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A survey of the theory and measurement of economic vulnerability and resilience to natural hazards

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SEF WORKING PAPER 03/2016

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Working Paper 03/2016
ISSN 2230-259X (Print)
ISSN 2230-2603 (Online)

A Survey of the Theory and Measurement of Economic Vulnerability and Resilience to Natural Hazards

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Abstract: About four decades ago, the discourse on disasters was largely about natural hazards and their characteristics. The failure of this approach to substantially explain disaster impacts led to a change in paradigm. This new paradigm places its emphasis on the influence of vulnerability and resilience on the resulting impacts of disaster– be they direct or indirect. Disasters triggered by natural hazards have since been perceived as un-natural occurrences brought about by a confluence of societal factors. Economic vulnerability and economic resilience, interacting with the hazard itself and the exposure of populations and economic systems, are considered critical determinants of the resulting disaster impacts. The theoretical conceptualization and empirical measures of vulnerability and resilience, however, remain subjects of contentions. An apparently dominant view is that while vulnerability and resilience have similar underlying factors, they refer to different things. For instance, economic vulnerability and economic resilience are both shaped by the level of development, quality of development governance, and characteristics of development (widespread inequality, rapid and unplanned urbanization, etc.), yet vulnerability is considered a pre-disaster concern, while resilience, a post-disaster issue. Here, vulnerability is taken as that component of disaster risk that explains the varying impacts on elements (people, assets, systems) that have the same level of exposure to a given hazard. Resilience is what enables the exposed elements to withstand, cope and recover from disaster impacts. Thus, in terms of disaster risk reduction priorities, vulnerability is typically linked to prevention, preparedness, and mitigation; while resilience, to rehabilitation, reconstruction, and recovery. The intensified application of economic theory resulted in important advances in concretizing the concepts of economic vulnerability and resilience, as well as in measuring them. Overall, the ultimate aim for these is for a sound and widely-accepted set of concepts and measures that can be easily adjusted for practical application in different contexts (e.g. developed and developing countries), levels of assessment and governance (e.g. macro and micro; community, city, province, country), hazard types (e.g. meteorological and geologic), and elements at risk.

Keywords: Economic vulnerability, economic resilience, natural hazard, disaster

I. Introduction

Decades ago, the discourse on disasters was largely about natural hazards and their characteristics. Disasters were viewed as products of processes of the geophysical world (Blaikie, Cannon, Davis, & Wisner, 1994). As such, governments' interventions were mainly structural, such as hazard protection measures such as flood defenses (Westen & Kingma, 2009). This paradigm was eventually seen to have failed to tackle the conditions that result in varying impacts of hazards on people (Wisner, Blaikie, Cannon, & Davis, 2004). Over time, and particularly with the experiences of developing countries, the concept of vulnerability emerged in the disaster discourse. Disasters triggered by natural hazards have since been perceived as un-natural occurrences brought about by a confluence of societal factors with these natural hazards (Westen & Kingma, 2009).

Consequent to this paradigm shift is the heightened interest by a multiplicity of disciplines in gaining a deeper understanding of the important underlying factors that allow hazards to become disasters. From this increasing understanding of vulnerability emerged a likewise increasing appreciation of the distinct role of resilience in shaping the consequences that follow from the resulting disasters impacts.

There is a large conceptual and empirical literature on vulnerability and resilience to natural hazards. While majority of these works are from diverse social sciences, the economic dimension of vulnerability and of resilience is typically covered. Researchers within economics started later, particularly around the year 2000, though the pioneering works on the economics of disasters came much earlier through the works of Dacy and Kunreuther (1969) and Albala-Bertrand (1993).[1] Economic vulnerability and economic resilience, interacting with the hazard itself and the exposure of populations and physical assets, are

considered critical determinants of the resulting disaster damages and losses. Indeed, disasters are largely influenced by economic forces so that "the very occurrence of disasters is an economic event" (Cavallo & Noy, 2011).

This work aims to describe the progress made in the conceptualization, and measurement of the economic dimensions of vulnerability and resilience in the context of natural hazards. We also aim to provide insights for practical applications of these concepts and measurements in policy decision-making. Given this specific contextual backdrop, we take off from the widely used three-component risk formulation[2] of the disaster risk reduction community as follows: $Risk = Hazard\ x\ Exposure\ x\ Vulnerability$

The UNISDR (2009) defines these variables: *Risk* is "The combination of the probability of an event and its negative consequences"; *Hazard* is "A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage"; *Exposure* refers to "People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses"; and, *Vulnerability* refers to "The characteristics and circumstances of a community, system or assets that make it susceptible to the damaging effects of a hazard."

We, likewise, adopt the UNISDR's (2009) definition of resilience, which is "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions."

This work is organized as follows: Section 2 provides highlights on selected perspectives and conceptualization on vulnerability and resilience across different disciplinary approaches. It then focuses the discussion on economic vulnerability and economic resilience in broad terms, and subsequently, in the specific context of the natural hazard discourse. Section 3 presents a selection of empirical works on determinants and measurement tools. Section 4 provides a synthesis and implication for policy, including areas needing further research and refinement.

