Natural disasters, poverty and inequality

new metrics for fairer policies

Stephane Hallegatte and Brian Walsh[1]
The World Bank

Conventional risk assessments underestimate the human and macroeconomic costs of disasters, leading to inefficient risk management strategies. This happens because conventional assessments focus on asset losses, neglecting important relationships between vulnerability and development. When affected by a hazard, poor households take longer to recover from disasters and are more likely to face long-term consequences. Forced to manage trade-offs between essential consumption and reconstruction, these households are more likely to face persistent health or education costs. This chapter proposes a review of existing research into the natural disaster-poverty-inequality nexus and the various metrics that can be used to measure disaster impacts, such as recovery times, economic (income or consumption) losses, poverty incidence, inequality, and welfare or well-being losses. Each of these metrics provides a different perspective on disaster costs and suggest different spatial and sectoral priorities for action. Focusing on the concepts of well-being losses and socioeconomic resilience, this chapter shows how more comprehensive accounting of disaster impacts can better inform disaster risk management and climate change adaptation strategies and support their integration into development and poverty-reduction policies.

1. Introduction

Worldwide, natural disasters pose a growing threat to economic and political stability. According to Munich Re, economic losses to natural disasters averaged US$187 billion per year from 2009-2018, a 30 percent increase over the inflation-adjusted 30-year average (Munich Re 2019). This increase is driven largely by economic growth and urbanization, poverty and inequality, and climate change, each of which presents unprecedented challenges in the decades ahead.

In a world of massive inequalities within and across countries, the increase in aggregate economic losses cannot inform us on the real impact of these disasters. In the conventional practice of disaster risk management, the severity of disasters is measured by their direct damages, or the replacement cost of assets damaged or destroyed by a shock. Other dimensions--such as the impact on health, education or quality of life--are not usually incorporated into disaster loss estimates or in cost-benefit analysis of possible risk reduction interventions.

[1] Stephane Hallegatte, Senior Climate Change Adviser, Climate Change Group, The World Bank, shallegatte@worldbank.org.
Brian Walsh, Senior Economist, Climate Change Group, The World Bank, bwalsh1@worldbank.org.

One implication of the use of economic or asset losses as a measure of disaster impacts is that Disaster Risk Management (DRM) strategies tend to favor the wealthy, central business districts, and other clusters of valuable assets. Interventions targeting poor people, who have few assets to start with, cannot generate large gains in terms of avoided asset losses and are therefore discouraged by this metric. And while this prioritization makes sense from a pure monetary perspective, it disincentivizes attractive investments in the poorest areas, even when small interventions could significantly reduce the stunting of children (Dercon and Porter 2014), disease transmission (Yonson 2018; Erman et al. 2019), absenteeism from work and school, lost wages, and many other types of disaster impacts on well-being (Hallegatte et al. 2017).

At a macroeconomic level, asset losses also obscure the relationship between vulnerability and development. Economic growth increases the value of assets and thus tends to increase disaster losses, when they are measured in asset losses (Kahn 2005; Schumacher and Strobl 2011; Hallegatte 2017). But development and higher incomes also make people more resilient: the long-term impacts of disasters on communities' well-being and prospects depend not only on direct impacts (asset losses), but also on the accessibility of financial tools (e.g., social transfers, formal and informal post-disaster support, savings, insurance, and access to credit). Households that lack access to these tools will struggle to cope with shocks, and could fall into chronic poverty as a result (Carter and Barrett 2006). In short, complete reliance on asset losses obscures the role of poverty reduction as a tool to reduce disaster impacts (Hallegatte et al 2016) and impedes the development of DRM strategies that can be integrated into larger development agendas.

Disasters have complex and diverse consequences that can be measured (and, increasingly, anticipated) in terms of recovery times, economic (income and consumption) losses, poverty incidence, or welfare and well-being losses, among other metrics. Each of these metrics provides a different perspective on disaster costs. In contrast to direct damages, many of these impacts of natural disasters accrue disproportionately to poor households. This is because income shocks can force the poor to make difficult decisions between food, housing, education and healthcare, and reconstruction. As a result of these tradeoffs, poor households take longer to recover from disasters, and are more likely to face long-term consequences.

The next section will trace the evidence for the impacts of disasters on poverty, accounting for both human and economic costs, which are well documented in case studies. In Section 3, we will flip the perspective, and consider the ways in which poverty exacerbates the effects of natural disasters. Section 4 introduces the concepts of well-being losses and socioeconomic resilience and quantified metrics to measure them. It then uses these concepts to explain how these metrics can lead to more effective and efficient DRM strategies. Finally, Section 5 summarizes the policy implications of the socioeconomic resilience framework.

2. Traditional economic assessments do not capture the full impact of disasters on poor people

Income and economic consumption are distributed very unequally in the world. In 2017, and using purchasing power parity (PPP) exchange rates, the GDP of Subsaharan Africa was

around $6 trillion, i.e. 4 percent of the world total of $141 trillion. In other terms, the economy of Subsaharan African is of the same size as the five richest cities in the world (Tokyo, New York City, Los Angeles, Seoul and London). It means that even tragic disasters in Subsaharan Africa are unlikely to have economic losses that compare with recent events in high-income countries (such as hurricanes Katrina, Sandy, and Harvey in the US). It does not mean, however, that disasters in Subsaharan Africa are less important, or less impactful on people's well-being.

The same issue is valid within countries. In Guatemala, the income of people in the bottom 20 percent of the population represents only 4 percent of the national income. It means that these people are 5 times poorer than the average. Even a massive loss of income or assets for this group cannot have a large impact on national GDP, which again does not mean that this loss is not important for the well-being and long-term prospects of a significant fraction of the population.

These considerations suggest the need to have a closer look at how disasters affect poverty and poor people, to make sure those impacts - which are unlikely to be well measured by GDP or income impacts - are given due consideration in risk assessments and in the design of risk management policies. This section examines this question.

Disasters have visible impacts on local poverty

Poverty increases in the direct aftermath of a disaster are widely documented. This section provides a short review of case studies that document this effect, for various hazard categories, regions, and timescales.

In Bolivia, the incidence of poverty climbed by 12 percent in Trinidad City after the 2006 floods, a fivefold increase compared with the national average (Perez-De-Rada and Paz 2008). Examining the ex post impacts of Hurricane Mitch, which struck Nicaragua in 1998, Jakobsen (2012) found that poorer households faced a larger *absolute* decline in productive assets immediately after Mitch. Furthermore, among those households affected by Mitch, the share of asset-poor households (those who own less than a given asset-poverty line) increased from 75 percent in 1998 to 80 percent in 2001.

Among households hit by Tropical Storm Agatha in 2010 in Guatemala, consumption per capita fell by 5.5 percent, increasing poverty by 14 percent (Baez et al. 2016). Whereas previous studies typically focused on the impacts of Agatha in rural areas, Baez et al. (2016) document the sharp impacts of Agatha in urban areas of Guatemala, where poverty increased by 18 percent, mainly because of higher food prices. Meanwhile, Ishizawa and Miranda (2019) find that an increase of one standard deviation in the intensity of a hurricane in Central America increases moderate and extreme poverty levels by 1.5 percentage points. Finally, a recent meta-analysis of 38 such studies found that incomes are consistently reduced by natural disasters (Karim and Noy 2014).

Beyond the immediate impact after a disaster, evidence suggests that natural disasters increase poverty over the medium and long term. Glave, Fort, and Rosemberg (2008) studied exposure

to disasters and poverty from 2003 to 2008 at the provincial level in Peru. They found that one extra disaster per year increased poverty rates by 16–23 percent. At the municipal level in Mexico, Rodriguez-Oreggia and his colleagues (2013) found that floods and droughts increased poverty levels between 1.5 and 3.7 percent between 2000 and 2005. And in Ecuador, Calero, Maldonado, and Molina (2008) found that from 1970 to 2007 exposure to drought increased the incidence of poverty by 2 percent on average.

