 2.1). One can apply rule-of-thumb impact multipliers from I-O models or the results of CGE models, which depend on various factors, but primarily direct sector(s) impacted, the size of the geographic area, and its structure, self-sufficiency and level of economic development. All but two of the categories pertain to conditions outside the US. International Trade Impacts would be exemplified by a potential ban by other countries on imports from the US (our exports abroad). The other category, International Linkages, valuates impacts of the events in foreign countries, but only in relation their potential impacts on the US.

The consequence categories are consistent with impact types identified in an extensive literature search for the National Biosurveillance Integration Center (Rose et al. 2015) and for other sponsors of CREATE ECA analyses (S&T Chem-Bio, Domestic Nuclear Detection Office, Federal Emergency Management Agency (FEMA), and the U.S. Coast Guard). In general, the groupings consist of mitigation, remediation, morbidity and mortality, general economic disruption, behavioral impacts, special focus on infrastructure, trade impacts, social disruption, and resilience. Note that qualitative scoring in this table corresponds to cases of major outbreaks or events (see, e.g., Dixon et al. 2010; Oladosu et al. 2013).

The Mitigation and Remediation categories (Rows 1 through 4) are self-explanatory. What is unique about them is their economic impact. Evacuation/Quarantine results in negative impacts associated with lost economic activity (due to individuals not being able to engage in normal, pre-disaster economic activity such as work and consumption patterns); hence, the minus sign preceding the qualitative measures in Row 2. However, the other three categories represent

expenditures, which could have a positive or negative bottom-line impact, depending on whether the economy is operating at full employment, hence the ambiguous +/− designations. One simplification is made here, however – the entry for vaccination and medical care reflect only the expenditures on these two items. They do include other effects, such as the reduction in morbidity and mortality, which we assume are taken into account in the estimates in Row 5.

Under the broad category of Mortality/Morbidity, Deaths and Infected individuals refer to the economic impacts of the reduction of labor services as explained above. This is also the case for the "Other" sub-category, best exemplified by caregivers, referring to those who are not able to work because they are taking care of ill household members and tending to sick or healthy children not attending school. All three of these sub-categories are major inputs into General Economic Disruption (Row 16), which includes the sum total of direct and indirect or general equilibrium effects.

Row 6 refers to Risk Management sub-categories. First is Information Gathering about the threat, vulnerability, consequences, and resilience to the biothreat. Even if employees already in place undertake much of this information gathering, the wages/salaries and overhead should be valued in their totality, because these staff could be devoting their time and other resources to other important pursuits. The same applies to the Administration and Coordination of the evaluation in response to the biothreat. Behavioral Effects in Row 7 pertain to Aversion to various public activities/gatherings, the first three of which come under the designation of impacts on the tourist industry. It is important to note that a decline in US residents traveling abroad, however, means more spending in the US, and hence is preceded by a plus sign.

Row 8 refers to the category of Other Behavioral Effects, which includes Public Anxiety (though this is not measured in economic terms and hence is not preceded by plus or minus signs). It also includes wage and investor premia required in some cases to attract workers and owners of capital back to the site of the biothreat, where applicable. These premia increase the cost of doing business and hence have a dampening effect on the economy. Note that an area may become stigmatized by the event, and hence these increased costs may last for years. The "Other" sub-category would include impacts such as retail stores and restaurants having to provide price incentives (discounts) in order to attract shoppers back to an area affected by an insidious biothreat.

Row 9 isolates key industries of an Infrastructure type, for which we include transportation, water, natural gas, and electricity infrastructure, as well as educational facilities, and agriculture. These can be affected both by outright interruption, as in the slaughter of animals in the face of a contagious disease, or from aversion behavior, such as finding alternatives to public transit.

International Trade Impacts listed in Row 10 have been discussed previously to some extent. We note here the possibility of the US banning imports from other countries (primarily agricultural products) for fear of further contamination from outside the US.

Social Disruption in Row 11 refers to changes in the ordinary course of life. It is given a qualitative designation but this does not refer to any economic impacts, which are subsumed by other categories.