II. Definitions and Frameworks on Vulnerability and Resilience

A number of comprehensive reviews reveal the distinct conceptualization of vulnerability and resilience in each of the disciplines and communities involved in the natural hazards discourse (Birkmann, 2006; Gaillard, 2010; Thywissen, 2006; Villagran de Leon, 2006). The multiplicity of separate efforts has led to differing understanding, if not confusion, on these concepts (Miller et al., 2010). This is not surprising as each discipline is likely to maintain its specific definitions and disciplinary frameworks when examining natural hazards and disasters, without making the adjustments and contextualization to align with other disciplines. Apart from the separate efforts of the various academic disciplines (e.g. sociology, geography, economics or public health), the definitions and frameworks continue to evolve by their usage within the disaster risk reduction (DRR) community, and the climate change community. Below, we present selected definitions and framework that capture some of these community or discipline-specific views.

a. Definitions of Vulnerability and Resilience

In tracing the evolution of the concept of vulnerability in the context of natural hazards, Birkmann (2007) found that vulnerability started with a narrow definition that focused only on the intrinsic characteristics of elements at risk. This eventually broadened into a human-centered concept that refers to the likelihood for elements to experience harm. Further, the concept widened to refer to both the element's susceptibility and capacity to cope. Further on, exposure of the elements and their capacity to adapt[3] were likewise considered as separate components of vulnerability. A broadly accepted version of the concept of vulnerability therefore includes that of a multi-dimensional vulnerability, covering economic, social, physical and institutional aspects.

The equation: $Risk = Hazard\ x\ Vulnerability$, is another popular variant of the risk equation, which captures the two opposing components under the Pressure and Release (PAR) framework (Blaikie et al., 1994; Wisner et al., 2004). Focusing on people, vulnerability is defined in this framework as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (Blaikie et al., 1994). In this conceptualization, it is evident that vulnerability encompasses exposure. Worthy of note it that this definition captures what generally are considered as components of resilience as defined by UNISDR (2009). However, despite this definition, the framework's three levels of progression of vulnerability trace the channels through which a disaster occurs when natural hazard affects the vulnerable.[4] The PAR's emphasis is the imperative to reduce vulnerability and through

adjustments to the existing economic and political systems, given that these are the underlying causes of rapid urbanization and population growth (Birkmann, 2006).

Apart from that in the PAR, there are a number of other earlier definitions of vulnerability that subsume either or both exposure and resilience. For instance, Pelling (2003) identifies three components of vulnerability: exposure, resistance (i.e. capacity to withstand adverse impact), and resilience (i.e. capacities to cope and adapt).

In the second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), vulnerability is presented as a function of sensitivity, exposure, and adaptive capacity (IPCC, 1996). It groups the negative and positive factors that determine vulnerability, into two separate components, namely, sensitivity and resilience. In its third Assessment Report, the IPCC presented the view that resilience is the "flipside of vulnerability" (IPCC, 2001).

At the time that these reports were released, the climate change community and the DRR community each adopts a framework that is lacking in commonality even though these communities tackle some common hazards. Nonetheless, more areas of convergence are observed through time as noted by (Cardona et al., 2012).

A major development in this conceptualization was contained in the IPCC's Fifth Assessment Report (IPCC, 2014). It is the adoption of a risk framework that mirrors the three components of the DRR community's Hazard/Exposure/Vulnerability risk equation. In this framework, the IPCC refers to vulnerability as the "propensity or predisposition to be adversely affected"(IPCC, 2014)[5], which basically captures only the "sensitivity" component of its earlier vulnerability definition, and which is consistent with the UNISDR (2009) definition. This harmonization by these two key institutions (UNISDR working on

DRR and the IPCC on climate change) can be considered a major step towards achieving greater synchronization of efforts between these two communities.

Meanwhile, the evolution of the concept of resilience dates about as far back as that of vulnerability, though, as previously noted, it has been typically subsumed either under vulnerability or other components of risk. Historically, Holling (1973) described resilience to shocks in the context of ecological systems. He refers to resilience as a system's ability to absorb changes and to persist amidst these changes. Meanwhile, in geosciences disciplines, the concept is interpreted as the ability to withstand the occurrence of the hazard, while incurring only of tolerable levels of losses (Mileti, 1999). Engineering, in contrast, puts particular attention on the amount of time it takes to recover from the adverse impact of a shock (Correia, Santos, & Rodrigues, 1987). As result of this increasing appreciation on the distinct influence of resilience on disasters, there are now disaster risk frameworks that include resilience as an additional component of disaster risk (Hallegatte, 2014; Rose, 2009).

b. Definition of Economic Vulnerability and Economic Resilience

In Economics, the concept of vulnerability is typically applied to four areas of interest, other than disasters: poverty, food security, asset-vulnerability, and sustainable development (Alwang, Siegel, & Jorgensen, 2001; Moret, 2014). Most often, vulnerability is analyzed in the study of the dynamics of poverty, focusing on the "risk of falling into poverty or deeper into poverty" (Moret, 2014). Likewise, resilience is used in three research strands: economic shocks; sustainability; and, institutions (Rose, 2009).