In Asia, Akter and Mallick (2013) surveyed households in coastal communities affected by Cyclone Aila in 2010 in the southwest of Bangladesh. Unemployment skyrocketed, from 11 percent in 2009 to 60 percent in 2010, and the poverty headcount rate increased from 41 percent before the storm to 63 percent afterward. In a recent analysis of the 2011 floods in Bangkok, Thailand, Noy and Patel (2014) report a large decrease in the agricultural and total income of poor households, compared with those with greater wealth. And even households that were not directly affected by the floods experienced a significant decrease in income—a spillover effect of the flood. In their study in the Philippines, Safir, Piza, and Skoufias (2013) found that low precipitation (below one standard deviation) decreases consumption by 4 percent, and all of the decrease occurs in food consumption, suggesting potential health impacts through undernutrition

Disasters can have permanent impacts on human capital and well-being through education and health, with poor children as the main victims

Disasters force poor households to make choices that can have detrimental long-term effects. Recurrent events, such as urban floods in informal settlements, have impacts on the health of adults and children and have large cumulative impacts on poor people, even if each event is relatively small (Erman et al. 2019). Such events lead in particular to missed days at school for children and missed days at work for adults because traveling to the workplace is impossible or because adults (mostly women) stay home to take care of sick children.

Impacts on education are prevalent. In Africa, enrollment rates have declined 20 percent in regions affected by drought (Jensen 2000). Similar postdisaster impacts on health and education have been found in Asia, Latin America, and elsewhere (Baez, de la Fuente, and Santos 2010; Maccini and Yang 2009). In Mexico, once children have been taken out of school, even just for a temporary shock such as a flood, they are 30 percent less likely to proceed with their education, compared with children who remain in school (de Janvry et al. 2006). The impacts of the 1970 Ancash earthquake in Peru on educational attainment can be detected even for the children of mothers affected at birth, demonstrating that the effects of large disasters can extend even to the next generation (Caruso and Miller 2015).

Evidence also suggests that disasters have acute impacts on health, either directly or indirectly, through lower post disaster consumption. After the 2004 floods in Bangladesh, more than 17,000 cases of diarrhea were registered (Qadri et al. 2005), and the 1998 cholera epidemic in West Bengal, India, was attributed to the earlier floods (Sur et al. 2000). In Pakistan, the incidence of infectious disease and diarrhea increased as a result of the impact of the 2010

floods on the quality of the water. Ongoing efforts to eradicate polio were also interrupted, further setting back this goal (Warraich, Zaidi, and Patel 2011).

In Subsaharan Africa, asset-poor households respond to weather shocks by reducing the quality of the nutrition provided to their children (Alderman, Hoddinott, and Kinsey 2006; Dercon and Porter 2014; Hoddinott 2006; Yamano, Alderman, and Christiaensen 2005), and they are less likely to take sick children for medical consultations (Jensen 2000). These behaviors have short- and long-term impacts, particularly for children younger than 2. Six months after a drought, children in households reducing nutrition were 0.9 centimeters shorter than other children (Yamano, Alderman, and Christiaensen 2005), and the stature of children in these households was permanently lowered by 2–3 centimeters (Alderman, Hoddinott, and Kinsey 2006; Dercon and Porter 2014).

In Central America, major disasters have also reduced investments in human capital. After Hurricane Mitch hit Nicaragua in 1998, the probability of child undernourishment in regions affected by the hurricane increased by 8.7 percent, and child labor force participation increased by 5.6 percent (Baez and Santos 2007). In Guatemala, Storm Stan increased the probability of child labor by 7.3 percent in departments hit by the storm (Bustelo 2011). Natural disasters also increase the multidimensional poverty index through a deterioration of “education conditions” and “child and youth conditions,” as demonstrated by Sanchez and Calderon (2014) for Colombia from 1976 to 2005.

From case studies to a global estimate: disasters contribute to global poverty

This collection of case studies suggest that disasters have a significant impact on poor people and contribute to poverty. But by how much? It’s difficult to extrapolate from case studies to global estimates, due to the heterogeneity in hazard distribution and vulnerability.

Although it remains impossible to quantify the full effect of natural disasters on the number of impoverished, it is possible to assess the short-term impacts of income losses (see Hallegatte et al 2016). To do so, a counterfactual scenario was built of what people’s income in developing countries would be in the absence of natural disasters. This scenario uses surveys of 1.4 million households, which are representative of 1.2 billion households and 4.4 billion people in 89 countries. The analysis concludes that if all disasters could be prevented next year, 26 million fewer people would be in extreme poverty—that is, living on less than $1.90 a day. Although this estimate is subject to large uncertainties and cannot capture all impacts, including those on health, education, and savings, it still shows how severely natural hazards affect poverty.

3. Poor people are disproportionately affected by natural disasters

One reason why disaster impacts on poverty are significant, probably more than impacts on GDP, is because disasters affect poor people more. Natural disasters hit poor people particularly hard for multiple reasons. Some of these reasons are linked to people’s exposure to natural hazards (the probability to be affected by a hazard); others are linked to their vulnerability (the impact on people’s assets and livelihoods when they are affected); and finally some of linked to people’s socio-economic resilience (their ability to cope with and recover from the shock). This section explores these three dimensions (figure 1).

Figure 1: A comprehensive framework to understand the impact of natural hazards on well-being. (Source: Hallegatte et al 2016).

Exposure: Poor people are often (but not always) more likely to be affected by natural hazards

In many places, poor people are more likely to be affected by a natural hazard than the rest of the population. In particular, poor people are often exposed to frequent, low-intensity events, such as the recurrent floods that affect many cities with insufficient drainage infrastructure. These events do not attract media interest and are poorly documented, but they can have significant cumulative impacts, especially through their effects on health. In Vietnam's Mekong Delta, 38 percent of the region's poor but only 29 percent of the region's nonpoor live in frequently flooded areas (Nguyen 2011).

This pattern also exists for major disasters. After Cyclone Aila hit Bangladesh in 2009, a post disaster survey of 12 villages on the southwest coast found that 25 percent of poor households in these villages were exposed to the cyclone, whereas only 14 percent of nonpoor households were (Akter and Mallick 2013). However, this pattern is not universal. After the 2011 floods in Kenya, almost everyone in the Bunyala District—poor and nonpoor—was affected (Opondo 2013). And in at least two documented cases, poor people were less exposed: after Hurricane Mitch struck Honduras in 1998, more than 50 percent of nonpoor households but only 22 percent of poor households were affected (Carter et al. 2007), and a similar pattern was observed after the 2011 floods in Thailand (Noy and Patel 2014).

Hallegatte et al (2016) performs a global analysis of poverty and exposure to disasters and conclude that the relationship between poverty and disaster exposure depends on the type of hazard, local geography, and institutions. In most countries (representing about 60 percent of

the population of the analyzed countries), poor people are more exposed to floods than the population average. This bias is only present among urban households, suggesting that it is land scarcity in cities that forces poor people to settle in dangerous areas. In parallel, around 85 percent of the analyzed population live in countries in which poor people are overexposed to drought. Finally, poor people are more exposed to extreme high temperature in 37 out of 52 countries (representing 56 percent of the population). Many of these countries are already hot. Cooler countries exhibit a smaller bias, and in some cool countries a negative bias because in these cool countries the nonpoor tend to settle in areas with higher temperatures, which are climatically more desirable.

These results suggest a sorting of the population into desirable and less desirable areas within a country, with wealthier households typically living in desirable areas and poorer households in less desirable ones.

For floods, another important issue is the availability of protective infrastructure such as dikes and drainage systems. FLOPROS (FLOod PROtection Standards), a global open and collaborative database, has illustrated the lack of infrastructure to protect poor people (Scussolini et al. 2016). People in low- income countries—especially those with GDP per capita of less than $5,000 in purchasing power parity (PPP) exchange rates —are significantly less protected than those in richer countries. This difference in protection alone can explain a factor 100 difference in flood risks between poor and rich countries (even before population vulnerability is considered). There are differences within countries as well, even if we cannot quantify them at this stage. Too often, investments—including those in disaster risk reduction—are directed toward the relatively wealthier areas at the expense of poorer neighborhoods. This effect can amplify the exposure gap between poor and nonpoor households and generate pockets of high risk.

