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Concepts and measurement of vulnerability to poverty and other issues: A review of literature

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EDITED BY

Jacques Silber • Guanghua Wan

The Asian 'Poverty Miracle'

Impressive Accomplishments
or Incomplete Achievements?



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3. Concepts and measurement of vulnerability to poverty and other issues: a review of literature

Tomoki Fujii¹

1 INTRODUCTION

There has been a surge in interest in vulnerability analysis among development economists in recent years. For example, the number of academic journal articles indexed in EconLit and containing the word ‘vulnerability’ in the title was only 76 in the last half of the twentieth century. The corresponding number between 2001 and 2013 was 444. A sizable fraction of these is also related to poverty.² The purpose of this chapter is to review this growing body of literature on vulnerability. We primarily focus on vulnerability to poverty, but we also discuss its relationship with other vulnerability studies.

The trend of increasing interest in vulnerability is not surprising. While progress has been uneven, the developing world has witnessed a massive reduction in extreme poverty since the end of the Second World War. The fight against poverty has been particularly successful in East and Southeast Asia. However, the threat of poverty has not yet become a thing of the past. This remains true even in relatively successful regions such as East and Southeast Asia. A noticeable fraction of people remain below the poverty line and even those who are above the poverty line can be pulled back into poverty when they are hit by a large negative shock such as a natural disaster or an economic crisis.

Vulnerability is a topic of interest on its own but it also has important implications for economic efficiency and long-run welfare of households. Those who are under the constant threat of poverty are often observed to choose to make safer, but less lucrative, investments than those who are free from the fear of poverty. As pointed out by Eswaran and Kotwal (1990), when the poor have less access to credit than the rich, the former may engage in less risky and less profitable behavior than the latter, even if everyone has the same preference. Therefore, in the presence of credit constraints, bad shocks can lead to a poverty trap (Morduch 1994).

Empirical evidence also supports this possibility. For example, in Tanzania, households with low asset holdings allocate more of their land to low-risk crops (Dercon 1996) and richer households make a substantial investment in cattle, which is profitable but lumpy, whereas poorer households specialize in low-risk low-return activities (Dercon 1998). In India, Rosenzweig and Binswanger (1993) find that uninsured weather risk is a significant cause of lower efficiency and lower average income.

Vulnerability to poverty also affects the accumulation of assets. On the one hand, the lack of credit access can be mitigated by accumulating assets over time because the poor can sell assets at bad times and buy assets at good times to smooth consumption over time (Carter and Zimmerman 2000). On the other hand, when the poor face a survival constraint, they may respond to negative shocks by adjusting consumption to defend or smooth their asset value to ensure their survival (Zimmerman and Carter 2003). Therefore, it may be useful to look at asset holdings to assess the vulnerability of households.

We start our review from the discussion on vulnerability to poverty in the next section. In section 3, we provide a brief overview of other areas of vulnerability studies. One important area is vulnerability to climate change. Although this body of literature has grown largely independent of the studies on vulnerability to poverty, it is interlinked with and arguably becoming increasingly more important to the analysis of vulnerability to poverty. Therefore, we briefly review the vulnerability issue related to climate change and its significance in the analysis of vulnerability to poverty. We also review several other aspects of vulnerability, including assets and nutrition. Section 4 offers some discussions, including policy relevance of vulnerability studies.

2 VULNERABILITY TO POVERTY

We begin this section with discussion on the concepts and measurements of vulnerability to poverty in section 2.1. These are important topics for two reasons. First, there has not yet been a universally accepted definition of vulnerability. Therefore, it is useful to review different formalizations of vulnerability to highlight the similarities and differences of vulnerability concepts proposed by various authors.

Second, measurement is important for the understanding of the situation and sources of vulnerability, which, in turn, is essential for formulating the policies to remove or reduce the risks and impacts of negative shocks.

In section 2.2, we provide a survey on empirical applications of the concepts and measurements of vulnerability to poverty discussed in section 2.1 and other related studies.

2.1 Concepts and Measurements

There have been a number of studies that aim to conceptualize and measure vulnerability to poverty. Partly using the terminology of Calvo and Dercon (2005), we classify the approaches to define vulnerability measures into the following three categories: the welfarist approach, the expected poverty approach, and the axiomatic approach. As discussed subsequently, these categories are not mutually exclusive.

Welfarist approach

Some of the earlier studies such as Ligon and Schechter (2003) and Elbers and Gunning (2003) develop a measure of vulnerability based on explicit welfare foundations. In Ligon and Schechter (2003), vulnerability v_i for individual i is defined as³

$$v_i \equiv u_i(z) - E[u_i(c_i(\omega))] \quad (3.1)$$

where u_i is the instantaneous utility function, $E[\cdot]$ is the expectation operator, $z(\geq 0)$ is the threshold-level certainty-equivalent consumption below which the individual is deemed vulnerable, and $c_i(\omega)(\geq 0)$ is the consumption expenditure per capita for individual i that depends on the state of the world $\omega(\in \Omega)$ for state space Ω .

Notice that z corresponds to the poverty line in the analysis of poverty in the static framework. Therefore, we also interpret z as the poverty line below when it is appropriate to do so. Also, while we interpret c_i as the consumption expenditure per capita, most of our presentation remains unchanged even if it is interpreted as income or other cardinal and observable measure of individual welfare.

Ligon and Schechter (2003) decompose vulnerability into poverty, aggregate risk, idiosyncratic risk, and unexplained risk based on a model of linear consumption equation, where poverty in their study refers to the difference between $u_i(z)$ and $u_i(E[c_i(\omega)])$. Applying this decomposition method to a panel data set in Bulgaria, they find that poverty is the largest single component of vulnerability, accounting for more than half of the observed vulnerability. They also find that aggregate risk is more important than idiosyncratic risk, though unexplained risk is much larger than these two.

The analytical framework of Ligon and Schechter (2003) is static. In contrast, Elbers and Gunning (2003) define vulnerability in the framework of a Ramsey model with income and asset shocks. Their measure of vulnerability has a form similar to equation (3.1), but u_i is taken as the welfare of the individual, which is the sum of the present-discounted

instantaneous utility over an infinite time horizon. Unlike most other studies discussed in this chapter, they explicitly incorporate the future streams of consumption and deal with the effects of risk on both the mean consumption and the volatility of consumption around the mean. The latter point is particularly important because the exposure to risks and the risk-coping strategies available to the individual affect not only the current volatility of consumption but also the investment decision and thus the future streams of consumption.

Their analytical framework allows for the explicit distinction between *ex ante* and *ex post* effects of risk, where the former arises from the anticipation of the risk that the individual is going to face and the latter arises from the shock that has been realized. They apply their model to a panel data for smallholders in Zimbabwe and show that the failure to account for the distinction between *ex ante* and *ex post* effects may lead to large errors in the estimates of chronic and transient poverty.

One obvious drawback of these welfarist measures is that they require explicit specification of the utility or welfare function. While both Ligon and Schechter (2003) and Elbers and Gunning (2003) use the constant relative risk aversion utility function, this is clearly not the only choice. Further, the estimation of the coefficient of relative risk aversion often poses a challenge.