Briguglio and colleagues (Briguglio, 2004; Briguglio, Cordina, Farrugia, & Vella, 2009; Briguglio & Galea, 2003) are among the first to simultaneously study economic vulnerability and economic resilience, and to posit that these two jointly determine a country's risk of being affected by external shocks. Specifically, they refer to economic vulnerability as a country's exposure to external shocks due to its inherent economic characteristics – the economic openness, export concentration, and dependence on strategic imports of the country in question. These are conceived as structural and therefore difficult to change with deliberate policies (at least in the short-term). On the other hand, economic resilience refers to the economy's coping ability that can, in contrast, be influenced by policies (Briguglio et al., 2009). Policies that induce and nurture resilience are those that enhance macroeconomic stability, increase market efficiency, improve governance and expand social development.

In an empirical inquiry they undertake, Briguglio et al. (2009) find that GDP per capita is negatively correlated with their index of economic vulnerability and positively correlated with their index of economic resilience. Additionally, they show there is greater responsiveness of GDP per capita to the resilience index than to the vulnerability index. As such, the authors conclude that a country's economic well-being is shaped more by its policies than by its structural economic characteristic (Briguglio et al., 2009).

Rose (2009), in his review of the economic literature, finds that important dimensions of economic resilience are not given adequate emphasis in this literature and some are not considered at all in the existing conceptualizations. He asserts that, above all, there is a need to distinguish between damages to stocks (i.e. property damage), and damages to flows (i.e. damages to production of goods and services).[6] The importance of this

distinction lies with the observation that while damages to stocks are incurred all at once at the time of the shock, the damages to flows, however, will continue to be incurred until full recovery is achieved. Thus, Rose (2009) argues that damages to flows are more relevant to the economic resilience concern. He further asserts that behavioral and policy dimensions of resilience should likewise be duly considered given that the pace of recovery depends critically on the decisions and actions of decision-makers.

There is also a need to consider the temporal aspects of resilience: static vs. dynamic resilience, and shorter vs. longer-term. Likewise, context, capability, market, cost, process and fairness dimensions need to be integrated into the definition of economic resilience (Rose, 2009). The market dimension refers to supply-side resilience and demand-side resilience, while the cost dimension refers to the cost efficiency of alternative resilience policy measures that can be undertaken. The process dimension refers to the manner in which the action happens and the target of resilience is achieved, while the fairness dimensions ensures that implementation of actions and targets are done in an equitable manner (though how one defines equitable is also contentious).

Considering the various dimensions he described, Rose (2009) defines economic resilience as "The process by which a community develops and efficiently implements its capacity to absorb an initial shock through mitigation and to respond and adapt afterward so as to maintain function and hasten recovery, as well as to be in a better position to reduce losses from future disasters." In terms of interventions, Rose (2004) states that preventative actions or mitigation measures reduce the magnitude of the hazard and/or the probability of a disaster to occur, as well as reduce vulnerability. Further, he argues that in the absence

of mitigation and prevention measures, disaster impacts can be reduced through resilience, particularly through ingenuity, resourcefulness, and speedy repair and reconstruction both during and in the aftermath of a disaster occurrence (Rose, 2004, 2007).

Hallegatte (2014) proposes an economic framework to guide the assessment of economic resilience. In his framework, resilience refers to the economy's ability to minimize people's welfare losses from a disaster, and the direct damages to assets do not fully capture the adverse impacts on people's welfare.[7] These asset losses lead to consequent losses of output, income, and consumption, which, together with asset losses, better captures the welfare losses resulting from a disaster.

This framework extends the risk equation into an "economic welfare disaster risk" with economic resilience as fourth component, along with hazard, exposure and vulnerability. On one hand, resilience at the macro level is determined by the economy's ability to limit the immediate losses in income resulting from losses in assets (or the economy's instantaneous resilience), and by the economy's ability to "reconstruct and recover quickly" (referred to dynamic resilience) (Hallegatte, 2014). On the other hand, resilience at the micro level is influenced by the distribution of the losses incurred across the affected households, the household's ability to smooth their consumption and their access to risk sharing schemes (Hallegatte, 2014). A principal contribution of the framework is that it takes into account socioeconomic heterogeneity, in order to measure the disparity in welfare losses, with a specific focus on losses for the poor.

The framework further traces the channels through which asset losses lead to welfare losses. The methodologies and economic models in this framework are translated into a set of algorithms and processes that capture these channels. Hallegatte (2014) identifies a

corresponding list of indicator as "a first step toward the construction of a meaningful and measureable indicator for economic resilience". Using this framework, he proposes two approaches to reduce 'economic disaster welfare risk.' The first approach is to reduce the direct impacts of disasters on assets, and the second approach is to reduce the output losses resulting from the asset losses. The latter entails increasing the resilience of socio-economic systems, both at the macro and micro levels.