Vulnerability - Poor people lose more (in relative terms) when they are affected by a natural shock

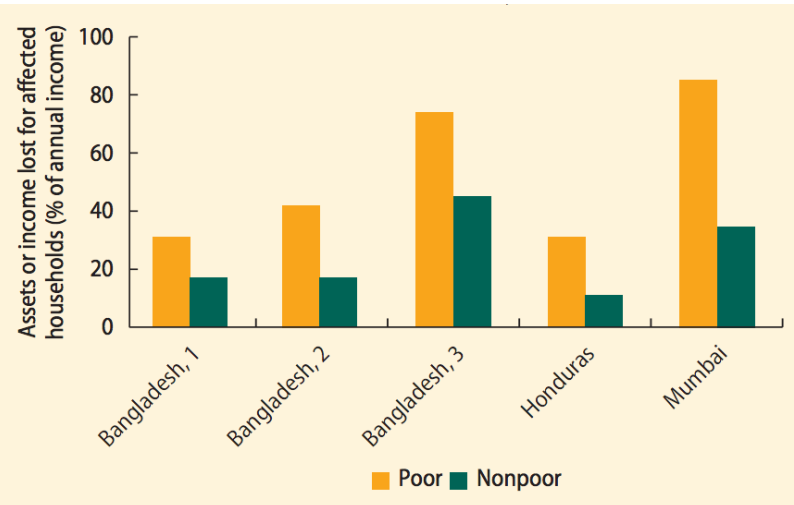
People’s vulnerability—that is, how much they lose when they are hit—is a critical determinant of the impacts of natural disasters. When poor people are affected, the share of their wealth lost is two to three times that of the nonpoor, largely because of the nature and vulnerability of their assets and livelihoods (see figure 2).

Why is it that poor people lose relatively more? First, poor people tend to have less diversified portfolios: they hold a larger percentage of their assets in material form and save “in kind.” The first savings of poor urban dwellers often take the form of investments in their home, which may be vulnerable to natural hazards such as floods or landslides (Moser and Felton 2007). Many rural poor use livestock as savings, despite their vulnerability to drought (Nkedianye et al. 2011). The nonpoor, who have higher financial access, are able to spatially diversify and save in financial institutions, and their savings are thus better protected from natural hazards.

In addition to the portfolio composition effect, the quality of assets owned by poor people is lower. An example is housing stock: households living in slums or informal settlements

constructed of wood, bamboo, and mud and occupying steep slopes will sustain greater damage from a natural disaster than households whose homes are made of stone or brick. In coastal communities in southwest Bangladesh following Cyclone Aila, 76 percent of households in kacha houses (traditional homes built of mud and bamboo) reported structural damage—far above the 47 percent for those in pucca houses (built of concrete and wood) (Akter and Mallick 2013). A global analysis, based on the Global Building Inventory database from PAGER (Jaiswal et al 2011), shows that, on average globally, the poorest 20 percent in terms of consumption are 1.8 times more likely than the average person to live in dwellings in the "fragile" category (Hallegatte et al 2016).

Figure 2. Percent of assets or income lost due to a disaster, for poor and nonpoor households: Bangladesh, Honduras, and Mumbai, India. (Source: Hallegatte et al. 2016)



Sources: del Ninno et al. 2001 for the 1998 floods in Bangladesh (Bangladesh 1); Brouwer et al. 2007 for floods in southeast Bangladesh (Bangladesh 2); Rabbani, Rahman, and Mainuddin 2013 for flooding due to cyclones Sidr (2007) and Aila (2009) (Bangladesh 3); Carter et al. 2007 for hurricane Mitch in Honduras; and the 2005 great flood in Mumbai for Patankar and Patwardhan, 2016, for Mumbai.

Note: Each study has a different definition of "poor" and "nonpoor" in its sample. Vulnerability depends on the type of hazard and context in which it occurs; even within the same country (Bangladesh), vulnerability measures vary based on location and severity of flooding. The first three studies use percent of income loss as a metric, while the Honduras case uses asset loss and the Mumbai case uses asset, income, and repair loss. For Honduras, the graph reflects asset losses relative to total assets.

Socioeconomic resilience: Poor people are less able to cope with and recover from disasters

The very fact that they are poor makes poor people less able to cope with income losses. A 50 percent drop in income has very different consequences for two households living on $1,000 and $30,000 a year. In particular, poorer households cannot cut back on luxury consumption or delay consumption the way wealthier households can, and in many countries they are close to the subsistence level, which means that reducing consumption can have immediate negative

impacts on health (if food intake is reduced or medical care becomes unaffordable), education (if children are taken out of school), or economic prospects (if essential assets have to be sold).

In rural areas, lack of access to markets can exacerbate food security issues: if local production is lost to a drought or a flood, isolated communities cannot rely on production from other areas. Safir, Piza, and Skoufias (2013) found a 4 percent decrease in food consumption in areas of the Philippines with low precipitation, but this effect disappears in areas close to highways. This finding suggests that well-connected areas are less vulnerable to the food-security consequences of natural disasters. But even in well-connected areas, natural disasters can result in food price spikes as a result of supply shocks. Disasters can destroy crops and seed reserves, destroying in turn productive assets in agricultural communities and sparking food price shocks, as occurred after the unprecedented 2010 floods in Pakistan (Cheema et al. 2016). The floods destroyed 2.1 million hectares of agricultural land, decimating production and sending the price of wheat up to more than 50 percent above the preflood level.

Poor people are more vulnerable than the rest of the population to increases in food prices. According to the World Bank Global Consumption Database, poor people in developing countries spend on average between 40 and 60 percent of their household budget on food—far more than the 25 percent spent by the nonpoor. However, net food producers could gain from higher food prices if they can maintain their production levels.

The impact of natural disasters on well-being also depends on the support affected people receive. In low income countries, only 19 percent of the bottom quintile are covered by social safety net systems (State of Social Safety Nets 2018). After they are hit by a shock, poor people receive less postdisaster support than do nonpoor people. For example, in response to the floods and landslides in Nepal in 2011, only 6 percent of the very poor sought government support, compared with almost 90 percent of the well-off (Gentle et al. 2014).

Even when poor households receive support, the amounts received are often too small to enable better coping strategies. In Bangladesh, following the 1998 Great Flood, 66 percent of households in the bottom quintile received transfers, compared with 33 percent in the top quintile, and 53 percent of the flood-exposed households received transfers, compared with 34 percent of nonflood-exposed households (del Ninno et al. 2001). Although the targeting was relatively good, the transfer amounts were small: only 4 percent of the total household monthly expenditure for poor households and 2 percent for all households. Household borrowing highlights this limit: poor households affected by the flood borrowed six to eight times more than the level of government transfers.

Post disaster support often fails to provide the poorest with enough resources because of their lack of voice and influence. As different categories of the population compete for help after a disaster, those with better connections are likely to get more, and more timely, support. When poor people are excluded from governance and have no say in the decision-making process, support is less likely to be timely or adequate. In case studies on Thailand, it was found that the majority of government support after a flood benefited the well-off, with 500 baht per capita

(about $14) going to the richest quartile, compared with 200 baht per capita for the poorest quartile (Noy and Patel 2014).

4. The need for a better measurement of disaster impacts - Modeling disasters at the household level

In summary, poor people are disportionately affected by disasters because they are often more likely to be affected by a shock, they lose more when they are affected, they have lower capacity to cope with their losses, and they receive less external support for recovery. These biases make it extremely problematic that our main metric of disaster severity is asset losses, since any impact on the poorest people is unlikely to be visible with this metric.

This section proposes an approach to measure natural disasters in a way that gives more visibility to the impact of poor people, and therefore better capture the real welfare- or wellbeing-related impacts of disasters. It is based on a series of papers, including some global analyses (Hallegatte et al 2016) and country studies, in the Philippines, Sri Lanka, and Fiji (Walsh and Hallegatte 2019, 2020; World Bank and Government of Fiji, 2017).

The methodology starts from the traditional metric (asset losses), but estimated at the household level, and then moves on to income losses, then consumption losses, and finally welfare losses. Comparing these different metrics at the global or national scale offers new evidence that using asset losses only leads to an underestimation of the welfare impact of disaster, and to policies that can be not only unfair, but also less efficient (in welfare terms).