Expected poverty approach

Another approach to vulnerability to poverty is to regard vulnerability as expected poverty. More precisely, given the current condition, vulnerability measures or relates to how likely it is for the individual to fall into poverty in a given time horizon. Thus, the time horizon is inherently relevant in the expected poverty approach. This point contrasts with Elbers and Gunning (2003) mentioned above, who consider the infinite time horizon. For the benefit of simplicity, we choose to discuss the expected poverty approach in a static framework by fixing the time horizon, even though the choice of time horizon is important. It should be noted here that the consumption measure used in the definition of vulnerability always refers to the *ex ante* consumption, whereas it is the *ex post* (realized) consumption in the case of poverty.

The seminal idea of using expected poverty measures to analyze vulnerability can be seen in Ravallion (1988), who analyzes the marginal impact of a random variable influencing the individual welfare on the poverty in society. He proposes a decomposition of the marginal impact into transient and chronic (persistent) poverty, which respectively refer to the marginal impact on extensive and intensive margins.

Chaudhuri et al. (2002) and Suryahadi and Sumarto (2003) formulate vulnerability as the probability of consumption per capita falling below the

poverty line z given the current set of observable individual characteristics X_i for individual i . They essentially define vulnerability v_i for individual i in the following manner

$$v_i \equiv \Pr(c_i < z \mid X_i), \quad (3.2)$$

where c_i is the (*ex ante*) consumption per capita. It should be noted that this is different from poverty, because the poor households are those households whose (*ex post*) consumption per capita falls below the poverty line.

To operationalize equation (3.2), both Chaudhuri et al. (2002) and Suryahadi and Sumarto (2003) assume that the logarithmic consumption is conditionally linear such that

$$\ln c_i = X_i \beta + \varepsilon_i, \quad (3.3)$$

where β is a vector of coefficients and ε_i is an idiosyncratic error term.

Further, denoting the standard deviation of ε_i by σ_i , which may be heteroskedastic across individuals, and assuming that ε_i is normally distributed, eq. (2) reduces to

$$v_i = \Phi\left(\frac{\ln z - X_i \beta}{\sigma_i}\right), \quad (3.4)$$

where $\Phi(\cdot)$ is the cumulative distribution function for the standard normal distribution.

Replacing the parameters (β, σ_i) with their estimates in equation (3.4), we obtain a measure of vulnerability. Individuals can be then classified into high vulnerability ($v_i \geq \ell$) and low vulnerability ($v_i < \ell$) groups, where the threshold value of vulnerability is denoted by ℓ .

An obvious question that arises here is how to choose ℓ . Suryahadi and Sumarto (2003) choose $\ell = 0.5$. While this choice is somewhat arbitrary, some justifications can be made. As Pritchett et al. (2000) argue, 50-50 odds has a nice focal point and it makes intuitive sense to say an individual is vulnerable if he or she faces even odds or worse. Second, if an individual is just at the poverty line and faces a symmetric shock with a zero mean, this individual has a vulnerability of 0.5.⁴ It should be noted that the definition of vulnerability in Pritchett et al. (2000) is slightly different from that of Suryahadi and Sumarto (2003), because the former defines vulnerability as a risk of falling into poverty at least in one period in the next n periods being greater than the threshold probability level. However, the justifications for choosing $\ell = 0.5$ explained above are nevertheless applicable to Suryahadi and Sumarto (2003).

Table 3.1 Poverty and vulnerability categories by Suryahadi and Sumarto (2003)

	Poor	Non-poor
$E[c] < z, v \geq \ell$	A	D
$E[c] \geq z, v \geq \ell$	B	E
$E[c] \geq z, v < \ell$	C	F

Suryahadi and Sumarto (2003) propose to further categorize individuals according to Table 3.1. This table helps us to understand the difference between poverty and vulnerability. They classify the vulnerable groups into high mean consumption ($E[c] \geq z$) and low mean consumption groups. For example, B corresponds to a group of individuals who are poor and have high mean consumption and high vulnerability in their categorization. Note that even when the mean consumption is high, an individual may still fall below the poverty line for a given period because of a negative idiosyncratic shock. Such a possibility is higher for individuals with high vulnerability.

Using this framework, Suryahadi and Sumarto (2003) divide the poor ($A + B + C$) into chronic and transient poor, which are respectively A (poor with expected consumption below poverty line) and $B + C$ (poor with expected consumption above poverty line) in Table 3.1.⁵ They also divide the high vulnerability group ($A + B + D + E$) into two groups, one characterized by low expected consumption ($A + D$) and the other characterized by high variability of the consumption group ($B + E$). They define the total vulnerability group ($A + B + C + D + E$) as those individuals who are either poor and/or in the high vulnerability group.

Suryahadi and Sumarto (2003) apply this framework to Indonesia. They first describe the profile of the poor and vulnerable individuals in Indonesia and then compare the change in poverty and vulnerability between 1996 and 1999 across geographic locations, sector of individual head's occupation, education level, and gender. They find that the vulnerability to poverty among Indonesian individuals after the Asian financial crisis has unambiguously increased and the proportion of the total vulnerable group almost doubled.

Kamanou and Morduch (2004) also use expected poverty to measure vulnerability, though they take vulnerability as the difference between the expected poverty in the future and the current poverty. They use a Monte Carlo method to simulate the possible future outcomes for individuals based on their observed characteristics and observed consumption fluctuations of similar individuals. Their measure, however, can be difficult to interpret because it could take a negative value.

Christiaensen and Subbarao (2005) define vulnerability as the expected value of the Foster–Greer–Thorbecke (FGT) poverty measure due to Foster et al. (1984), which is given as follows:

$$v_{i,\gamma} = E \left[\left(\frac{z - c_i}{z} \right)^\gamma \cdot \text{Ind}(c_i < z) \right] = \int_0^z \left[\frac{z - c_i}{z} \right]^\gamma f(c_i) dc_i, \quad (3.5)$$

where $\text{Ind}(\cdot)$ is the indicator function, which is equal to one if the argument is true and zero otherwise, $f(\cdot)$ is the probability density function for consumption, and γ is a parameter for the FGT measure. Because $f(\cdot)$ is not known in general, we need to make additional assumptions to calculate vulnerability based on equation (3.5). As with Chaudhuri et al. (2002) and Suryahadi and Sumarto (2003), they estimate the parameters for the conditional mean and the variance of c_i . Hence, the vulnerability measure considered by Christiaensen and Subbarao (2005) can be thought of as an extension of equation (3.4), because equation (3.5) reduces to equation (3.4) under a log-linearity condition in equation (3.3) and normality assumption when $\gamma = 0$.

Unlike Chaudhuri et al. (2002) and Suryahadi and Sumarto (2003), Christiaensen and Subbarao (2005) utilize a repeated cross-sectional data that is augmented with historical information on the shocks. They find that individuals in arid areas, who experience large rainfall volatility, appear more vulnerable than those in non-arid areas in Kenya.

