Chapter 2
Economic Framework

The quantification of economic losses from natural and man-made hazards is necessary to gauge individual and community vulnerability, evaluate the worthiness of mitigation and resilience, determine the appropriate level of disaster assistance, improve recovery decisions, and inform insurers of their potential liability. Several major studies setting forth principles of hazard loss estimation have been undertaken in recent years, including National Research Council (1999), Heinz Center (2000), MMC (2005), and Rose (2004, 2009b).

The purpose of this chapter is to identify major issues surrounding conceptual and empirical aspects of disaster hazard loss estimation, more recently termed economic consequence analysis (ECA) (Rose 2015). This includes clarifying basic economic principles of loss estimation, such as the need to consider both property damage and business interruption, the distinction between direct and indirect losses, and real resource costs and transfers. It emphasizes the importance of the spatial and temporal context in which a natural or man-made disaster takes place, and the fact that hazard losses are highly variable because of business/consumer resilience and public policy.

2.1 Basic Principles

2.1.1 Welfare Economics

Welfare economics, the scientific basis for economic policy-making (see, e.g., Boardman et al. 2010), provides a starting point for an analysis of economic losses from natural and man-made hazards. A major point is that cost should be measured in terms of the value of resources used (or destroyed) and at prices that represent their efficient allocation, and not necessarily at market prices, which often do not account for inefficiencies, may not even exist in cases such as environmental

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resources, or, more broadly, where massive destruction has caused turmoil in the market institution. This provides a guide for covering all resources, including non-market ones, and avoiding double-counting.

Business interruption losses represent a proxy for the ideal resource valuation because of the difficulty of measuring the latter. Hence, businesses, insurers, and governments typically make decisions on the basis of such metrics as lost sales revenue or profits.

Economists distinguish between gross output, the total value of production or sales, including the production of intermediate goods (industrial goods used to produce other goods), and net output, the value of final products. On the income side, net output is equivalent to the return to primary factors of production (labor, capital, natural resources, in the form of wages, profits and royalties). This is sometimes confusing because the major macroeconomic indicator, gross national product (GNP), is really a net measure, except that it includes depreciation. When depreciation is subtracted, the quantity is referred to as net national product. Business interruption losses are in gross terms if measured by lost production or sales, and they are in net terms if measured by lost wages, profits, and royalties.

Measurement is further complicated when what economists call "welfare" (well-being) metrics are calculated, typically using the concepts of producer and consumer surplus (see, e.g., Zerbe and Dively 2004). The former is equivalent to economic profits, or net returns of business (including deducting a market rate of return on investment and deducting depreciation). The latter includes consumer satisfaction from goods and services in excess of their market price, a concept very difficult to measure. It is no wonder that concepts like sales revenue are used as a proxy in everyday decision-making.[1]

2.1.2 Stocks Versus Flows

One of the fundamental distinctions recognized in economics is between *stocks* and *flows*. Stocks refer to a quantity at a single point in time, whereas flows refer to the services or outputs of stocks over time. Property damage represents a decline in stock value and usually leads to a decrease in service flows. Business interruption (BI) losses are a flow measure, but can emanate in part from a company's own property damage.

Property damage estimates have dominated loss reporting until recently, but flow measures are important in their own right. First, in recent major disasters, such as the 9/11 World Trade Center Attacks and Hurricane Katrina, BI losses have far exceeded property damage.

[1] It should be noted that the use of GDP underestimates the pure Welfare impact. It only values goods at their price, which, except for the marginal consumer is lower than the willingness to pay of all other consumers. Similarly, the sales price for the marginal producer may be equal to marginal cost, but it is higher than the marginal cost for all other producers.

Second, direct BI losses can take place even in the absence of property damage, and hence represent broader coverage of the scope of losses. For example, a factory may be unscathed by an earthquake, but may be forced to shut down if its electricity supply is cut off due to earthquake-induced damage to power stations, substations, transmission lines, or distribution lines.[2]

A third reason flow measures are useful is that they are more consistent with indices of individual wellbeing, such as consumer satisfaction and business profits, or with aggregate measures, such as gross national (or regional) product. In this regard, property damage measures can exaggerate losses because only a portion of the property value translates into service flows in any 1 year. Additional reasons flow measures are superior is that they have a time dimension and are more readily linked to the majority of indirect effects (see below).