A traditional metric: asset losses

Typically, asset losses is the metric used to measure disaster severity. For instance, the amount of asset losses is what makes headlines in newspapers after a disaster. The main reinsurers publish every year an assessment of the total asset losses during the year, as cited in the introduction to this chapter. While these assessments sometimes include agricultural production losses (e.g., the value of the crops lost to a flood or a drought) and business interruptions (i.e., the inability of firms to produce in the immediate aftermath of a disaster), these additional components are similarly focusing on the pre-disaster value of what has been lost or damaged. Similarly, risk assessments are generally limited to average annual asset losses in the area of interest.

To provide a fair assessment of the well-being impact of disaster, however, providing the aggregate asset losses is not enough. One needs to consider who is affected and how aggregate losses are distributed among households. This is what is done in Hallegatte et al. (2016) (considering two categories of households per country in a simple model) and Walsh and Hallegatte (2020) (considering 40,000 households in the Philippines).

Using household-level data on exposure (Where are people living? Are they exposed to floods or earthquakes?) and vulnerability (In what type of dwelling do people live? How much asset do they have?), these studies estimate the distribution of asset losses, and usually find that poor

people tend to lose a larger fraction of their assets than richer individuals. However, the absolute value of the losses is larger for richer people: in a subset of 117 countries, the bottom 20 percent in terms of income (one of many possible definitions of the poorest segment of the population) experiences “only” 11 percent of average annual asset losses. It means that poor people experience asset losses that are half of the country average.

Moving from aggregated asset losses to household-level asset losses already provides a much more granular view of disaster impacts as well as a better starting point to assess disaster impacts and design risk management interventions.

Income losses

Since asset losses are only a partial measure of the impact of disasters, it is possible to extend the analysis to explore how asset losses translate into income losses at the household level. In this process, the analysis moves from a *stock* analysis to a *flow* analysis, and the result becomes time-dependent through the recovery and reconstruction period.

Over the short term, total income losses are likely to decrease in proportion to total asset losses, and total income losses can be estimated as the product of the total asset losses and the *average* productivity of capital (Hallegatte and Vogt-Schilb, 2019).[2] A pastoralist losing one-third of his or her herd is likely to lose one-third of the income derived from it.

Since housing and public infrastructure represent a significant part of disaster damages, it is also critical to account for the loss in housing and infrastructure services, even when these are not exchanged on a market. For instance, a household who owns a dwelling will experience the equivalent of an income loss if their dwelling is destroyed and stop generating housing services (something that’s often missed in economic statistics in low- and middle-income countries). Also, the services provided by roads and bridges is usually not traded on a market (with the exception of toll roads and bridges), but the loss of services when they are damaged can affect well-being in a significant manner (see Hallegatte et al, 2019, for an estimate of the economic and health implications of infrastructure disruptions).

At the individual level, focusing on one household, it is important to account for the fact that people are affected by the loss of assets they do not own, but use to generate their income. This includes public assets, such as road and the power grid (and environment and natural capital) and some assets that are owned by other households, such as factories. In the methodology proposed here, the solution to ensure that all relevant asset losses are considered is to estimate the value of the assets household use to generate their income (including the value of housing and infrastructure services) based on their income and an estimate of the

[2] Note that a simple inclusion of capital losses into a traditional growth model would lead to a different calculation in which income losses are the product of the asset losses and the *marginal* productivity of capital. Hallegatte and Vogt-Schilb (2019) provides theoretical and empirical evidence - based on the heterogeneity of capital assets and the network effect within an economy - that using the average productivity is a better approximation.

average productivity of capital in the considered country (see Walsh and Hallegatte 2020 for details). As a result, the loss of a factory will affect the owner(s) of the factory, but also all the workers who depend on this asset for their income.

Moving from household-level asset losses to household-level income level makes it possible to look not only at the immediate consequences of a disaster (damage and destruction), but at the full recovery and reconstruction process. It redefines a disaster from an event during which an event causes damages (from a few minutes for an earthquake to months or more for droughts), to a much longer event that encompass years or decades of recovery and reconstruction. This broader definition means that the severity of the disaster depends not only on the extent of the damages, but also on the duration of the recovery and reconstruction period, which in turn depends on the ability of the affected communities to respond and rebuild. While a more efficient reconstruction leaves asset losses unchanged, it can significantly reduce income losses to disasters (Hallegatte et al 2018).

Consumption losses

To better understand well-being losses, income losses can then be translated into consumption losses, accounting for the response to the disaster. Two dimensions are important.

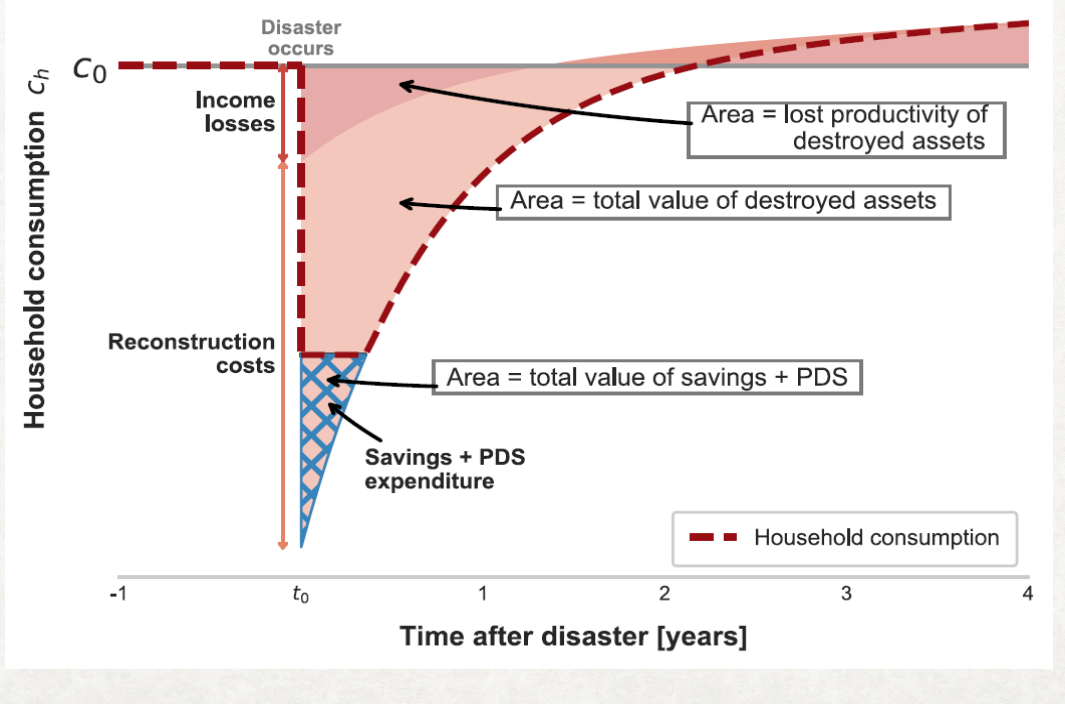
First, households often experience a drop in income after a disaster (there are exceptions such as people working in the construction sector), but they also have to use part of their income to replace the asset they have lost. For instance, they need to replace or fix their roof after a storm; to replace their appliance after a flood; or to replace livestock after a drought. It means the consumption losses can often be larger than income losses, a major difference with pure income shocks (e.g., due to fluctuation of demand) (World Bank 2013).

The pace at which households replace their lost asset depends on their characteristics, but it can take years or more before poor households can restore their asset stock to the pre-shock level (Dercon and Porter 2014). These reconstruction spending explains why household expenditures are often found to increase after a disaster (Erman et al, 2018; Noy and Patel, 2014). This increase in spending does not mean that their well-being increases compared with a no-disaster counterfactual. Instead, they correspond to forced spending (or “defensive expenditures”). In the assessment of consumption losses, we therefore remove reconstruction spending from the income stream.