III. Assessment of Economic Vulnerability and Economic Resilience

Amidst the continuing evolution of the concepts, efforts have been made to translate these conceptual approaches into practical tools to empirically identify the determinants of the various dimensions of economic vulnerability and resilience.

a. Indices of Vulnerability and Resilience

One of most commonly used methods to assess vulnerability and resilience to natural hazards is the index method. These indices aim to capture the multi-dimensionality of vulnerability and resilience, and therefore include their economic dimensions. The most common economic variables included are on output (GDP or regional production), income, employment, inflation, consumption, expenditures, savings, domestic and international financial transfers, public finance and trade (Angeon & Bates, 2015; Cutter et al., 2008; Villagran de Leon, 2006).

These indices vary in terms of purpose (e.g. assessment of vulnerability and/or resilience), spatial coverage (e.g. global, regional, local), scale of analysis (e.g. governments, local authorities, firm-level, household), and methodological approach (e.g. deductive, inductive,

econometric). A majority of these indices employ an inductive approach and the identification of indicators are based on relevant conceptual frameworks and/or on identified important indicators in the earlier empirical literature. The aggregation of indicators into a composite index is commonly done through ad-hoc arithmetic or geometric averaging, and standardization is typically done prior to aggregation. Where weights are applied, these are often based on expert judgment, or by participatory approaches, or a combination of both. A more systematic method to identify relevant variables and assign weights involves econometric algorithms, including data reduction methods as Principal Component Analysis (PCA) and Factor Analysis (FA).[8]

In the next two sub-sections, we present two global indices. The objective is to show how indices based on a similar framework can be designed for a different purpose and employ different approach.

Vulnerability Index

The Disaster Risk Index or the DRI is the first index employing a statistical approach that attempts to demonstrate the manner in which development affects human vulnerability and disaster risk (Peduzzi, 2006; Pelling, 2006). The DRI is global in its coverage and has a country-level scale of analysis. It is noted that the DRI was commissioned by the United Nations Development Program to be used to guide decisions by international and national policy-makers (Peduzzi, Dao, Herold, & Mouton, 2009; UNDP-BCPR, 2004). The DRI employs a deductive approach to identify different economic, social, and environmental indicators, which are then examined for their correlation with disaster deaths (Pelling, 2006). The DRI equation below mirrors the standard risk equation: $R = H \times Pop \times Vul$; where R is disaster risk, measured in terms of number of deaths, H is the proxy for

hazard, measured in terms of frequency of occurrence, *Pop* is the number of people living in the area exposed to the hazard, and *Vul* is vulnerability. Vulnerability is considered as the component of risk that explains why people with the same level of exposure face varying levels of risk (Peduzzi, 2006). As noted, the DRI uses only data on deaths to proxy for risk.

A total of 32 socio-economic and environmental variables were tested as potential important vulnerability factors for each hazard type (Peduzzi et al., 2009). The final set of vulnerability variables varies across hazards depending on the results of separate regression specifications. Among the economic variables found important are GDP per capita for tropical cyclones, droughts and floods, and urban growth for earthquakes. The results indicate that indeed development influences vulnerability to natural hazards, but the aspects of development that affect each hazard vary. Vulnerability to hydro-meteorological hazards, for example, is influenced by the level of development as measured by per capita GDP, while vulnerability to earthquakes is influenced by the process of development (in this case, urban population growth). A multiple-hazard composite index is constructed using the estimated risk for each hazard. A final output of the process is a risk map, where the countries covered are depicted in seven DRI classes/categories.

Resilience Index

The Index for Risk Management (InFORM) is designed for a global analysis of humanitarian risk and its target users are humanitarian organizations, donor agencies, country governments, and development stakeholders that have resilience as their key agenda (De Groeve, Poljansek, & Vernaccini, 2015). Like the DRI, the InFORM takes off

from the three-component risk equation. In addition, the InFORM integrates the other factors identified in the PAR, thus adding a fourth component - the lack of coping capacity (De Groeve et al., 2015; JRC-EC, 2014). Also like the DRI, the InFORM takes a multiple hazards approach. However, unlike the DRI that covers only natural hazards, InFORM covers human-made hazards as well. While the DRI employs a deductive approach in indicator selection, the InFORM employs an inductive approach. The InFORM is a composite index of over 50 indicators categorized and computed as follows:

$$Risk = Hazard\ \&\ Exposure^{\frac{1}{3}} \times Vulnerability^{\frac{1}{3}} \times Lack\ of\ coping\ capacity^{\frac{1}{3}}$$

Consistent with UNISDR definition, the InFORM defines vulnerability as people's susceptibility to hazards, and in the construction of the index it is represented in two categories: socio-economic vulnerability and vulnerable groups (JRC-EC, 2014). Economic vulnerability is captured under the socio-economic category, which is computed as the arithmetic mean of indicators measuring development and deprivation, inequality, and aid dependency. We note that resilience is captured, though not in its entirety, under lack of coping capacity, which refers to the available resources that help people to "absorb the shock" (JRC-EC, 2014). For this component, governance, institutional and infrastructure indicators are used.

b. Econometric Approach: Determinants and Measures of Economic Vulnerability

Within Economics, econometric methods using cross-section or panel data approaches are the most commonly used to systematically identify the underlying factors influencing vulnerability and resilience. Econometric methods are mainly deductive, an approach

which Pelling (2006) asserts provides more realism than an inductive approach. Studies on the economics of disasters using these methods belong to two strands.