The major reason flow measures are superior to stock measures is that the former include a time dimension. Stock measures pertain simply to the value of an asset at a single point in time. The typical measure of damage (purchase or replacement cost) is thus invariant to how long the asset is out of service. For example, if the roof of a factory is blown off by a hurricane, there is a tendency to specify the loss in fixed terms, irrespective of whether production is shut down for a week or a year awaiting repairs. This makes all the difference with respect to BI.

Attention to flow losses represents a major shift in the focus of hazard loss estimation—that losses are not a definite or set amount but are highly variable depending on the length of the "economic disruption," typically synonymous with the recovery plus reconstruction periods. This also brings home the point that disaster losses are not simply determined by the strength of the stimulus (coupled with initial exposure and modified by mitigation that reduces vulnerability), but also highly dependent on human ingenuity, will, and resources following the shock. Caution should be exercised, however, before rushing toward minimizing losses without consideration of the increased recovery costs incurred. The broader objective is to minimize the joint cost of impacts and recovery/reconstruction. Fortunately, a set of costless, or near costless, tactics to greatly reduce BI losses during the recovery period exist in the form of resilience (see, e.g., Rose 2004, 2009). These include both market (private sector) and non-market (public policy responses) to be discussed further below.

[2] The value of an asset is the discounted flow of net future returns from its operation. Hence, for ordinary property damage the stock and flow measures represent the same things, and, at first pass, including both would involve double-counting. The situation is, however, complicated in the case of natural hazards. This is a controversial subject. I am in agreement with analysts who suggest it is appropriate to include both the stock and flow measures in the case of damaged property, but only where the latter is confined to the opportunity costs of delays in restoring production because of the repair and reconstruction process.

2.1.3 Double-Counting

In addition to some stock/flow overlaps, care should be taken to avoid other types of double-counting of hazard losses. Many goods and services have quite diverse attributes, and all of those damaged/interrupted should be counted (e.g., a hydroelectric dam provides electricity, recreational opportunities in the reservoir behind it, and flood control). It is important, however, to remember that some goods and services cannot yield all of these attributes to their maximum simultaneously, and that only one or the other, or some balance of the two, should only be counted (e.g., a river can provide services to swimmers or it can be a repository for waste but not both at the same time).

Double-counting can be avoided by not attributing losses to more than one entity in the case of private goods, as in the case of avoiding counting retail store sales as a loss to both the storeowner and its customers. Just as important, however, is the inclusion of all relevant losing entities or stakeholders. Caution must be exercised here because of the regional character of most hazards and the inclination just to consider those living within its boundaries. Tourism associated with natural environments is an excellent case in point. Loss of environmental value should not just be gauged by local residents and also not by current users but by all potential users in terms of a concept known as option demand (Freeman et al. 2014).

A closely related consideration pertains to the distinction between costs and transfers. If the expenditures needed to repair flood damage to a bridge are $10 million, and 5 % of the expenditures were various types of taxes (sales, import tariffs, property, etc.), taxes do not reflect the use of resources and are not real costs to society. In general, such taxes are important to individual households or businesses, but simply represent a shifting of dollars from one entity to another. The complication that arises here, however, pertains to the spatial delineation of the affected group. Local property or sales taxes within a region are transfers, but payments of federal income tax do represent an outflow and can be legitimately included in the regional cost estimates. Of course, there is the danger of being too provincial in such assessments.[3]

2.1.4 Direct Versus Higher-Order Effects

The distinction between direct and indirect effects has been the subject of great confusion in hazard loss estimation from the outset. For example, the characterization that direct loss pertains to property damage and indirect loss pertains to business interruption (see, e.g., ATC 1991; Heinz Center 2000) is not helpful

[3] Some taxes, such as property taxes, do reflect an indirect payment for services, such as water and sewer, but tariffs and sales taxes do not. Property taxes would only be included in the resource cost tabulation if the water and sewer services were actually used in the construction of the hydroelectric dam and then only at a level commensurate with the service costs.

because both have direct and indirect components.[4] While total business interruption losses are the bottom line, distinguishing components helps ensure everything is counted and provides more precise information for decision-making (e.g., as illustrated below, direct effects usually pertain to private concerns of individual businesses, while indirect effects raise additional public policy issues).