The vulnerability studies mentioned above typically use either some form of consumption or income regressions to estimate parameters such as β in equation (3.3). It is not immediately clear, though, how vulnerability estimated via a regression approach actually matches the expected poverty. Using a multi-period panel data for rural areas in the People's Republic of China (PRC), Zhang and Wan (2009) attempt to answer how accurately vulnerability can be computed.⁶

To this end, they define vulnerability as the probability of being in poverty in the future and calculate vulnerability assuming that income is log-normally distributed. Exploiting the panel structure, they evaluate the precision of the estimated vulnerability by comparing the vulnerability computed from earlier rounds of data against the actual observed poverty based on later rounds. They find that the precision of estimated vulnerability depends on ℓ and the poverty line. They obtain a more precise estimate under the US\$2 per day poverty line than the US\$1 per day poverty line. They also argue that the choice of $\ell = 0.5$ is appropriate because the vulnerability under this threshold appears to be more precise than other choices they tried.

It is worth pointing out here that the expected poverty measure can be

considered a welfarist measure by treating the individual-level poverty measure as the individual utility. However, these two types of measures differ in the following two aspects (Christiaensen and Subbarao 2005). First, the welfarist approach explicitly considers the risk preference, while the expected poverty measure does not. Second, the former considers the entire distribution of c including the states in which c exceeds z , whereas the latter only focuses on what is below z .

It is also worth noting that the mathematical expression of the expected poverty measure in the form of equation (3.5) is similar to the total poverty, or the sum of the transient poverty and chronic poverty, as proposed by Jalan and Ravallion (1998, 2000). They define total poverty to be simply the poverty averaged over all periods, whereas chronic poverty is at the level of consumption averaged over all periods. Therefore, transient poverty, which is the difference between total poverty and chronic poverty, comes from the nonlinearity of poverty with respect to consumption in their definition.⁷

To further elucidate the relationship between vulnerability and chronic/transient poverty, suppose that the poverty measure of interest is the FGT measure with parameter γ and the vulnerability measure is equation (3.5). Consider a situation where vulnerability coincides with total poverty.⁸ Then, the chronic poverty $CP_{i,\gamma}$ and transient poverty $TP_{i,\gamma}$ can be written as follows:

$$CP_{i,\gamma} = \left(\frac{z - E[c_i]}{z} \right)^\gamma,$$

$$TP_{i,\gamma} = v_{i,\gamma} - CP_{i,\gamma}.$$

This result also points to the fact that high vulnerability to poverty may be due to low mean consumption (or high chronic poverty), high consumption variability (or high transient poverty), or a combination of both. Therefore, this result qualitatively relates to Table 3.1.

Axiomatic approach

Instead of basing the definition of vulnerability on utility or poverty at the individual level, it is also possible to derive a vulnerability measure from a set of axioms, which lists the properties that an ideal vulnerability measure would satisfy. Calvo and Dercon (2005, 2007, 2013) make seminal contributions to the derivation of vulnerability measures from a set of axioms. Our discussion on axiomatic approach is mainly based on these studies. We then discuss the relationship between these studies and others.

Because we hereafter focus on a particular individual, we drop the subscript i for the time being to simplify the notation. We also introduce additional notations to present the axioms formally. There are K possible states in Ω such that $\Omega = \{s^1, \dots, s^K\}$. Further, we denote the consumption in state s^k by $c^k \equiv c(s^k)$ and the probability that the state s^k arises by $p^k (\equiv \Pr(\omega = s^k))$ for $k \in \{1, \dots, K\}$. We denote the K -vectors of c and p by $\mathbf{c} \equiv (c^1, \dots, c^K)$ and $\mathbf{p} \equiv (p^1, \dots, p^K)$, respectively. We define the consumption right-censored at the poverty line by $\tilde{c}^k \equiv \min(c^k, z)$ and its vector analogue by $\tilde{\mathbf{c}} \equiv (\tilde{c}^1, \dots, \tilde{c}^K)$. We denote the k -th unit vector in a K -dimensional space by \mathbf{e}^k , whose elements are all zero except for the k -th element, which is one. For example, $\mathbf{e}^1 = (1, 0, \dots, 0)$.

Calvo and Dercon (2005, 2013) consider a class of vulnerability measures that can be written as a function of z , \mathbf{c} , and \mathbf{p} such that vulnerability measures in this class can be written as $v(z, \mathbf{c}, \mathbf{p})$. One assumption that is implicit here is that the poverty line is common across states. We also maintain this assumption here to avoid unnecessary complications. Calvo and Dercon (2005, 2013) require the following properties as basic properties of individual vulnerability measures.

Axiom 1 (Focus): For every $(z, \mathbf{c}, \mathbf{p})$, v satisfies $v(z, \mathbf{c}, \mathbf{p}) = v(z, \tilde{\mathbf{c}}, \mathbf{p})$.

Axiom 2 (Symmetry): For every $(z, \tilde{\mathbf{c}}, \mathbf{p})$ and $K \times K$ permutation matrix \mathbf{B} , v satisfies

$$v(z, \tilde{\mathbf{c}}, \mathbf{p}) = v(z, \mathbf{B}\tilde{\mathbf{c}}, \mathbf{B}\mathbf{p}).$$

Axiom 3 (State-dependent effect of outcomes): Suppose that we have $1 \leq k \leq K$, $\tilde{c}_a^k = \tilde{c}_b^k > -d$, $p_a^k p_b^k \neq 0$. Then, $p_a^k = p_b^k$ if and only if

$$v(z, \tilde{\mathbf{c}}_a, \mathbf{p}_a) - v(z, \tilde{\mathbf{c}}_a + d\mathbf{e}^k, \mathbf{p}_a) = v(z, \tilde{\mathbf{c}}_b, \mathbf{p}_b) - v(z, \tilde{\mathbf{c}}_b + d\mathbf{e}^k, \mathbf{p}_b). \quad (3.6)$$

Axiom 4 (Probability transfer): Suppose that we have $1 \leq k, l \leq K$, $a \neq b$, $p^k \geq d > 0$, and $1 - d \geq p^l \geq 0$.⁹ For every $(z, \tilde{\mathbf{c}}, \mathbf{p})$, v satisfies

$$v(z, \tilde{\mathbf{c}}, \mathbf{p}) v(z, \tilde{\mathbf{c}}, \mathbf{p} - d\mathbf{e}^k + d\mathbf{e}^l) \text{ if and only if } \tilde{c}^l \tilde{c}^k.$$

Axiom 5 (Risk sensitivity): For every $(z, \tilde{\mathbf{c}}, \mathbf{p})$, v satisfies

$$v(z, \tilde{\mathbf{c}}, \mathbf{p}) \geq v(z, \bar{c} \mathbf{1}_K, \mathbf{p}), \text{ for } \bar{c} \equiv \mathbf{p}^T \tilde{\mathbf{c}}, \quad (3.7)$$

where $\mathbf{1}_K$ is a K -vector of ones and the equation is held with equality if and only if $\tilde{c}^k = \bar{c}$ for all $1 \leq k \leq K$.¹⁰

Axiom 6 (Scale invariance): For every $(z, \tilde{\mathbf{c}}, \mathbf{p})$ and $\lambda > 0$, v satisfies

$$v(z, \tilde{\mathbf{c}}, \mathbf{p}) = v(\lambda z, \lambda \tilde{\mathbf{c}}, \mathbf{p}).$$

Axiom 7 (Differentiability): $v(z, \tilde{\mathbf{c}}, \mathbf{p})$ is twice differentiable in $\tilde{\mathbf{c}}$.