The first strand seeks to identify the factors affecting the direct disaster impacts on people and assets. These models generally take the following form:

$Y_{it} = \alpha_0 + \beta_1 Haz_{it} + \beta_2 Exp_{it} + \beta_2 Vul_{it} + \varepsilon_{it}$; where Y_{it} is the measure of actual direct impacts either on people or on assets in spatial unit *i* at time *t*; Haz_{it} is a vector of hazard characteristics; Exp_{it} is a measure of the exposure of people or assets; Vul_{it} is the vector of control variables hypothesize to influence vulnerability to the hazard. *Y, Haz, Exp ,Vul* correspond to Risk, Hazard, Exposure and Vulnerability in the standard risk equation discussed earlier. By controlling for hazard characteristics and exposure of people and assets, these empirical models generate insights about the vulnerabilities of the exposed. The dependent variable is a direct disaster impact, either on people or on assets, so these studies examine direct damage/cost (Lazzaroni & van Bergeijk, 2014).

The second strand aims to measure the economic impacts typically in either the short-run (months to several years) or long-run (at least 3-5 years). These studies also attempt to understand the factors that influence these impacts, thereby also providing insights on the determinants of economic resilience. As surveyed by Cavallo and Noy (2011), these models generally take the following form: $Y_{it} = \alpha + \beta X_{it} + \gamma DIS_{it} + \varepsilon_{it}$; where Y_{it} is the economic indirect impact for a spatial unit *i* at time *t*. These indirect impacts may include GDP (or growth), GDP per capita, human development index, poverty and employment, among others. DIS_{it} is the immediate disaster impact to assets and/or to population. In some studies, this includes the hazard characteristics. X_{it} is the vector of

control variables affecting Y_{it} (Cavallo & Noy, 2011). These studies invariably aim to describe the indirect disaster impact.

As previously argued, resilience refers to the ability to minimize welfare losses (Hallegatte, 2014). Any systematic assessment of welfare losses requires the conduct of economic assessment of indirect losses (Hallegatte & Przyluski, 2010). For this purpose, there is a need to decide what are appropriate measures of welfare. Mechler (2009) argues that consumption should be used as it is deemed a better proxy for welfare than GDP and other similar macroeconomic indicators.

Determinants of Economic Vulnerability

While the DRI uses a cross sectional dataset, the cross-country econometric empirical works that followed use panel datasets, with the disaster impact data coming mainly from EM-DAT.[9] Toya and Skidmore (2007) and Raschky (2008) examined the correlation between several aspects of development. Toya and Skidmore (2007) assess the extent at which disaster fatalities and losses decline as economies grow. Raschky (2008) examines the important influence that institutions have on the vulnerability of people and assets to disasters. Their respective models took a relatively simple form, as they did not have proxies for the characteristics of the hazards studied.

Many of the succeeding studies address the exogeneity concerns pointed out by Noy (2009) by integrating into their models indicators on hazard characteristics. The number of fatalities and cost of damage are the main proxies for disaster risk, or the dependent variables of the econometric model. Some, opt to directly use proxies for the hazard such as wind-speed or the magnitude of an earthquake (Felbermayr & Gröschl, 2014; Strobl, 2012)

Using earthquake fatalities as the dependent variable, Kahn (2005) aimed to examine the presence and extent of correlation between fatalities, and geography, income and institutional quality. Anbarci (2005) used negative binomial models to examine the influence of inequality on disaster risk, using a political economy model. Kellenberg and Mobarak (2008) investigated the correlation of deaths due to floods, earthquakes, landslides, windstorms and extreme temperature with income level and demonstrated a non-linear correlation between these measures. In their specifications, risk first increases with income, but beyond a certain income threshold, it starts decreasing.

There is general consensus in these cross-country empirical studies that indeed a country's level of economic development affects its vulnerability to disasters (Anbarci, Escaleras, & Register, 2005; Kahn, 2005; Raschky, 2008; Toya & Skidmore, 2007). However, there is difference in the findings as to the direction of relationship between the level of economic development and disaster (as in Kellenberg and Mobarak 2008), as well as the extent to which the level of development influences vulnerability between developed and developing countries and/or regions.

Peduzzi et al. (2009) use GDP per capita as proxy for economic development, and find that it is negatively correlated with the fatalities across tropical cyclone, drought, and flood hazards. Likewise, Kahn (2005) finds that developed countries have fewer fatalities from earthquakes than those of developing countries. He thus concludes that economic development serves as an "implicit insurance" that cushions the adverse disaster impacts on people.

Of particular interest is the finding that while income is also an important predictor of the number of disaster deaths in both developing and developed countries, the magnitude of its effect in the former group of countries is lower than those in the latter; in developing countries, social conditions matter more than the level of income in reducing the number of deaths, and a more educated citizenry are better able to make informed decisions ensuring their safety.