Row 12 represents two types of irreversibilities in relation to structures, natural resources and the environment. The first refers to iconic targets of both the built environment, such as the World Trade Center, Statue of Liberty and Golden Gate Bridge; and natural resources, such as Arches National Park and Mount Rushmore. With the exception of events like an anthrax attack, for which decontamination is difficult and prolonged, this category is more likely for CBRN threats other than bio, but is presented here for the sake of generality. The second sub-category refers to Eco-Systems, which can be destroyed by purposeful biological contamination and natural predators, as well as other types of disasters and terrorist attacks. Many national parks are vulnerable to combinations of these two sub-categories.

Complex Event Impacts are represented in Row 13. The first sub-category refers to Compound Events, as exemplified by hurricanes, which generate both wind and flood damage, or by a technological accident that causes both blast damage and a subsequent accidental release of biological contamination. The second sub-category is Cascading Events, which are akin to the metaphor of falling dominos, with one disaster type causing another, which in turn leads to another disaster. This category is best exemplified by the 2011 Japanese earthquake/tsunami/nuclear reactor catastrophes. Another example would be a widespread epidemic that causes political instability, rare in the US, but not uncommon in developing countries.

Row 14 represents International Aspects not covered in the International Trade category in Row 10. It includes disasters in foreign countries that impact the US – for example, by raising fear of disease spread to domestically that results in aversion behavior or other forms of social disruption. It also includes the opposite flow—biothreats in the US that cause fear overseas and may reduce international travel or decreased foreign investment in the US.

Resilience, presented in several sub-categories in Row 15, refers to actions that reduce losses by using resources more efficiently or investing in a manner that hastens recovery (Rose 2009b). Their focus is on post-shock activities that reduce business interruption in contrast to pre-shock mitigation/interdiction. Medical Care is in essence a resilience tactic, since it reduces lost productivity, but is listed above in its typically separate role in Row 4. The magnitude of the resilience categories is bounded by the level of negative General Economic Disruption in Row 16a.

Net General Economic Disruption listed in Row 16b refers to the bottom line impacts of the biothreat, taking into account all of the negative *and* positive direct and indirect impacts that take place. It would ideally be measured in a common denominator (e.g. dollars), but it would also be important to measure the number of deaths and injuries/infected separately. The entries in this row are not just a summing of those above it in a given column. First, a couple of the other categories, such as Social Disruption, do not lend themselves easily to being expressed in dollars or by any simple indicator. Second, there may be interactive or synergistic effects between the categories.

Finally, we list property damage in Row 17. Again, it is not a flow, so it cannot be included in BI, but is included as a useful point of reference.

2.3 Application to the Ebola Virus

The qualitative scoring of the categories can be illustrated by the Ebola Virus case in the last column of Table 2.1. Again, the scoring in the table refers to major outbreaks or events. Also, with the exception of the entries in Row 14 and indirectly in Row 10, we refer to impacts only with respect to the US and hold incidents of the biothreat abroad constant.

There is no vaccine against the virus at the time of this writing, so the entry in the first row is very low (VL), referring to only an acceleration of research. Given the severe nature of the disease, quarantine is likely for infected populations and also those exposed to them, which could be many people. However, the severity of the disease is likely to spur vigilant action to contain it and thus lessen the impact.

The number of Deaths is likely to be contained and only slightly lower than the number of Infected because of its severity. Caregiver impacts are likely to involve even more people because of the infectious nature of the disease and the activities like tending children at home because of school closings.

Risk Management pertaining to the Ebola Virus would likely be more costly than that of more ordinary threats, such as Influenza, because of the severity of the former. Information gathering, especially with regard to tracking the spread of the disease, is likely to be especially impacted relative to others.

The seriousness of the Ebola Virus is likely to cause a relatively greater reduction of visitors to the US than other events in Table 2.1 through what we term "avoidance" behavior (see, e.g., Gordon et al. 2007). It is also likely to deter Americans from traveling abroad given the ease of spreading disease during travel, generating more spending within our borders; hence, the positive impact in Row 7b.