Axiom 1 states that the change in consumption measure in a particular state makes no difference so long as it is above the poverty line. In other words, the outcome of interest is not the consumption itself but the censored consumption. From a technical perspective, this axiom is not essential because the results presented below including equations (3.9) and (3.10) hold by appropriately replacing $\tilde{\mathbf{c}}$ with \mathbf{c} .

It is worth pointing out that welfarist measures do not satisfy this axiom in general. This means that the possibility of severe destitution can be compensated by another state that is sufficiently good under the welfarist measures. Therefore, individuals are not necessarily deemed vulnerable, even in the presence of the possibility of severe destitution. This feature appears unattractive when we are concerned with vulnerability to poverty. Hence, we regard Axiom 1 as an essential requirement for our purpose.

Axiom 2 states that the states of the world can swap their indices without any impact on vulnerability. That is, only the censored consumption and probability in each state matter. Therefore, given \tilde{c}^k and p^k , all states are treated equally.

To interpret axiom 3, imagine $d > 0$ such that equation (3.6) is positive. The 'if' part of the axiom states that the probability of k -th state is the same if the reduction in vulnerability is the same for the same change in consumption in the k -th state (that is, from $\tilde{c}_a^k (= \tilde{c}_b^k)$ to $\tilde{c}_a^k + d (= \tilde{c}_b^k + d)$). The 'only if' part requires that the change in vulnerability is the same if the probability of the k -th state is the same and the consumption in the k -th state changes in the same way.

Axiom 4 says that if the probability is hypothetically transferred from a good (bad) state, in which the censored consumption is high (low), to a bad (good) state, then the vulnerability would increase (decrease). Axiom 4 also implies that increases in vulnerability are monotonically related to decreases in consumption as long as outcomes are below the poverty line. Note that the expected poverty rate given in equation (3.2) fails to satisfy this axiom.

Axiom 5 requires that vulnerability is lower if the (stochastic) censored consumption is replaced with its expected value \bar{c} . In this axiom, the risk

is implicitly taken as a probability transfer from the middle to the tails. That is, the right-hand side of equation (3.7) assumes that the probabilistic weight falls entirely on \bar{c} , whereas the left-hand side spreads that weight away from the expected outcome towards the tails. The risk and vulnerability are higher as a consequence.

Alternatively, Axiom 5 can be interpreted in the following manner. Define the certainty-equivalent consumption $c^* = c^*(z, \tilde{c}, \mathbf{p})$ by:

$$v(z, \tilde{c}, \mathbf{p}) = v(z, c^* \mathbf{1}_K, \mathbf{p}). \quad (3.8)$$

Thus, the certainty-equivalent consumption $c^* = c^*(z, \tilde{c}, \mathbf{p})$ is a fixed amount of consumption that gives rise to the same vulnerability. By axioms 4 and 5, we have $c^* < \bar{c}$. Therefore, if perfect insurance becomes available so that the individual gets the expected consumption for sure, the individual would be willing to pay up to $\bar{c} - c^*$ as a premium to reduce its vulnerability.

Axiom 6 implies that the individual becomes neither more nor less vulnerable when both the poverty line and consumption change by the same proportion. This makes intuitive sense, because this axiom requires that the vulnerability measure is not affected by the currency unit used for the poverty line and consumption.

Axiom 7 implies that small changes in consumption cause no abrupt reactions in v and the marginal impact of consumption on vulnerability is also smooth. Calvo and Dercon (2005) show that vulnerability measures satisfying axioms 1–7 can be written in the following form:

$$v(z, \mathbf{c}, \mathbf{p}) = E[\phi(q)] = \sum_{k=1}^K p^k \phi(\tilde{c}_k/z), \quad (3.9)$$

where $q \equiv \tilde{c}/z$ is the (random) censored consumption normalized by the poverty line, which necessarily lies on the unit interval, and $\phi(\cdot)$ is a monotonically decreasing and convex function. We can interpret $\phi(\cdot)$ as a state-dependent deprivation index because it tends to increase as c^k falls when $c^k < z$.

The expected FGT measure given in equation (3.5) fails to satisfy axiom 5 if $\gamma \leq 1$ because it means that the poor individuals are risk-neutral or risk-loving below the poverty line. If $\gamma > 1$, the expected FGT measure satisfies all of axioms 1–6 (Calvo and Dercon 2005). However, the expected FGT measure with $\gamma > 1$ is not without problems. As pointed out by Ligon and Schechter (2003), this implies that poor individuals are implicitly assumed to have increasing absolute risk aversion, which is at odds with empirical evidence.

To address this point and pin down the desirable vulnerability index,

Calvo and Dercon (2013) propose to require the following two additional axioms:

Axiom 8 (Normalization): If $\mathbf{c} = z\mathbf{1}_K$, $v(z, \mathbf{c}, \mathbf{p}) = 0$ for all (z, \mathbf{p}) .

Axiom 9 (Constant relative risk sensitivity): For every $\lambda > 0$ and $(z, \mathbf{c}, \mathbf{p})$, v satisfies

$$v(z, \lambda \mathbf{c}, \mathbf{p}) = v(z, \lambda c^* \mathbf{1}_K, \mathbf{p})$$

Axiom 8 states that the vulnerability measure should be equal to zero if the individual's consumption is equal to poverty line for sure. This axiom makes intuitive sense because the individual barely escapes from the threat of poverty in this case. Note that the welfarist measures generally do not satisfy this axiom.

Axiom 9 essentially states that if the consumption increases by the proportion λ in all possible states of the world, then the certainty-equivalent consumption must also increase by the same proportion. Further, because the expected consumption also increases by the proportion λ in this case, the ratio of the certainty-equivalent consumption to the expected consumption is independent of λ . This requirement also addresses the shortcomings of the expected FGT measure with $\gamma > 1$ discussed above.

Calvo and Dercon (2013) show that the vulnerability measure v that satisfies Axioms 1–9 can be written as a multiple of the following expression:

$$v(z, \mathbf{c}, \mathbf{p}) = \begin{cases} (1 - E[q^\theta])/\theta & \text{for } \theta < 1 \text{ and } \theta \neq 0. \\ -E[\ln q] & \text{for } \theta = 0 \end{cases} \quad (3.10)$$

Note that the first and second cases above are the expected Chakravarty measure of poverty (Chakravarty 1983) and the expected Watts measure of poverty (Watts 1968), ignoring the factor θ^{-1} in the first case. Therefore, the individual-level vulnerability measure axiomatically derived by Calvo and Dercon (2005, 2013) can be also regarded as an expected poverty measure.