Kellenberg and Mobarak (2008) do not completely refute the findings of a linear disaster-economic development relationship. However, they argue that in the case of developing countries, economic development may actually increase the risk that people face by "changing micro behaviour in such a way so as to increase aggregate exposure to disasters" (Kellenberg & Mobarak, 2008). They also suggest that risk to disasters is also determined by vulnerabilities that are created or enhanced as consequences of development processes. Urbanization, in particular, can have varied effects on risk to disasters. That is, urbanization may reduce or increase vulnerability depending on the context within which it occurs. They find that countries with comparable levels of income but with different degrees of urbanization can have different risk levels. Competent urban planning, where structures are appropriately designed and where there is adequate capacity to provide economic and social services, urbanization may not necessarily increase vulnerability to disasters. But, where the capacity of urban areas to deliver key services cannot cope with the rapid influx of population (as is the often the case in developing countries), urbanization may lead to increased exposure and vulnerability to disasters. Employment opportunities in dense urban areas attract low-income families, even if relocation to the urban fringe means increased exposure to disasters. Hence, urbanization in this case

increasingly entices people with inherent vulnerability into harm's way (because of relatively fewer resources and weaker capacities to adapt and cope in times of disaster). The effects of aspects of governance on disaster fatalities and damages have likewise been explored. Kahn (2005) finds that democratic countries experience relatively fewer deaths from disasters than those with other forms of governance. Under a democracy, governments adopt intervening measures to mitigate the adverse consequences of hazards (Kahn, 2005). Raschky (2008), as well, finds that a country's institutional framework is a key determinant of vulnerability to disasters. There are fewer fatalities among countries with better institutions because resource allocation is better, and laws and legislations are in place, and effectively enforced (Raschky, 2008).

Anbarci et al. (2005) use inequality, measured in terms of Gini coefficient, as a proxy for quality of governance and institutions. They argue that a political economy that has low income and high inequality experiences difficulty in generating collective action to provide public goods such as disaster preventive measures. Against this backdrop, these economies suffer more deaths from disasters. In like manner, Kahn (2005) finds that, all else equal, countries with higher inequality suffer more fatalities from earthquakes than countries with lower inequality.

An earlier work by Adger (1999) shows similar results. With Vietnam as a case study, which is in transition from a centrally planned economy, he finds that the increasing inequality and the breakdown of collective community action that results from the economic transition have contributed to greater vulnerability. However, he asserts that the resulting institutional change and economic restructuring towards a market system augurs

well in terms of reducing vulnerability as informal coping mechanisms have started to re-emerge.

Determinants of Economic Resilience

Not surprisingly, the findings from the indirect-costs econometric studies are similar to the direct cost literature; specifically, that countries with higher level of development are more resilient. Using a panel dataset for 109 countries covering the period 1970 – 2003, Noy (2009) pursued a two-fold inquiry. The first is to quantify the short-run impacts of disasters on the macro-economy; and the second is to examine the determinants of these impacts. This paper finds that disaster damage to capital stock results in reduced short-run macroeconomic growth, and that the value of damage is reflected in the extent of growth reduction. He further finds that for a disaster of a given magnitude, the corresponding change in output growth (measured in % of GDP) among small economies and developing countries are greater than those of big economies and developed countries. Interestingly, the direction of change may also vary between these two types of countries. In developing countries, a one standard deviation increase in asset damage results in a 9% reduction in output growth. In the case of developed countries, there is instead a corresponding increase in output growth, albeit minimal. Meanwhile, disasters, alternatively measured in terms of number of deaths and affected persons, do not result in statistically observable reductions in output growth.

On Noy's (2009) second inquiry, results reveal that countries with higher income per capita, greater trade openness, and literacy rate, higher levels of public spending, and better institutions are able to withstand the initial impacts of disasters, and are also able to prevent spillovers. Noy (2009) attributes this to the capacity for resource mobilization to

implement the necessary reconstruction. It is worthwhile to note that the above findings already provides preliminary quantitative confirmation that indeed economic vulnerability and economic resilience are both shaped by the same common economic factors.

Unlike the other econometric studies with a similar research question and methodological approach, Hochrainer (2009) establishes a counterfactual to the observed post-disaster GDP. He uses an autoregressive integrated moving average (ARIMA) model to forecast post-disaster GDP level. He then uses the difference between the forecasted and observed GDP level five years after the disaster as the dependent variable in a multivariate regression analysis to determine the influence of explanatory variables on output levels. Like Noy (2009), he finds evidence of the negative (but small) consequences of the direct disaster impacts on capital stock to macroeconomic output, though his focus is on the medium-term and in the long-term (five years).

Using this approach, he finds that the inflows of remittances and aid reduce the adverse macroeconomic consequences significantly. In this framework, disaster with damage to capital stock, above a value of 1% of GDP, would overwhelm the internal capacity of the country to self-finance post-disaster reconstruction needs; and hence the importance of aid. Moreover, that remittances have a significant influence likewise suggests that external sources of finances are also important for individual or household level recovery, perhaps particularly for the affected individuals to go back to productive activities and contribute to output production. Overall, while the direct impacts on capital stock have a strong influence on the follow-on impacts of disasters on output, external funds also have influence on post-disaster dynamics (Hochrainer, 2009).