Direct flow losses pertain to production in businesses damaged by the hazard itself, or what the NRC (1999, p. 15) study refers to as the “consequences” of physical destruction, though without distinguishing direct vs. indirect components as does Mileti (1999; p. 98). They have also come to include lost production stemming from direct loss of public utility and infrastructure services (Rose et al. 2011). For example, earthquake-induced disruptions of water supplies may force the closing of a high-rise office building for fire safety reasons (fire engine hoses can only reach the first several floors, and the remainder of fire control is dependent on internal sprinkling systems). A factory may have to shut down because the bridge that its suppliers and employers use to reach it is damaged. Again, the office building and factory may not suffer any direct physical damage.

The extent of BI does not stop here, but sets off a chain reaction. A factory shutdown will reduce supplies to its customers, who may be forced to curtail their production for lack of critical inputs. In turn, their customers may be forced to do the same, as will the customers of these customers, and so on. These types of effects are called downstream, forward, or supply-side linkages. A set of counterparts refers to upstream, backward linkage, or demand-side indirect effects. The factory shutdown will also reduce orders for its inputs. Its suppliers will then have to reduce their production and hence cancel orders for their inputs. The suppliers of the suppliers will follow suit, and so forth. The sum total of all of these indirect effects is a multiple of the direct effects; hence, the concept of a “multiplier” is often applied to their estimation (Rose and Miernyk 1989; FEMA 2014).[5] The state of the art modeling approach, computable general equilibrium (CGE) analysis, has gained prominence in ECA (see, e.g., Rose 2005, 2015. It is able to estimate a broader range of “higher-order” impacts, typically referred to as “general equilibrium” effects, which, rather than being confined to economic interdependence (based solely on

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[4] Indirect effects can also be associated with stock losses or property damage (e.g., earthquakes causing damage from fires, hazardous materials leakages, and buildings made more vulnerable to subsequent weather damage). However, except in extreme cases, such as the 2011 Japanese earthquake and tsunami followed by the Fukushima nuclear reactor accident, these indirect stock effects are likely to be relatively small when compared with the flow-induced indirect losses

[5] Some further clarification is in order. First, the current line of demarcation between direct and indirect effects is somewhat arbitrary, specifically, the convention of counting business losses due to cut-off from utility lifelines as direct effects. There is equal justification for considering these to be first-round indirect effects. The advantage to including these as direct losses is that it emphasizes the key role of utilities and infrastructure in the economy, and emphasizes their prominent role in contributing to losses. Also, it helps ensure that these effects will be taken into account, because most analysts are not able to or do not bother to consider what are termed “indirect” effects.

quantities of inputs and outputs), also capture responses to price changes in factor and product markets (Dixon and Rimmer 2002; Rose et al. 2017).

Many analysts are hesitant to measure higher-order losses for various reasons. First, they cannot be as readily verified as direct losses. Second, modeling them requires utilizing simple economic models carefully, or, more recently, utilizing quite sophisticated economic models. Third, the size of higher-order effects can be quite variable depending on the resiliency of the economy and the pace and pattern of recovery (see, e.g., Rose et al. 1997, as well as the discussions and illustrations below). Fourth is the danger of manipulating these effects for political purposes (e.g., it is not unusual in the context of economic development for promoters to inflate multipliers). However, none of these reasons undercut the importance of higher-order effects, especially if one considers that their likely size is often greater than direct effects (see, e.g., Cochrane 1997; Webb et al. 2000; Bram et al. 2002).

2.2 Non-market Effects

Hazard researchers are becoming increasingly aware of the ever-broader scope of disaster losses. Heinz (2000) does an excellent job of enumerating their extent, including categories of Social, Health and Safety, and Eco-System costs. Most of the losses in the latter category, as well as a significant portion of losses to one of the other two categories identified in the Heinz Report—the Built Environment—are characterized by economists as "non-market." This means they are not bought or sold and hence do not readily have a price tag. However, just because something does not have a price does not mean it does not have value; it simply means a "market failure" has occurred. In this case, a market will fail to perform it major function, because the absence of prices will cause resources to be misallocated.