An Ebola epidemic is likely to lead to a high level of Public Anxiety, as well as the additional sub-categories of Behavioral Effects, which we refer to as "aversion" behavior (see, e.g., Giesecke et al (2012). These other effects are estimated to have a relatively lower impact because they would be redundant in the face of areas quarantined and because they would not linger in time, in contrast to anthrax, which is much harder to decontaminate.

In terms of Infrastructure Interruption, relating primarily to another type of aversion, it is likely to affect public transportation, and, at a higher level, schools. Trade Impacts are likely to be nil, except that the US is likely to produce fewer goods for export (but see Row 14 below). Social Disruptions are likely to be relatively high, but again this is not measured in economic terms.

Irreversibilities are not likely to be present, but Complexities could arise, if the epidemic causes some civil unrest or rampant discrimination against socioeconomic or racial/ethnic groups that have a higher incidence of the disease.

In terms of International Linkages, the presence of the disease in other countries could lead to negative effects by reducing demand for U.S. exports and raising prices of U.S. imports. It would also likely raise the price of U.S. exports thus stunting our export sales and dampening economic activity in other countries. The latter could lead to even further declines in the world demand for U.S. exports. On the outbound side, a downturn in the U.S. economy would have an impact on the world economy. It could also lead to reduced international travel to our country

Several sub-categories of Resilience are operative, including Substitution for goods/services whose production is lowered (e.g., in regions where the outbreak is centered), Relocation (outright or to branch facilities for businesses and telecommuting for workers), and Production Recapture (the ability to make up lost production once the epidemic is over). Again, the effectiveness of Resilience is bounded by the magnitude of the General Economic Disruption in Row 16a.

General Economic Disruption is not likely to be as high or as widespread as an Influenza epidemic, again because the Ebola Virus case is likely to result in a relatively much greater effort to contain it.

Each type of biothreat is unique in terms of its relevant impact categories and scoring, and the overall category of biothreats well differ greatly from other types of natural and man-made threats. For example, chemical threats are more likely to affect eco-systems than are biothreats, and terrorist attacks are likely to affect iconic targets than are other threats.

2.4 Estimating the Numerical Values of Biothreat Impact Categories

Once again, we emphasize that the numbers in Table 2.1 are intended for illustrative purposes only, and, are at best ballpark estimates. More research is needed in specifying and validating them.

Several strategies can be applied to this estimation. The first would be to perform a critical synthesis of the literature for numerical estimates. “Data-Transfer” techniques can be applied generalize the estimates or to apply them to a given context. Care must be taken in this endeavor.

The second would be to undertake new studies, especially for severe threats, as well as for categories of impacts that have been relatively neglected. It would be important to establish a standard lexicon, data protocols, assumptions, and other estimation concerns to reduce ambiguity and to promote accuracy.

Given the limited number of actual cases for many events, simulation techniques can be very helpful. It would be especially important to incorporate uncertainty in these analyses via sensitivity tests and other mathematical techniques.

Finally, expert elicitation could be used to populate the numerical values Table 2.1 for the broad range biothreats. Again, various protocols and good experimental design are necessary to yield reliable estimates.

2.5 Conclusion

We have identified, explained, and qualitatively estimated the major categories of economic consequences of man-made and natural disasters. These are summarized in a Check-List of Consequence Categories table, in which they are applied to three diverse biothreats. A brief explanation of the qualitative scoring is provided for the Ebola Virus. All of the estimates are only intended as illustrative.

The analysis is intended to serve several useful purposes. It can help identify gaps in the coverage of the approaches to economic consequence estimation. It can also help separate impact categories that have a major bearing on bottom line results from those that do not.

The analysis can serve as the basis for quick turn-around consequence estimation tool. Qualitative estimates, and even ballpark quantitative estimates, can be established for all impact categories through a synthesis of findings from actual and simulated threats or from expert elicitations, or a combination of the above. Moreover, its simplicity facilitates the ability to convert it into a user-friendly automated system.

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