Second, households have instruments to smooth their consumption when they experience a shock, such as the use of savings, formal and informal insurance (Kunreuther 1996; Skoufias 2003), remittances (Le De, Gaillard, and Friesen 2013), ad hoc postdisaster transfers, and the scaling up of social protection (Siegel and de la Fuente 2010). These mechanisms can replace some of the lost income after a disaster and reduce the resulting consumption losses. Some of them are transfers across time (like the use of savings), others are risk-sharing mechanisms across people or households that also transfer consumption across time (like formal or informal insurance), and finally others are pure transfers (such as humanitarian aid).

In practice, estimating the dynamics of consumption losses is difficult. In our approach, this is done by assuming that households determine the optimal pace of reconstruction to minimize the long-term welfare losses, through a trade-off between a quick reconstruction (which increases income fast but at the expense of short-term consumption) and a limited drop in near-term non-reconstruction consumption (but a drop that will last longer, since the recovery of the asset stock will take longer). Figure 3 illustrates one reconstruction pathway, showing both the drop in income, the larger drop in consumption due to reconstruction needs, and the role of savings and post-disaster support (PDS) in mitigating the consumption shock.

Figure 3. Illustrative consumption pathway during the reconstruction period, showing both the drop in income, the larger drop in consumption due to reconstruction needs, and the role of savings and post-disaster support (PDS) in mitigating the consumption shock.



Moving from income losses to consumption losses allows for a better accounting of people's socioeconomic resilience and access to coping mechanisms and instruments, such as savings, insurance, or social protection. Here again, the broader definition of the disaster and its losses highlights not only larger welfare losses, but also new opportunities to reduce them through a new set of intervention (from financial inclusion to social protection).

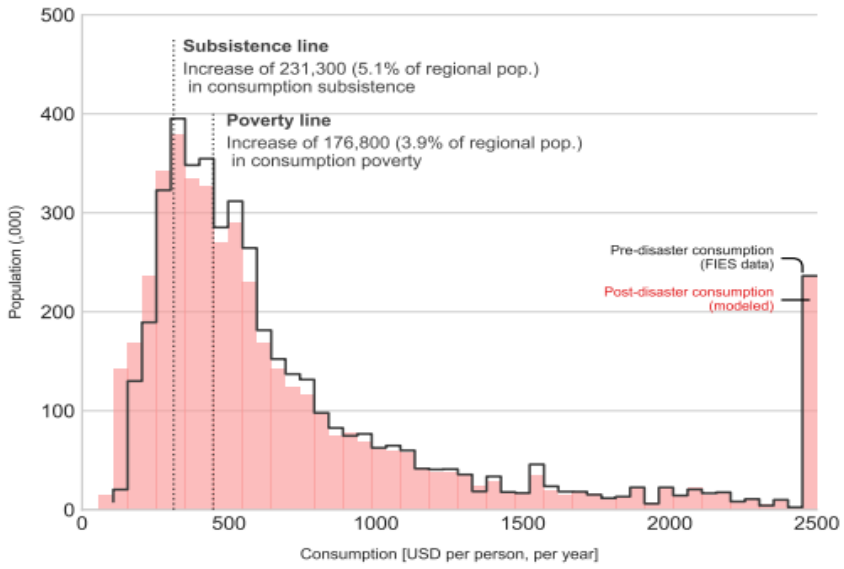
Welfare (or well-being) losses and other related metrics

As stated earlier, it is well accepted that the impact of the same consumption loss (say $1000) translates into different wellbeing consequences for a rich or a poor household, so a different metric is needed to capture these consequences.

One first option to look at wellbeing impacts is to focus on poverty headcount. This metric has many shortcomings. In particular, it measures only what happens to a small share of the population. For instance, it is independent of what happens to people already in poverty before the disaster: since they are in poverty already, their fate cannot affect the number of people falling in poverty. But it has the advantage of being simple and easy to communicate, even to non-experts.

The calculation of the household-level impact of the disaster on consumption makes it easy to calculate the number of people who will be (temporarily) in poverty due to the shock, as illustrated in Figure 4 for a Yolanda-like (100-year) typhoon making landfall in the Eastern Visayas region of the Philippines. In that case, the modeling exercise estimates that about 176,800 people, i.e. 4 percent of the region's population, would fall in poverty. Such an estimate provides a measure of the storm severity that is a good complement to the pure monetary losses.

Figure 4. Shift in the consumption distribution after a 100-year typhoon landfall in the Eastern Visayas region of the Philippines. (Source: Walsh and Hallegatte 2020.)



A poverty headcount is useful but does not capture many important factors. Hence the need for a more comprehensive metric that would still be able to account for the disproportionate impacts on poor people. This is the objective of the "well-being losses."

At a country level, well-being losses can be measured as *equivalent consumption losses*, defined as the decrease in national aggregate consumption (optimally shared across the population) that would lead to *the same decrease in welfare* as the actual, individual losses from the disaster. (Note that we use welfare and wellbeing interchangeably in this text; in practice, welfare is the economic term that refers to a traditional measure of well-being.)

While $1 in asset or consumption losses affect a poor individual more than a rich one, wellbeing losses are defined such that a $1 wellbeing loss affect the rich and the poor equally. Wellbeing losses are calculated from consumption losses using a constant relative risk aversion function (CRRA) (Wakker 2008) This operation translates into welfare units the value of a household's consumption at each point in its unique recovery, with decreasing returns to represent the fact that increasing consumption by $1 increases more the wellbeing of a poor individual (compared with a rich person). The difference in the welfare generated by $1 of consumption is a simple proxy for the continuum from survival consumption (the very first units of consumption that have the largest impact on wellbeing) to luxury consumption (which increases welfare less and less). This continuum is described in practice by the marginal utility of consumption. The elasticity of the marginal utility describes how the marginal utility of consumption decreases as income grows (in other terms, how much less does a hedge fund manager in London care about one dollar compared with a Haitian farmer).

In global assessments, the elasticity has often been assumed to be between 1 and 3 (Dasgupta 2012; Heal and Miller, 2014). Here, we use a value of 1.5 (consistent with, e.g., Evans, 2005). This choice will always be partly arbitrary. It represents objective factors, like the unquestionable fact that the impact of losing one dollar on the quality of life of an individual depends on his or her wealth. But it also depends on values and political choices, such as *whether* societies want to eradicate extreme poverty, provide decent quality of life to all, and ensure that children are given the opportunities they deserve. In a sense, this elasticity represents our "aversion for inequality" or our "preference of an equal society."

Moving from consumption losses to well-being losses, using a traditional welfare function, is a simple and practical way of accounting from the common sense idea that poor people suffer more when experiencing the same monetary loss than richer people. Most importantly, it offers a way to maximize the welfare benefits from disaster risk management interventions and prevents these interventions to be captured by the richest households who experience the largest asset losses.

Socioeconomic resilience

The ratio of asset and welfare losses is an important indicator: it measures the ability of the affected population to cope with and recover from $1 in asset losses without experiencing large well-being losses, and is what we refer to as the "socioeconomic resilience."

$$Socioeconomic\ resilience\ = \frac{Asset\ losses}{Welfare\ losses}$$

If socioeconomic resilience is 50 percent, then well-being losses are twice as large as asset losses. That is, $1 in asset losses from a disaster is equivalent to $2 in consumption losses, perfectly shared across the population. As illustrated in Figure 1, socioeconomic resilience can be considered a driver of the risk to well-being, along with the three usual drivers of risk assessment:

$$Risk\ to\ well-being = \frac{Expected\ asset\ losses}{Socioeconomic\ resilience} = \frac{(Hazard) \cdot (Exposure) \cdot (Vulnerability)}{Socioeconomic\ resilience}$$

The socioeconomic resilience measure used here captures part of the United Nations definition of resilience: the ability to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner. But it does not cover all the areas discussed in research on resilience (see Barrett and Constas 2014; Engle et al. 2013). For example, this framework does not take into account direct human impacts (such as death, injuries, and psychological impacts), cultural and heritage losses (such as destruction of historical assets), social and political destabilization, and environmental degradation (such as when disasters affect industrial facilities and create local pollution).

A global application of this framework

In Hallegatte et al. (2016), we apply this framework in more than 117 countries through a simple model exercise showing that well-being losses from natural disasters (river floods, coastal floods due to storm surge, windstorms, earthquakes, and tsunamis) are larger than asset losses.