As with Calvo and Dercon (2005, 2013), Dutta et al. (2011) also derive a vulnerability measure at the individual level from a set of axioms, which are: (i) decomposability; (ii) transferability; (iii) monotonicity of (future) consumption; (iv) monotonicity of current consumption; and (v) independence.¹¹ It is worth noting that, unlike Calvo and Dercon (2005), Dutta et al. (2011) let the deprivation explicitly depend on both current and future consumption. Therefore, the critical difference between these two studies lie in axiom (iv) of the monotonicity of current consumption.

In Calvo and Dercon (2005), the current (*ex post*) consumption plays

no role in the measurement of vulnerability. However, Dutta et al. (2011) require that vulnerability can only either monotonically increase or decrease compared with the status quo when there is an increase in the current living standard. The monotonic increase is possible when, for example, individuals who enjoy higher current consumption find it hard to cope with negative shocks compared with current poor people because of the lack of previous experience of coping with poverty. On the other hand, the monotonic decrease is also possible when, for example, lower current consumption means the lack of assets and networks that individuals can count on at the time of distress. Also, axiom (iv) on the monotonicity of current consumption in Dutta et al. (2011) implies that their vulnerability measure is, in general, not an expected poverty measure unlike Calvo and Dercon (2005).

However, if vulnerability is assumed to be independent of the current standards of living, the axioms presented in Calvo and Dercon (2005, 2013) and Dutta et al. (2011) are strikingly similar. For example, axiom 4 implies axiom (iii) of monotonicity in consumption, which states that an increase in c^k for a particular state k does not affect vulnerability ordering of two consumption-probability profiles, (\bar{c}_a, p_a) and (\bar{c}_b, p_b) . Similarly, axiom 5 is closely related to axiom (ii) of transferability, which states that the transfer of consumption from a bad state to a equally-likely good state increases vulnerability. Axiom 3 relates to axiom (i) of decomposability, which restricts vulnerability to be a expected deprivation function, and axiom (v) of independence, which requires that the vulnerability ordering of two consumption profiles for given probability profile is the same after consumption increases in a particular state.¹²

A study related to the above-mentioned studies is Chakravarty et al. (2015), who explore a partial ordering of vulnerability to poverty based on expected poverty measures. They find, among other things, that the condition that situation a ($\mathbf{c}_a, \mathbf{p}_a$) is no more vulnerable than situation b ($\mathbf{c}_b, \mathbf{p}_b$) is equivalent to the condition that the deprivation function in each meager state $k \in \{\kappa \mid 1 \leq \kappa \leq K_a, c^k < z\}$ in situation a is obtained by a smoothing of the meager states in situation b .

Hardeweg et al. (2013) also propose a method that leads to a partial ordering of vulnerability. In their approach, two groups are compared by the first-, second-, and third-order stochastic dominance of consumption (or income) distribution up to a certain threshold such as the poverty line. When a higher-order stochastic dominance is used, it is more likely to be able to rank the two different groups but the set of vulnerability measures that is consistent with the ranking shrinks. This approach has an attraction that the comparison of vulnerability across groups does not depend on the (arbitrary) choice of the vulnerability measure.

The discussion thus far has been concerned with the individual-level vulnerability to unidimensional poverty. However, the vulnerability measure given in equation (3.10) has been extended in at least two directions. The first direction is due to Calvo (2008), who extends to multidimensional poverty in a spirit similar to Calvo and Dercon (2005), even though its development is not fully based on a set of axioms. This extension is important because consumption poverty cannot possibly capture every relevant dimension of poverty.

Formally, the outcome ('consumption') in the j -th dimension for individual i is denoted by c_{ij} and the threshold-level outcome ('poverty line'), below which the outcome is deemed 'deprived' by z_j for $1 \leq j \leq J$, such that we can define the multidimensional counterpart of q_i by $q_{ij} \equiv \min(c_{ij}, z_j) / z_j$. Dimension j has a weight γ_j where the sum of weights is equal to one. Calvo (2008) considers constant-elasticity-of-substitution aggregation across different outcomes such that the index of vulnerability to multidimensional poverty v_i^{MP} is given by the following:

$$v_i^{MP} = 1 - E \left[\left(\sum_{j=1}^J \gamma_j q_{ij}^\rho \right)^{\frac{\alpha}{\rho}} \right] \text{ with } \alpha \in (0,1) \text{ and } \rho \in [0,1]. \quad (3.11)$$

Because q_{ij} does not exceed one, it is not possible to (fully) compensate a bad outcome in one dimension by a good outcome in another. Applying this index to a panel dataset in Peru for the dimensions of consumption and leisure, Calvo (2008) finds that the gap in the multidimensional vulnerability between rural and urban areas tends to become larger as the substitutability between leisure and consumption decreases (that is, when ρ is lower). This is because the idiosyncratic shocks in rural areas exhibit stronger negative correlation than urban areas, which in turn means that rural areas (relative to urban areas) depend more heavily on rare positive shocks in both dimensions to escape from poverty as ρ gets lower.

The second direction of extension is due to Calvo and Dercon (2007, 2013), who consider vulnerability to poverty at an aggregate level. The reason why we may need a measure for the society is that a simple aggregation of individual-level vulnerability may not be an appropriate measure for the society.¹³

To further elaborate on this point, we introduce some notations. Suppose that there are I individuals in the society. We denote the state-contingent consumption profile by a $(K \times I)$ -matrix \mathbf{C} , whose i -th column vector is a K -vector \mathbf{c}_i of state-contingent consumption for individual i .

Now, consider a simple example with $I = K = 3$ and $\mathbf{p} = \mathbf{1}_K / 3$. We assume $c = 0$ means poor and $c = 1$ means non-poor. Now, consider the following two state-contingent consumption profiles:

$$\mathbf{C}_a = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \mathbf{C}_b = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

From each individual's perspective, vulnerability is the same for these two profiles because each individual falls into poverty with probability 1/3. However, from the social perspective, they are not the same. In profile *a*, exactly one of the three individuals is poor in each of the three possible states. On the other hand, everyone is poor in state 1 and no one is poor in the two other states in profile *b*. Arguably, the latter situation is less desirable because there is a catastrophic state in which everyone is poor.

Based on this idea, Calvo and Dercon (2013) propose a set of axioms for aggregate vulnerability similar to axioms 1–7. However, there are three important differences. First, axioms 3 and 4 must be modified to the case where everyone faces the same state-contingent, censored consumption. In other words, these axioms are focused on covariate risk in a world where the risk is fully shared in the society.

Second, they do not require axiom 6 for aggregate vulnerability. They instead require sensitivity to correlation, which requires avoidance of catastrophic states. This alternative requirement is sufficient to secure that an increase in covariant risk raises vulnerability.

Finally, they require symmetry over individuals and replication invariance. The former states that all individuals are treated equally and the latter requires that population size plays no role. Calvo and Dercon (2013) have shown that these requirements are satisfied if and only if the aggregate measure of vulnerability \mathbf{v} can be written as a positive multiple of the following expression:

$$V(\mathbf{z}, \mathbf{p}, \mathbf{C}) = \frac{1}{\theta} \left(1 - E \left[\left(\prod_{i=1}^I q_i^{1/I} \right)^\theta \right] \right), \text{ with } \theta < 0. \quad (3.12)$$

It is interesting to note that equation (3.12) becomes the expected value of the poverty measure proposed by Clark et al. (1981) when θ is set equal to one, though this possibility is excluded by the condition $\theta < 0$. As we have seen, a number of measures derived from a set of axioms can also be interpreted as expected poverty measures.