The major area of attention to non-market aspects of natural hazards to date has been on one part of the built environment—public infrastructure, such as highways/bridges and utility lifelines (electricity, gas, and water). Non-market effects arise here primarily because the former category is typically publicly (rather than privately) owned, and hence services are typically provided without exacting a direct payment, and/or because both categories have features of decreasing cost activities (natural monopolies), and appropriate pricing is made difficult (see also Howe and Cochrane 1993).[6]

[6] Both eco-system losses and public infrastructure losses arise in the context of what economists call "public goods," which have the characteristics that two or more people can utilize the services of the good simultaneously without detracting completely from one another, and from which people cannot be excluded because it is technologically impossible, socially unacceptable, or economically impractical. Major examples of public goods are national defense, television broadcasting signals, national parks, and environmental resources in general. This is in contrast to more typical "private goods," which are utilized by one person at a time and for which a price can readily be extracted (e.g., clothing, restaurant meals, etc.). Not all public goods are provided by government; some are provided by the private sector under the right circumstances, and most

The various flow impacts of natural hazards on the public sector built environment have been termed "infrastructure user costs" (see Rose et al. 1998). For the case of a highway washed away by a flood, there is no direct production loss measure, e.g., no lost public highway "sales," except in the case of toll roads, where the toll is not necessarily an accurate measure of lost value in any case. Direct losses would, according to the convention noted earlier, best be represented by lost revenue of businesses that are required to shut down because their employees could not get to work, inputs could not be accessed, or outputs could not be delivered.

Several other non-market direct impacts take place, however, as do conventional market and unconventional non-market higher-order impacts. Commuters are adversely impacted by transportation outages through loss of time due to congestion (even the subsequently decreased leisure time has a value); however, there are no multiplier effects associated with this activity. On the other hand, the loss of productivity to producers or transportation companies results in cost increases that have price multiplier effects first (a form of "cost-push" inflation) and output multiplier effects subsequently. Consumers may also curtail their shopping trips due to bridge or highway outages. These decreases in direct consumption also generate higher-order effects (see, e.g., Gordon et al. 1998).

For the case of utility lifelines, direct and indirect production losses are likely to be the major loss category. Production losses stem from downtime or decline in product quality and will spawn multiplier effects, as in the transportation example. Decreases in household activity (reduced showers, reading time, cooking) are not part of economic indices, but they should be considered in broader measures of well-being, though multiplier effects are not applicable (Rose and Oladosu 2008).[7] The consumer side is important but lifeline disruptions will have little effect on shopping over and above that attributable to business operation itself. For example, if a power outage causing the closure of a department store were listed as a direct output (sales) loss for the producer, it would be double-counting if included as a consumption loss as well.

The largest potential area of non-market losses pertains to the natural environment, ranging from conventionally marketed economic activity, such as agriculture

environmental goods are provided by nature. There is considerable momentum to reduce the number of goods and services provided by government, even for what were previously thought to be public goods. This involves enhancing the "excludability" characteristics so that a user fee can be charged. This is not necessarily simple since efficient pricing would actually require that different users be assessed different charges, according to their marginal willingness to pay. Another complication is that some goods have different values and different degrees of "publicness" at different times (a classic example is a road, which can accommodate traffic at zero cost during normal hours, but that is subject to congestion, which imposes costs on all users during peak hours). Several remedies to this situation have been proposed, as well as for the more complicated situation where periods of congestion (and hence increasing costs) exist. All of these remedies require careful scrutiny to make sure that the price charged represents accurate valuation of the resources used.

[7] Property damage to residential structures also has a flow counterpart, termed the "imputed rental value of owner-occupied dwellings." This non-market cost might be measured as well; it has no higher-order effects, except those associated with payments for temporary shelter.

and forestry, but extending to damages to the environment in general, even including "option value" (in part, the value one places on potential access to the resource in the future). An extensive literature on non-market valuation exists (see, e.g., Freeman et al. 2014) but was largely unnoticed by hazard researchers, though it is a major focus of the closely related area of research on damages from climate change (see, e.g., IPCC 2014). Note that while climate change is usually characterized by long-term warming, it also gives rise to short-term climate variability, which many scientists have concluded manifests itself in increasing frequency and magnitude of hurricanes and other types of severe storms that can lead to direct and indirect losses through water or wind damage.