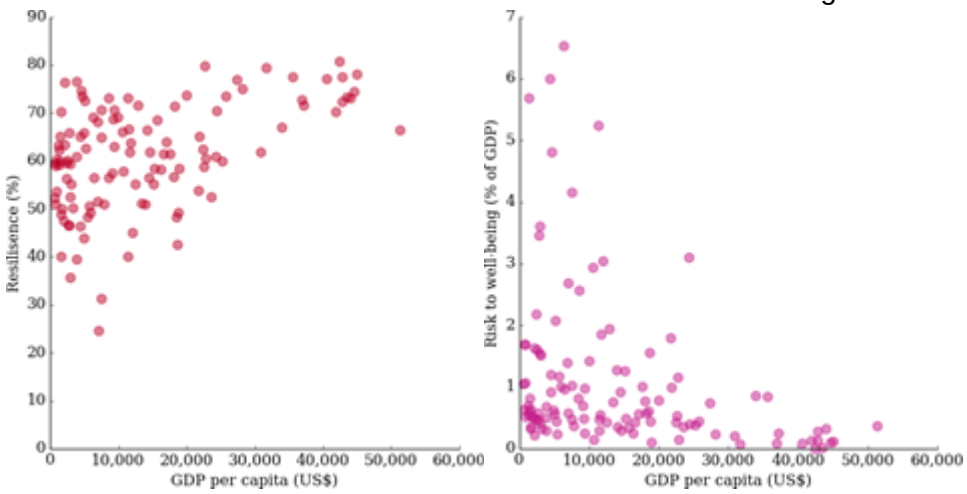
According to the *United Nations Global Assessment Report on Disaster Risk Reduction*—the so-called GAR (UNISDR 2015)—total asset losses from natural disasters in these countries average $327 billion a year. But because disaster losses are concentrated on a small share of country populations, imperfectly shared, and affect more poor people (who have limited ability to cope with them), well-being losses are larger than asset losses. Hallegatte et al (2017) estimates that well-being losses are equivalent in terms of well-being to a $520-billion drop in consumption, uniformly distribution across the population. This is 60 percent larger than what asset losses suggest.

Risk to well-being decreases with country income (figure 5b). This decrease is mostly driven by better protection against floods, higher-quality buildings, and widespread early warning systems in wealthier countries, but resilience also matters. Figure 5a also shows that, overall, resilience grows with GDP per capita. The fact that rich countries are more resilient than poor countries is not a surprise. But resilience varies widely across countries of similar wealth because it depends on many other factors, including inequality and safety nets.

Globally, poor people are disproportionately affected by well-being losses: people in the bottom 20 percent experience only 11 percent of total asset losses but 47 percent of well-being losses. Thus poor people experience asset losses that are only half of what the average person experience, but well-being losses that are more than twice as large as those experienced by the average people. It suggests that targeting poorer people with disaster risk reduction interventions—such as dikes and drainage systems— would generate lower gains in avoided asset losses but larger gains in well-being.

Figure 5: Socioeconomic resilience tends to increase with income, while risk to well-being decreases (Source: Hallegatte et al. 2017)

a. Socioeconomic resilience b. Risk to well-being



5. Implication for policies and actions

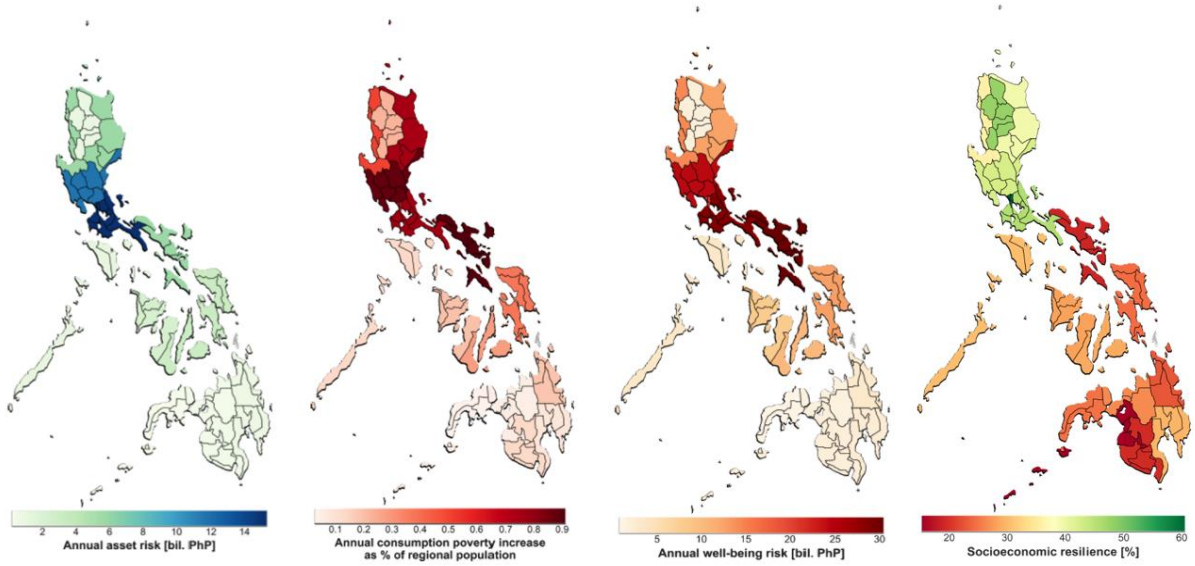
When deciding where to invest in risk management or resilience, what matters is not only how much benefit a project generates, but also who benefits. To ensure that investments in resilience are distributed fairly across the population, one option is to measure the impacts of disasters and infrastructure disruptions using a metric that accounts for the socioeconomic status of the affected populations. This section explains how using socioeconomic resilience and wellbeing losses can help decide where to invest, but also which interventions to favor.

A recent analysis in the Philippines employed a multimetric assessment of disaster risks at the regional level using (1) traditional asset losses; (2) poverty-related measures such as poverty headcount; (3) well-being losses for a balanced estimate of the impact on poor and rich households; and (4) socioeconomic resilience, an indicator that measures the ability of the population to cope with and recover from asset losses (Walsh and Hallegatte 2020).

In the Philippines, the most important interventions will take place in the Manila area if asset losses are the main measure of disaster impacts (Figure 6). Other regions become priorities if the policy objectives are expressed in terms of poverty incidence and well-being losses. In particular, a risk mitigation policy focusing on preventing impacts on poverty would focus on the Bicol region more than in Calabarzon, because it hosts much more people who are near poor and less resilient and thus more vulnerable to falling in poverty in case of disasters. Mindanao appears as a priority in terms of socioeconomic resilience (because of its socioeconomic context, it is the least resilient region of the country), but not so much in terms of risk, because of its much lower exposure to typhoons. It means that the region will not be affected often by large shocks, but it will struggle to recover and suffer from large well-being losses when it does. To be inform policymaking, assessments of national risk and identification of critical

infrastructure need to account for multiple policy objectives and, therefore, use a set of metrics that goes beyond asset losses.

Figure 6. Different measures of natural risks in the Philippines highlight different priorities for interventions



a. Annual asset risk b. Number of people falling into poverty every year c. Annual well-being risk d. Socioeconomic resilience

Source: Walsh and Hallegatte 2020.

No matter how much countries try to reduce people's exposure to natural hazards or to make assets more resistant to hazards such as earthquakes and floods, natural risk cannot be reduced to zero. Disasters will continue to inflict damage, and so it is critical to supplement actions on exposure and vulnerability with improvements in the ability of people to cope with the shocks that cannot be avoided despite efforts to reduce exposure or vulnerability.

Of course, one challenge is that these measures do not yield any measurable benefits, if the benefits of disaster risk management are measured in terms of the conventional metric, asset losses. Insurance, social protection, and remittances do not reduce the direct damages that a disaster may cause. However, they can significantly reduce the welfare impacts of such a disaster.