Calvo and Dercon (2013) also compute various poverty and vulnerability statistics, including the FGT poverty measures, the average individual-level vulnerability measure in equation (3.10), and the aggregate vulnerability measure in equation (3.12) using a panel data survey from Ethiopia. Their finding underscores the importance of distinguishing between vulnerability and poverty, because their profiles can be very different.

2.2 Empirical Studies

In this subsection, we review a number of empirical studies on vulnerability to poverty. We start our discussion with the PRC, because there are multiple studies on vulnerability to poverty and several other related studies in the PRC. We then discuss the rest of Asia and the rest of the world.

PRC

McCulloch and Calandrino (2003), Zhang and Wan (2006), and Imai et al. (2010) study vulnerability to poverty at the household level in the PRC. All of these studies adopt an expected poverty approach and use equation (3.4) or a similar form to estimate vulnerability. However, the data source, geographic coverage, and focus of these studies are different.

Using a five-year panel data of rural Sichuan households for 1991–95, McCulloch and Calandrino (2003) investigate the factors that affect vulnerability. They find that demographic characteristics, education, the value of assets, and location are important for vulnerability. They also find that some factors such as education and location are a significant determinant for transient poverty but not for chronic poverty.

Zhang and Wan (2006) analyze vulnerability in six rural districts of Shanghai between 2000 and 2004. They compare vulnerability across education levels and whether the share of income from agricultural activities exceeds the sample average in a given year. They find that low-education households are substantially more vulnerable than high-education households.

Imai et al. (2010) use a large repeated cross-sectional survey dataset for 1988, 1995, and 2002 collected under the Chinese Household Income Project and study the effect of a regressive tax system on poverty and vulnerability in rural PRC. They find that poverty and vulnerability have been significantly reduced during their study period in the PRC. The after-tax poverty and vulnerability dropped more than their before-tax counterparts, because the tax system has become less regressive, but the geographic disparity of poverty and vulnerability increased during the same period. Imai et al. (2010) also find that head's education and access to electric power supply are found to be negatively associated with both poverty and vulnerability. On the other hand, a few factors, including farm land size and the share of the farm land irrigated, are associated with vulnerability but not poverty.

As mentioned previously, vulnerability, defined as expected poverty, is closely related to chronic poverty and transient poverty. Using rural household surveys, Jalan and Ravallion (1998) find that a substantial fraction of poverty in rural PRC is transient. Poverty regression results reported in

Jalan and Ravallion (2000) indicate that some factors such as demographics and wealth are important for both chronic and transient poverty but other factors only matter for one of them.

The above-mentioned studies show that vulnerability to poverty is heterogeneous across households. Education and location appear to be among the factors that consistently emerge as the significant covariates of vulnerability to poverty in the PRC.

Asia outside the PRC

Currently, studies on vulnerability to poverty in Asia outside the PRC are limited. One notable exception, however, is Viet Nam. In addition to Hardeweg et al. (2013), discussed in the previous subsection, Imai et al. (2011a, 2011b) compute various vulnerability measures in Viet Nam. In Imai et al. (2011b), expected poverty measures for various ethnic groups in Viet Nam are calculated using equations (3.2) and (3.3). They find that households in an ethnic minority group are not only poor but also more vulnerable than those in an ethnic majority group such as Chinese and Kinh. Imai et al. (2011a) use the vulnerability measure calculated in this way as a regressor. They run a probit regression of future poverty as well as a multinomial logit regression of the poverty transition between current and future poverty. In both cases, vulnerability to poverty was found to be statistically significant.

Jha et al. (2010) analyze poverty and vulnerability in Tajikistan using a panel data set for 2004–05. They use the expected poverty approach to describe the profile of vulnerable households. Their analysis indicates that rural households tend to be poorer and more vulnerable than urban households. They also adopt the vulnerability measure proposed by Ligon and Schechter (2003) to conduct a decompose analysis. Their analysis indicates that vulnerability comes mostly from poverty.

Gaiha and Imai (2004) study the vulnerability to poverty of rural households in South India during 1975–1984 using a variant of the expected poverty approach. They first use a dynamic-panel income regression model and simulate the effects of negative crop shocks of various sizes and duration. They find that even relatively rich households are highly vulnerable to long spells of poverty when severe crop shocks occur.

Using panel data from two Bangladeshi villages, Amin et al. (2003) analyze vulnerability as the inability of households to insure against idiosyncratic risks, which is measured by the comovement between household income and household consumption based on a risk-sharing test (Townsend 1994). Using this test, they find that microcredit is successful at reaching the poor. However, it is less successful at reaching the vulnerable and unsuccessful at reaching the vulnerable poor. This may be because the

forces that make some poor households vulnerable may also make them greater risks for microcredit providers. Their study suggests that the necessary anti-poverty intervention may be different between the vulnerable and non-vulnerable poor.

Note that the vulnerability measure used in Amin et al. (2003) is a measure of uninsured exposure to risk and not a direct measure of vulnerability to poverty. Further, as pointed out by Klasen and Povel (2013), the vulnerability measure used in Amin et al. (2003) is at odds with the concept of vulnerability to poverty in the literature, because it is not an *ex ante* measure and ignores the current consumption level and the likelihood of adverse idiosyncratic and covariate shocks.

Despite these drawbacks, similar methods have been used in a number of other studies. For example, Skoufias and Quisumbing (2005) study vulnerability as uninsured exposure to risk in five countries including Bangladesh. They find that there is no perfect risk sharing and that food consumption tends to fluctuate less than nonfood consumption by idiosyncratic shocks. Using panel data from Pakistan, Kurosaki (2006) also studies vulnerability based on a risk-sharing test. His study, however, allows for the asymmetry between positive and negative income shocks. His results show that the ability to cope with negative income shocks tends to be lower for those households which are aged, landless, and without regular remittance receipts.

Rest of the world

Using cross-sectional data in Madagascar and equation (3.4) as a measure of vulnerability, Günther and Harttgen (2009) propose a method to assess relative importance of various sources of vulnerability. They find, among other things, that risk-induced vulnerability is relatively more important than poverty-induced vulnerability in urban areas but the opposite is true for rural areas. They also find that the relative importance of covariate vulnerability to idiosyncratic vulnerability in rural areas is higher than urban areas.

Milcher (2010) also uses the expected poverty in equation (3.4) as a measure of vulnerability. He compares the profile of vulnerability to poverty for Roma and non-Roma households in Southeast Europe. He finds that Roma tends to have higher levels of vulnerability than non-Roma. The characteristics of vulnerable households include large households, households with a poorly-educated head, households whose main source of income is benefits or informal activities.