In a similar attempt to determine welfare changes due to the occurrences of disasters, Mechler (2009) measures the corresponding changes in consumption, instead of the usual changes in GDP. In a global sample, Mechler (2009) finds that assets losses do not cause significant changes in consumption. However, by narrowing the sample to low-income countries only, he finds that asset losses do adversely alter consumption. In a further inquiry, he finds that inflows of regular and post disaster aid likewise do not result to significant changes in consumption, except among low-income countries.

Noy and Vu (2010) undertook one of the earliest sub-national empirical inquiry on the impact of disasters to output growth, by looking at the experiences of 61 provinces in Vietnam for 1995-2006. They use output level and output growth rate as dependent variables in separate regressions, and the number of deaths to population ratio and value of damaged assets in proportion to GDP as proxies for direct disaster impacts in separate regressions. They find that direct asset damages impact positively on output growth, estimated at 0.03% for every percentage point in asset damage as proportion to GDP. In a further inquiry on the heterogeneity of experiences across the eight regions in Vietnam, the results suggest that regions with higher level of development, and that have better access to funds for reconstruction from the central government, experience this 'creative destruction' dynamics, and a consequent short-run growth spurt in the disaster aftermath. The authors claim that this provides support for an earlier observation by Cuaresma, Hlouskova, and Obersteiner (2008) that areas with high level of development benefit from capital upgrading for assets damaged during a disaster.

The household micro-econometric study of Antilla-Hughes and Hsiang (2013) examines tropical cyclones and study the Philippines by constructing a panel data from various

nationwide household surveys and other datasets. The authors find that consequent to the sharp drop in household income due to disasters are alterations in investment, expenditure and consumption patterns of the households surveyed. There is an evident reduction in investments in human capital, resulting in children dropping out from school, and a reduction in household expenditures on medicine and nutritious foods. Several other papers report similar findings for other case studies (surveyed in Karim and Noy, 2013); but neither of these examines whether these short-term patterns of impact on investment in health and education have any long-term impacts. An exception is Caruso and Miller (2015) that find that these impacts on education persist even in the second generation after a catastrophic event (in their case, an earthquake in Peru in 1970).

Arouri, Nguyen, and Youssef (2015) undertook a household level study on Vietnam to determine the effects of floods, storms and droughts on household welfare, and determine the characteristics of households and communities that made them resilient to the adverse disaster impacts. In their model using commune-level fixed-effect, they ran separate regressions for each of four dependent variables: income per capita, per capita consumption expenditure, poverty status of households, and share of income of alternative sources of income. The authors posit that resilient households experience relatively less adverse disaster impacts on their welfare, as proxied by these indicators (Arouri et al., 2015).

For storm-related disasters, their results reveal that those households with fewer members of working age, those with more household members, and those belonging to the ethnic minority groups are all less resilient. The authors' interpretation is that households with fewer members of the working age cannot increase labor supply to generate income to

cover the losses in income and consumption. Meanwhile, large households have lower per capita income and minority groups have lower access to services that will help in smoothing their consumption. Internal remittances are found to be important contributor of resilience to all three hazards. Likewise, access to finance—such as microfinancing, international remittances and social allowances—is found as a significant contributor to resilience. Yet, in communes with either more equal distribution of expenditure (as measured by a commune's Gini coefficient of expenditures) or higher level of average per capita expenditure, households are found to be more resilient. Furthermore, households with high level of education are also more resilient to the adverse effects of floods and droughts.

IV. Synthesis and Implications for Policy

Several broad conclusions and useful insights for disaster risk reduction (DRR) policy decisions can be generated from the findings described here. The empirical evidence provides systematic support for the hypothesis that apart from the characteristics of the hazards, the potential for people to avoid adverse impacts and their capacity to withstand and rebound from a disaster are influenced by a confluence of socio-economic factors. Hence, DRR measures must include an appropriate mix of structural and non-structural measures that aim to affect these factors. In addition, findings reveal that indeed vulnerability and resilience are interrelated. Vulnerability is predominantly a pre-disaster concern, while resilience is mainly considered post-disaster. This implies that in terms of DRR priorities, vulnerability is typically linked to prevention, preparedness and mitigation; while resilience, to response, rehabilitation, reconstruction, and recovery.

There is a general consensus in the cross-country studies that low-income countries are more vulnerable and less resilient than countries with higher levels of development. What this means in practical terms is that assistance and investments in development yield the greatest benefits in terms of lives spared and assets protected from disasters if low income countries, particularly those with high exposure, are favored. Moreover, social conditions may matter more than the level of income in reducing the number of deaths, likewise indicates the nature of intervention needed to significantly address vulnerability among these countries.