One advantage of using wellbeing losses as a metric to measure disaster impacts is that it makes it possible to assess and compare measures that reduce asset losses (e.g., building a dike) and measures that increase socioeconomic resilience (e.g., providing insurance to the population at risk). By expanding the range of policies that are considered to reduce disaster impacts, the hope is to create cheaper and more efficient policy packages that are also more equitable.

Returning to the Yolanda-like hurricane event discussed earlier, one can illustrate the benefits of postdisaster support: expected wind damage to household assets in the Eastern Visayas region is valued at US$633 million. Wellbeing losses from the same event are valued at US$2,176 million. If it is assumed that the government can provide a total of US$187 million in post-disaster support, distributed uniformly among all affected households, then the first quintile would see its wellbeing losses halved (while the impact on the richest quintile is almost invisible). In total, post-disaster support reduces wellbeing losses to US$1,265 million, a 42% decrease relative to the nominal simulation.

Because post-disaster support does not impact asset losses, such programs cannot be subjected to traditional cost-benefit analyses that focus on avoided asset losses. Indeed, an efficient cash transfer does not directly reduce the exposure of the population to floods or hurricanes, and it does not reduce the physical damages when an earthquake hits. Its disaster-related benefit-cost ratio, if expressed in avoided asset losses divided by the cost, is zero. However, cash transfers do increase the socioeconomic resilience of the region from 29 to 50 percent, because it makes the population better able to cope with and recover from any physical damages from a natural disaster. It means that, without any change in asset losses, a cash transfer can reduce the well-being impact of disasters by close to a factor two. As a result, the benefit-to-cost ratio of this intervention is estimated at 4.9, if its disaster-related benefits are expressed in avoid well-being losses.

6. Conclusion

This paper has outlined a risk assessment based on an expanded framework, which includes in the analysis the ability of affected households to cope with and recover from disaster asset losses, and which uses well-being losses as a measure of disaster severity to complement asset losses. This framework adds to the three usual components of a risk assessment---hazard, exposure, and vulnerability---a fourth component, socioeconomic resilience. And to the traditional measure of disaster severity (mostly asset losses), it adds the possibility to look at income losses, consumption losses, or well-being losses.

Measuring disaster impacts using these additional metrics helps quantify the benefits of interventions that may not reduce asset losses, but do reduce well-being consequences by making the population more resilient. These interventions include financial inclusion, social protection, and more generally the provision of post-disaster support to affected households. By expanding our accounting of disaster impacts and quantifying the benefits of resilience-building measures, these new metrics expand the DRM toolbox and help identify more effective opportunities to manage natural risks.

Well-being losses is a metric that is of particular importance because it captures the impact of disasters in a way that is not biased toward the richer people and regions, like other economic metrics. Comparing various metrics shows how the regions and communities identified as priorities for interventions differ depending on how risk is measured. While a simple cost-benefit analysis based on asset losses would drive risk reduction investments toward the richest regions and areas, a focus on poverty or well-being losses accounts for a broader set of

disaster impacts, and leads to a set of priorities that are both fairer for poor individuals and better integrated with the broader development agenda.

7. References list

Akter, Sonia, and Bishawjit Mallick. "The poverty–vulnerability–resilience nexus: Evidence from Bangladesh." Ecological Economics 96 (2013): 114-124.

Alderman, Harold, John Hoddinott, and Bill Kinsey. "Long term consequences of early childhood malnutrition." Oxford economic papers 58, no. 3 (2006): 450-474.

Baez, Javier E., and Indhira V. Santos. "Children's vulnerability to weather shocks: A natural disaster as a natural experiment." Social science research network, New York (2007).

Baez, Javier E., Leonardo Lucchetti, Maria E. Genoni, and Mateo Salazar. "Gone with the Storm." (2016).

Baez, Javier, Alejandro De la Fuente, and Indhira Vanessa Santos. "Do natural disasters affect human capital? An assessment based on existing empirical evidence." (2010).

Barrett, Christopher B., and Mark A. Constas. "Toward a theory of resilience for international development applications." Proceedings of the National Academy of Sciences 111, no. 40 (2014): 14625-14630.

Bustelo, Monserrat. "Bearing the burden of natural disasters: child labor and schooling in the aftermath of the tropical storm stan in Guatemala." University of Illinois at Urbana-Champaign (2011).

Calero, C., R. Maldonado, and A. Molina. "Disaster Risk and Poverty in Latin America: The Case of Ecuador." Background paper of the ISDR/RBLAC-UNDP Project on Disaster Risk and Poverty in Latin America (2008).

Carter, Michael R., and Christopher B. Barrett. "The economics of poverty traps and persistent poverty: An asset-based approach." The Journal of Development Studies 42, no. 2 (2006): 178-199.

Carter, Michael, Peter Tewodaj Mogues Little, and W. Negatu. "Poverty Traps and the Long-term Consequences of Natural Disasters in Ethiopia and Honduras." World Development (2007).

Caruso, Germán, and Sebastian Miller. "Long run effects and intergenerational transmission of natural disasters: A case study on the 1970 Ancash Earthquake." Journal of development economics 117 (2015): 134-150.

Cheema, Abdur Rehman, Abid Mehmood, and Muhammad Imran. "Learning from the past." Disaster Prevention and Management (2016).

Chibani-Chennoufi, Sandra, Josette Sidoti, Anne Bruttin, Marie-Lise Dillmann, Elizabeth Kutter, Firdausi Qadri, Shafiqul Alam Sarker, and Harald Brüssow. "Isolation of Escherichia coli bacteriophages from the stool of pediatric diarrhea patients in Bangladesh." Journal of bacteriology 186, no. 24 (2004): 8287-8294.

Dasgupta P (2012) Time and the generations. Climate Change and Common Sense: Essays in Honour of Tom Schelling, eds Hahn RW, Ulph A (Oxford Univ Press, New York).

De Janvry, Alain, Frederico Finan, Elisabeth Sadoulet, and Renos Vakis. "Can conditional cash transfer programs serve as safety nets in keeping children at school and from working when exposed to shocks?." Journal of development economics 79, no. 2 (2006): 349-373.

Del Ninno, Carlo, ed. The 1998 floods in Bangladesh: disaster impacts, household coping strategies, and response. Vol. 122. Intl Food Policy Res Inst, 2001.

Dercon, Stefan, and Catherine Porter. "Live aid revisited: long-term impacts of the 1984 Ethiopian famine on children." Journal of the European Economic Association 12, no. 4 (2014): 927-948.

Engle, Nathan L., Ariane de Bremond, Elizabeth L. Malone, and Richard H. Moss. "Towards a resilience indicator framework for making climate-change adaptation decisions." Mitigation and Adaptation Strategies for Global Change 19, no. 8 (2014): 1295-1312.

Erman, A., Motte, E., Goyal, R., Asare, A., Takamatsu, S., Chen, X., ... & Hallegatte, S. (2018). The road to recovery: the role of poverty in the exposure, vulnerability and resilience to floods in Accra. The World Bank.

Evans, D.J. (2005), The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries*. Fiscal Studies, 26: 197-224. doi:10.1111/j.1475-5890.2005.00010.x

Gentle, Popular, Rik Thwaites, Digby Race, and Kim Alexander. "Differential impacts of climate change on communities in the middle hills region of Nepal." Natural Hazards 74, no. 2 (2014): 815-836.

Glave, Manuel, Ricardo Fort, and Cristina Rosemberg. "Disaster Risk and Poverty in Latin America: The Peruvian Case Study." (2008).

Government of Fiji. Climate Vulnerability Assessment: Making Fiji Climate Resilient. World Bank, 2017.

Hallegatte, Stephane, Adrien Vogt-Schilb, Mook Bangalore, and Julie Rozenberg. Unbreakable: building the resilience of the poor in the face of natural disasters. World Bank Publications, 2016.

Hallegatte, Stephane, and Adrien Vogt-Schilb. "Are Losses from Natural Disasters More Than Just Asset Losses?." In Advances in Spatial and Economic Modeling of Disaster Impacts, pp. 15-42. Springer, Cham, 2019.

Hallegatte, Stephane, and Julie Rozenberg. "Climate change through a poverty lens." Nature Climate Change 7, no. 4 (2017): 250-256.