Using a panel dataset of villages in rural Ethiopia, Dercon and Krishnan (2000) compute (predicted) poverty measures under a combination of various possibilities, such as (1) whether there is a safety net (food aid and consumption from food-for-work), (2) whether the rainfall that households face is 'normal' (at the long-term mean) or 'bad' (half thereof),

and (3) whether there is seasonal price fluctuations. Comparison of these scenarios indicates that poverty can change substantially within a relatively short period of time.

As with Amin et al. (2003), Skoufias and Quisumbing (2005), and Kurosaki (2006) discussed above, there are also studies that take vulnerability as uninsured exposure to risk. Using a panel dataset from Peru, Glewwe and Hall (1998) analyze the effect of macroeconomic shock between 1985 and 1990. They find that households headed by relatively well-educated persons, households headed by females, and households with fewer children tend to be less vulnerable.

In the Russian Federation, Gerry and Li (2010) apply quantile regression to a model similar to Glewwe and Hall (1998). They find that a well-functioning labor market is highly valuable, because individuals entering unemployment faced heightened levels of vulnerability among those experiencing the severest consumption shocks, whereas households containing individuals entering the labor market are well equipped to smooth consumption.

Gerry and Li (2010) also find that personal networks are important for the most vulnerable. Those in receipt of increased support from relatives were better able to smooth consumption at lower quantiles. They find no evidence that social welfare benefits, such as childcare allowances, unemployment benefits and disability benefits, cushion individuals against declining consumption but pension benefits appear to help individuals smooth consumption, particularly for higher quantiles.

In Papua New Guinea, Jha and Dang (2010) estimate poverty and vulnerability, where the latter is computed as expected poverty. Using a sub-sample of households with an observation in the second round of the survey, they compare the vulnerability derived from the cross-sectional estimation in the first round against the realized poverty in the second round and find that the prediction is reasonably good. Their results are reassuring because vulnerability studies based on cross-sectional data may still be informative.

Empirical studies of vulnerability discussed above are either purely descriptive or try to identify the causes of vulnerability. In contrast, de la Fuente (2010) uses vulnerability as an explanatory variable. He investigates the impact of vulnerability, as measured by the probability of poverty in the future, on remittance flows in Mexico. His findings indicate that money remitted from abroad does not end up with those who are more likely to be needy in the future. While this would be less of a problem if an injection of remittances anywhere within the village would trickle down to those in most need but such social exchanges proved almost inexistent in his study households.

We have reviewed a broad range of empirical studies on vulnerability to poverty in this subsection. The geographic coverage, techniques used, and the covariates considered all differ across studies. However, we make three points that emerge out of this review.

First, poverty and vulnerability to poverty are related but different. Therefore, it is important to understand the underlying causes of poverty and vulnerability. Some policies such as one-off food aid are likely to alleviate current poverty but do little to reduce vulnerability. Other policies such as improved access to credit would help those entrepreneurial poor facing a credit constraint but will not help reduce vulnerability of farmers who lack the knowledge to diversify crops.

Second, many of the studies discussed above indicate that education is among the important factors that help reduce both poverty and vulnerability to poverty. One possible explanation is that educated people are able to exploit and adapt to the changes in the economic environment and use assets more efficiently (Schultz 1975).

Finally, location is an important determinant of vulnerability to poverty in many of the studies reviewed above. This is not surprising given that the economic conditions are different across different locations. However, there is currently little knowledge about which location-specific characteristics affect vulnerability. Certain characteristics, such as access to markets, are possible to change by policies. Other characteristics, such as the pattern of rainfall, are more difficult to change, in which case policies should focus on the mitigation of rainfall variations. Hence, understanding the underlying cause of vulnerability at each location is a first step to determine the appropriate location-specific policy to cope with vulnerability. We revisit policy issues in section 4.

3 OTHER AREAS OF VULNERABILITY

The study of vulnerability is not limited to the vulnerability to poverty. In this section, we briefly review other areas of vulnerability that are related to vulnerability to poverty. In the first subsection, we review studies on vulnerability to climate change. We review this literature because climate change is becoming increasingly important and has implications for poverty. In the second subsection, we review vulnerability studies in which the outcome of interest is not household income or consumption but other measures such as nutrition, assets, and some aggregate-level outcomes.

3.1 Vulnerability to Climate Change

There is now a wide agreement among scientists that the rapid increases in the atmospheric concentration of greenhouse gases, such as carbon dioxide and methane, since the industrial revolution are largely anthropogenic. The impacts of the increased concentration of greenhouse gases are already apparent. The global surface temperature is estimated to have risen by more than 0.5 degrees Celsius over the last century and the global average sea level rose at an average rate of 1.8 millimeters per year between 1961 and 2003 (Solomon et al. 2007). Even if stringent climate policies are implemented immediately, global mean surface temperature is expected to rise in years to come.

Climate change affects, among others, agriculture, forestry, water resources, human health, and industry. The impact of climate change is complex because it varies across regions and may be positive or negative. For example, in Asia, crop yields could increase up to 20 percent in East and Southeast Asia, whereas they could decrease up to 30 percent in Central and South Asia by the mid twenty-first century (Parry et al. 2007). Although it is beyond the scope of this chapter to discuss specific impacts of climate change,¹⁴ it is evident that climate change affects various aspects of social, economic, and ecological systems, and may have profound impacts on the lives of the poor. Therefore, it is useful to review studies on vulnerability to climate change in relation to poverty.

To understand the relationship between vulnerability to poverty and vulnerability to climate change, Adger (2006) provides a useful overview of these two strands of literature. He argues that the idea of vulnerability to poverty originates from the school of thought that views vulnerability as absence of entitlements (for example, Sen 1981). On the other hand, the roots of studies on vulnerability to climate change are the analysis of vulnerability to hazards (for example, Burton et al. 1993). Adger (2006) suggests that the conceptualization and measurement of vulnerability to poverty discussed above complements the hazard-based approach. While there is a dearth of studies linking climate change and vulnerability to poverty,¹⁵ this is potentially a fruitful area of research.¹⁶

To bring insights in the study of vulnerability to climate change to the context of vulnerability to poverty, it is useful to consider the following four dimensions to describe a vulnerability situation (Fussel 2007): system, attribute of concern, hazard, and temporal reference. All of these are important for considering the impact of climate change on poverty and its policy implications. They also offer potentially fruitful areas of research.

First, the system of analysis, which may be, for example, a population group, an economic sector, or a geographic region, has important policy

implications. This is because a policy that makes a particular group less vulnerable may make other groups more vulnerable. Therefore, the analysis of vulnerability to poverty discussed in the previous section may become misleading if the system, or the population relevant for the analysis, is not appropriately identified.

Second, the valued attribute of the vulnerable system threatened by its exposure to a hazard is also important. In the previous section, the attribute of concern was taken as consumption, but it may include other dimensions such as nutrition.¹⁷ We briefly discuss vulnerability in nutrition outcome in the next subsection.

Third, it is also important to clarify what type of hazard – or potentially damaging physical event, phenomenon, or human activity that may cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation (United Nations Office for Disaster Risk Reduction 2004) – is being considered. Most of the studies on vulnerability to poverty presented in the previous section abstract from specific hazards and analyze vulnerability from the perspective of stochastic consumption. Because appropriate policies to reduce or remove vulnerability depend on the specific hazards at issue, more research is needed to identify the link between various hazards that climate change brings about and poverty.