Moreover, findings consistently suggest that policies that are most effective in minimizing indirect impacts and spillover effects at the macroeconomic level are mostly about the provision of adequate access to funds, including aid, to speed up the reconstruction, rehabilitation, and subsequent economic recovery. External sources of funds, such as aid and remittances, are likewise critical for household-level recovery, particularly among the financially constrained; though internal sources, including saving, are also important. With the apparent critical role of credit and access to funding, more research on financial risk-transfer tools, such as insurance, as a tool for building resilience is still required.

Vulnerability and resilience have been typically studied separately, even within disciplines. However, within the study of disaster risk, studying them simultaneously will assist in painting a more comprehensive picture of total disaster impacts (i.e. covering both direct and indirect), and subsequently, aid in the identification of a comprehensive package of interventions that addresses the various channels though which vulnerabilities are reduced and resilience enhanced. It has been argued that a deep appreciation of the channels of

causality allows for an informed pre- and post-disaster policy actions (Cavallo & Noy, 2011). Thus, it is important for vulnerability and resilience to be studied simultaneously, yet measured separately in an integrated manner, as one cannot be fully address one without addressing the other as well.

Results of the global and country-level studies provide general indications on what broadly determines vulnerability and resilience across countries, and how each country fares against others. Sub-national and household level assessments are better able to capture context-specific concerns; hence, their findings have greater practical usefulness to any country. The existing empirical studies employ various methods of indicator selection and of construction of indices and other measures. The most appropriate method is likely to vary across different contexts and levels of analysis. What is of concern, however, is that various measures with the same spatial scale, and similar objectives and focus yield differing results either in terms of the set of indicators of vulnerability and resilience, or relative importance among the indicators in the set. Given these differences, there will likewise be corresponding differences in policy recommendations. Hence, there is a need to apply a careful and comparative examination, qualitative and quantitative, so that one can successfully and reliably identify a plausible set of indicators that measure and then determine a robust menu of policy options to reduce economic vulnerability and increase resilience.

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[1] Among others, Dacy and Kunreuther (1969) examine the determinants of long-run recovery, including infrastructure networks, insurance, and public policy. Meanwhile, Albala-Bertrand (1993) develops a framework for the analysis of disasters in developing countries, and argues that while development influences the occurrence of a disaster, disasters are not obstacles towards development.

[2] The framework that disaster risk comprises three components namely, hazard, vulnerability and exposure was first presented by the United Nations Disaster Relief Co-ordinator in 1979 as contained in the Report of Expert Group Meeting (UNDRO, 1979) and later contained in their disaster risk training modules (UNDRO, 1992).

[3] It is noted here that while coping capacity and adaptive capacity are often used interchangeably, Cardona et al. (2012) make a distinction between the two, as follows: "coping focuses on the moment, constraint, and survival; adapting (in terms of human response) focuses on the future, where learning and reinvention are key features and short-term survival is less in question".

[4] The Progression of Vulnerability Framework (Wisner, Gaillard, & Kelman, 2012) further elaborates the PAR framework. This framework distinguishes among three levels of progression of vulnerability: "Root causes" include the economic and social structures that influence how resources, wealth, and power are distributed; the ideologies in governance; and, history and culture. "Dynamic pressures" are grouped into the deficiencies of society's economic, social and political processes, and macro-forces, such as rapid population growth and rapid urbanization, deforestation, decline in soil productivity, among other. These serve as the channels through which the root causes result in fragile livelihoods in unsafe locations, which is the final level in the progression (Blaikie et al., 1994; Wisner et al., 2012).

[5] The other two component of this framework are hazards and exposure. Hazard refers to the "potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources"; and Exposure refers to "people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and setting that could be adversely affected" (IPCC, 2014).

[6] The ECLAC also makes a similar stock-flow typology, where *direct damages* refer to the damages to the *stock* of assets that are incurred at the time of the disaster and immediately after, while *indirect loss* refer to the reduction in the economic *flows* due the decrease in the production of goods and services and other macroeconomic effects (ECLAC & WB, 2003). It will be noted, however, that mainly for reasons of convenience, ECLAC use *damage* to refer to *direct damage* and *loss* to refer to *indirect loss (ECLAC & WB, 2003).* This usage of damage (for impacts on stocks) and loss (for impacts on flow) is not adopted in this paper.

[7] In this framework, asset losses and output losses are alternative typologies of economic costs resulting from a disaster that are, to an extent, distinct from the usual *direct damage* and *indirect loss* typology used by the ECLAC. Specifically, asset losses here refer to reduction in the value of the *stock* of assets, while output losses refer to the reduction in the income *flow* (Hallegatte, 2014).

[8] The Social Vulnerability Index (SoVI) of Cutter, Boruff, and Shirley (2003) is one of the earliest indices employing the PCA. The SoVI and its descendents is often used in microlevel, or sectoral level studies such as the series of empirical work on risk management and climate change undertaken by of the International Food and Policy Research Institute (IFPRI, 2015).

[9] Besides EM-DAT, other available databases include DesInventar (compiled by UNISDR) and privately held datasets collected by the two re-insurance companies (MunichRe and SwissRe).


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