Hallegatte, Stéphane, Jean-Charles Hourcade, and Patrice Dumas. "Why economic dynamics matter in assessing climate change damages: illustration on extreme events." Ecological economics 62, no. 2 (2007): 330-340.

Hallegatte, Stéphane, Jun Rentschler, and Brian Walsh. Building back better: achieving resilience through stronger, faster, and more inclusive post-disaster reconstruction. World Bank, 2018.

Hallegatte, Stephane, Jun Rentschler, and Julie Rozenberg. Lifelines: The Resilient Infrastructure Opportunity. The World Bank, 2019.

Heal, G. M., and A. Miller. 2014. Agreeing to disagree on climate policy. Proceedings of the National Academy of Sciences Mar 2014, 111 (10) 3695-3698; DOI: 10.1073/pnas.1315987111

Hoddinott, John. "Shocks and their consequences across and within households in rural Zimbabwe." The Journal of Development Studies 42, no. 2 (2006): 301-321.

Ishizawa, Oscar A., and Juan Jose Miranda. "Weathering storms: Understanding the impact of natural disasters in Central America." Environmental and Resource Economics 73, no. 1 (2019): 181-211.

Ivaschenko, Oleksiy, Claudia P. Rodriguez Alas, Marina Novikova, Carolina Romero, Thomas Vaughan Bowen, and Linghui Zhu. The state of social safety nets 2018. World Bank Group, 2018.

Jaiswal, K. S., David J. Wald, Paul S. Earle, Keith A. Porter, and Mike Hearne. "Earthquake casualty models within the USGS Prompt Assessment of Global Earthquakes for Response (PAGER) system." In Human Casualties in Earthquakes, pp. 83-94. Springer, Dordrecht, 2011.

Jakobsen, Kristian Thor. "In the eye of the storm—The welfare impacts of a hurricane." World Development 40, no. 12 (2012): 2578-2589.

Jensen, Robert. "Agricultural volatility and investments in children." American Economic Review 90, no. 2 (2000): 399-404.

Kahn, Matthew E. "The death toll from natural disasters: the role of income, geography, and institutions." Review of economics and statistics 87, no. 2 (2005): 271-284.

Karim, Azreen, and Ilan Noy. "Poverty and natural disasters: A meta-analysis." (2014).

Kunreuther, Howard. "Mitigating disaster losses through insurance." Journal of risk and Uncertainty 12, no. 2-3 (1996): 171-187.

Lam-Dao, Nguyen, Viet Pham-Bach, Minh Nguyen-Thanh, Mai-Thy Pham-Thi, and Phung Hoang-Phi. "Change detection of land use and riverbank in Mekong Delta, Vietnam using time series remotely sensed data." Journal of Resources and Ecology 2, no. 4 (2011): 370-374.

Le De, L., J. C. Gaillard, and W. Friesen. "Remittances and disaster: a review." International Journal of Disaster Risk Reduction 4 (2013): 34-43.

Maccini, Sharon, and Dean Yang. "Under the weather: Health, schooling, and economic consequences of early-life rainfall." American Economic Review 99, no. 3 (2009): 1006-26.

Moser, Caroline, and Andrew Felton. "The construction of an asset index measuring asset accumulation in Ecuador." Chronic poverty research centre working paper 87 (2007).

Munich Re, “Natural catastrophes factsheet 2019.” Accessed online 27 January, 2020.

Nkedianye, David, Jan de Leeuw, Joseph O. Ogutu, Mohammed Y. Said, Terra L. Saidimu, Shem C. Kifugo, Dickson S. Kaelo, and Robin S. Reid. "Mobility and livestock mortality in communally used pastoral areas: the impact of the 2005-2006 drought on livestock mortality in Maasailand." Pastoralism: Research, Policy and Practice 1, no. 1 (2011): 17.

Noy, Ilan, Cuong Nhu Nguyen, and Pooja Patel. "Floods and spillovers: Households after the 2011 great flood in Thailand." (2014).

Noy, Ilan, Cuong Nhu Nguyen, and Pooja Patel. "Floods and spillovers: Households after the 2011 great flood in Thailand." (2014).

Opondo, Denis Opiyo. "Erosive coping after the 2011 floods in Kenya." International Journal of Global Warming 5, no. 4 (2013): 452-466.

Patankar, A., and A. Patwardhan. 2016. “Estimating the Uninsured Losses due to Extreme Weather Events and Implications for Informal Sector Vulnerability: A Case Study of Mumbai, India.” Natural Hazards 80 (1): 285–310. doi:10.1007/s11069-015-1968-3.

Perez-De-Rada, E., and D. Paz. "Análisis de la relación entre amenazas naturales y condiciones de vida: El Caso de Bolivia." ISDR/RBLAC Research Project on Disaster Risk and Poverty (2008).

Rabbani, G., S. H. Rahman, and L. Faulkner. 2013. “Impacts of Climatic Hazards on the Small Wetland Ecosystems (Ponds): Evidence from Some Selected Areas of Coastal Bangladesh.” Sustainability 5: 1510–21. doi:10.3390/su5041510.

Rodriguez-Oreggia, Eduardo, Alejandro De La Fuente, Rodolfo De La Torre, and Hector A. Moreno. "Natural disasters, human development and poverty at the municipal level in Mexico." The Journal of Development Studies 49, no. 3 (2013): 442-455.

Safir, Abla, Sharon Faye Piza, and Emmanuel Skoufias. Disquiet on the weather front: The welfare impacts of climatic variability in the rural Philippines. The World Bank, 2013.

Sanchez, Fabio, and S. Calderon. "Natural Disasters and Multidimensional Poverty in Colombia." In World Bank Workshop on Climate Change and Poverty in the LAC Region. 2014.

Schumacher, Ingmar, and Eric Strobl. "Economic development and losses due to natural disasters: The role of hazard exposure." Ecological Economics 72 (2011): 97-105.

Scussolini, Paolo, Jeroen CJH Aerts, Brenden Jongman, Laurens M. Bouwer, Hessel C. Winsemius, Hans de Moel, and Philip J. Ward. "FLOPROS: an evolving global database of flood protection standards." Natural Hazards & Earth System Sciences 16, no. 5 (2016).

Siegel, P., and Alejandro De La Fuente. "Mainstreaming natural disaster risk management into social protection policies (and vice versa) in Latin America and the Caribbean." Soc. Policy 6 (2010): 131-159.

Skoufias, Emmanuel. "Economic crises and natural disasters: Coping strategies and policy implications." World development 31, no. 7 (2003): 1087-1102.

Sur, D., P. Dutta, G. B. Nair, and S. K. Bhattacharya. "Severe cholera outbreak following floods in a northern district of West Bengal." Indian Journal of Medical Research 112 (2000): 178.

UNISDR, GAR. "Global Assessment Report on Disaster Risk Reduction, Making Development Sustainable: The Future of Disaster Risk Management." United Nations, Geneva (2015).

Wakker, Peter P. "Explaining the characteristics of the power (CRRA) utility family." Health economics 17, no. 12 (2008): 1329-1344.

Walsh, Brian, and Stephane Hallegatte. Measuring Natural Risks in the Philippines: Socioeconomic Resilience and Wellbeing Losses. Economics of Disasters and Climate Change, 2020.

Walsh, Brian, and Stephane Hallegatte. Socioeconomic Resilience in Sri Lanka: Natural Disaster Poverty and Wellbeing Impact Assessment. The World Bank, 2019.

Warraich, Haider, Anita KM Zaidi, and Kavita Patel. "Floods in Pakistan: a public health crisis." Bulletin of the World Health Organization 89 (2011): 236-237.

World Bank. "World development report 2014. Risk and Opportunity. Managing Risk for Development." Washington, DC (2013).

Yamano, Takashi, Harold Alderman, and Luc Christiaensen. "Child growth, shocks, and food aid in rural Ethiopia." American Journal of Agricultural Economics 87, no. 2 (2005): 273-288.

Yonson, Rio, Ilan Noy, and J. C. Gaillard. "The measurement of disaster risk: An example from tropical cyclones in the Philippines." Review of Development Economics 22, no. 2 (2018): 736-765.