2.3 Distributional Considerations

Often neglected in hazard loss estimation and ECA is the distribution of costs and benefits. These considerations relate to how impacts are spread across regions, sectors and socioeconomic groups. Most of loss estimates to date in this area have disaggregated their results by economic sector, fewer by region, and even fewer by income bracket or race/ethnicity.

Distributional considerations are important for at least three reasons. First, numerous studies have determined that the least well-off and minority groups are those most vulnerable to disasters; moreover, their condition is exacerbated by these events (Mileti 1999). Thus, disasters are a great concern from an equity, or justice, standpoint. Second, lagging socioeconomic groups or lagging regions have been found to represent a drag on economic growth and development. Third, identifying the impacts on various stakeholders provides insight into the motivations of government decision-makers and the likelihood of support or lack of support for disaster risk management policies. Distributional information can better inform stakeholders and thus enhance the public participation process, as well as serving as a predictive tool for the decisions the process is likely to yield. Used appropriately, distributional information can fill in many needed informational gaps and help lead to a more enlightened citizenry, and hence decisions more attuned to the needs of the public (Rose et al. 1988).

Distributional impacts are likely to be more controversial than aggregate ones but no less important. For example, achieving accuracy is more difficult for subsets of a region. Also, there is likely to be a mismatch between those who may have to incur the costs of mitigation or post-disaster recovery and those who benefit from their implementation. Still, accurate distributional estimates are a useful supplement to the aggregate numbers used in most benefit-cost analyses (BCA). Ordinary BCA implicitly justifies decisions on the basis of how the community is impacted as a whole. It works well in the context of a single, custodial decision-maker (increasingly less the case these days), or, in the case of public participation if people are entirely altruistic (also unlikely). Distributional information, on the other hand, can help affected parties to see what stake they have in dealing with natural hazards. At the very least, this will help make potential impacts more poignant and generate greater interest in the issue.

Distributional loss estimation also addresses the increasingly prominent issue of “environmental justice,” which has typically been applied to evaluating differential environmental impacts of public policy across racial/ethnic groups (Schlosberg 2007). This topic is important for reasons of fairness, but also for pragmatic reasons relating to lawsuits brought by minority group members when they have felt an unequal burden of environmental damage and can readily be extended to natural hazard damage, or felt they were incurring a disproportionate percentage of the cost of mitigation or remediation.

The distribution of hazard impacts is often omitted because of lack of models or data. However, the models discussed below are well-suited to performing distributional analysis of natural hazards, and have been applied extensively to related contexts of climate change policy (see, e.g., Kverndokk and Rose 2008; Rose et al. 2012). They disaggregate the economy into sectors, providing insight to the inherent unevenness of direct and higher-order impacts across industries and between industries, households, government, and other institutions. Many of the models allow for further analysis of socioeconomic or institutional accounts by disaggregating income, consumption, and trade flows (Batey and Rose 1990; Hanson and Rose 1997; IMPLAN 2016).[8] This modeling is reasonably straightforward, including calculation of short-cut distributional multipliers, e.g., how a direct change in income to one socioeconomic group affects all others directly and indirectly (see, e.g., Okuyama et al. 1999). The major limitation is data, especially mapping of income flows from sectors to socioeconomic groups. Still, some useful data reduction and adaptation techniques exist here as well (see Rose et al. 1988; Li et al. 1999), so that this area of application is considered to be reasonably accurate, though not as much as aggregate impact estimation.

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[8]The number of income brackets is limited by the availability of data but typically involves as many as ten separate classes. Extensive disaggregations of occupational groups are possible because of the longstanding work of the U.S. Bureau of Labor Statistics. Disaggregations according to racial/ethnic groups are more difficult, but a good deal of data is generally available from the U.S. Bureau of Census.

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