Finally, temporal reference is particularly relevant in the context of climate change. Most of the studies mentioned in the previous section only have a rudimentary treatment of time with only one or two periods in their models. However, intertemporal tradeoffs are fundamentally important for mitigation of climate change. Temporal reference is also important from the perspective of adaptation, because long-term impact of climate change depends on how the economy and society are able to respond. Therefore, a careful examination of the relevant time frame is essential for appropriately dealing with vulnerability to poverty due to climate change.

3.2 Vulnerability in Non-monetary Outcomes

The studies discussed in the previous section are based primarily on an individual-level money-metric outcome measure such as consumption per capita. However, vulnerability can be analyzed by other observable outcomes. First, there is a critical relationship between vulnerability and asset ownership. As Moser (1998) argues, analyzing vulnerability involves identifying not only the threat but also the 'resilience,' or the responsiveness in exploiting opportunities and in resisting or recovering from the negative effects of a changing environment. Therefore, the assets and entitlements available to individuals and households are critically related

to vulnerability. This point is consistent with the theoretical argument put forward by Elbers and Gunning (2003).

Chiwaula et al. (2011) propose a variant of the expected poverty approach discussed in the previous section, which includes asset indicators in an income regression. They decompose expected poverty into structural-chronic (that is, vulnerable and mean consumption more than one standard deviation below the poverty line), structural-transient (that is, vulnerable and mean consumption less than one standard deviation below the poverty line), and stochastic-transient (that is, not vulnerable and mean consumption above the poverty line). In their empirical application to Cameroon and Nigeria, they find that the majority of households are vulnerable for structural reasons. That is, their asset base is so low that even if favorable production conditions would occur or risk-reducing measures would be introduced they are unlikely to be able to move out of poverty permanently. Their study underscores the importance of building productive assets to increase income and decrease the variance of income to escape from the threat of poverty.

It is also possible to analyze vulnerability with nutritional outcomes. Using six nutritional outcomes, Stillman and Thomas (2008) examine the effect of dramatic income change on nutritional well-being during the crisis in 1998 in the Russian Federation. They test whether young women and the elderly are particularly vulnerable to worsening economic conditions and find that there is no significant difference in nutritional intakes between males and females nor across different demographic groups.

The discussion of vulnerability so far has been mainly concerned with vulnerability at the individual or household level. However, it is also useful to consider vulnerability at a more aggregate level. For example, consider vulnerability from trade openness (Montalbano 2011). While trade openness has been generally found to be beneficial to economic growth, it can adversely affect the lives of the poor, for example, when the prices of goods that the poor consume increase or when prices of goods that the poor produce decrease. Further, trade openness can increase the volatility of prices of certain goods.

The impact of trade openness on vulnerability to poverty can be analyzed at the household level, because it would manifest itself in relative prices and their volatilities. However, it is also useful to consider vulnerability from openness to trade at the country level. Briguglio et al. (2009), for example, define economic vulnerability as the exposure of an economy to exogenous shocks arising out of economic openness. They then present an index of vulnerability and resilience, where the latter is defined as the policy-induced ability of an economy to withstand or recover from the effect of shocks.

Montalbano (2011) argues that a meso approach, which is between household and country levels, is important for holistic welfare analysis of the risks induced by trade liberalization. Montalbano (2011) identifies two main strands of the literature: the 'vulnerability of subnational regions approach' and the 'industry-level volatility approach'. The former strand includes Naudé et al. (2009), who construct a local vulnerability index using principal component analysis for 354 magisterial districts in South Africa. The latter includes Koren and Tenreyro (2007), who decompose the volatility of gross domestic product growth into various sources and quantify their contributions to volatility. According to their findings, as countries develop, their productive structure moves from more volatile to less volatile sectors.¹⁸

4 DISCUSSION

In this chapter, we have reviewed vulnerability studies primarily in relation to poverty. While there is some agreement on what characterizes vulnerability across various studies, there is as yet no concept or measurement of vulnerability that is widely accepted. This is true even within the narrowly defined literature on vulnerability to poverty discussed in section 2. As discussed in section 3, there are even larger varieties of concepts of vulnerability originating from different disciplines and traditions.

Therefore, one obvious area of research that arises from this review is further refinement of the vulnerability concept and its measurement, particularly those based on the axiomatic approach discussed in section 2.1. We argue that the measures proposed by Calvo and Dercon (2013) provide an excellent starting point because they satisfy a set of desirable axioms. However, their analytical framework abstracts from the time dimension. It may be fruitful to explicitly incorporate intertemporal tradeoffs, especially when we consider the vulnerability of households to poverty induced by climate change.

This review also indicates that there is still a dearth of empirical studies on vulnerability. This is true for most countries in Asia and elsewhere. One obvious reason for this observation is the lack of high-quality data. While the availability of socioeconomic surveys with a panel structure is rapidly improving, the availability is still limited and most available panel data that could be used for vulnerability analysis contain only a few time periods at best. To seriously evaluate the risk of falling into poverty, a longer and possibly more frequent data collection is desirable.

From the perspective of data availability, the situation surrounding vulnerability studies is somewhat similar to poverty analysis in the early

1980s when there was a lack of relevant high-quality consumption survey data. Just as subsequent expansion of consumption survey data stimulated poverty research, better availability of long panel data is almost sure to stimulate vulnerability research.

Long panel data may also create new areas of research. For example, long panel data would also allow us to consider a distinction between vulnerability to chronic poverty and vulnerability to transient poverty. This distinction may be important because certain negative shocks may be persistent (for example, disability) while others may be transient (for example, diarrhea). This distinction is also important because vulnerability to chronic poverty and vulnerability to transient poverty are likely to require different solutions and different targeting policies.

Besides the lack of long panel data, current surveys often do not contain sufficient information about the shocks that households face to estimate the impact of these shocks on vulnerability. From this perspective, the study by Günther and Harttgen (2009) would be useful. They collect information about important shocks that households face including malaria, tuberculosis, typhoid, cholera, rice pest, swine flu, Newcastle disease, flooding, impassible bridge or road, drought, and cyclones. There may be other shocks such as asset losses, labor market disturbances, harvest failure and civil unrest. Hence, collecting data on some of these and other relevant indicators may prove valuable for the analysis of vulnerability.

The current state of research on vulnerability is also inadequate for designing appropriate policies to deal with vulnerability. As noted earlier, there are some common factors, including education and location, that help to explain vulnerability. However, existing studies provide little guidance on the appropriate choice of policies to reduce or remove vulnerability. Therefore, more research is needed to understand the impact of policy on vulnerability.

There are a number of policies that can potentially reduce individual vulnerability. As Morduch (1999) argues, increasing macroeconomic stability, reining in inflation, securing property rights, improving transport and communications, and creating a stable political environment can go a long way toward reducing the frequency and size of downturns and creating a supportive environment to facilitate private risk-reducing activities. Similarly, risk can be reduced through public health campaigns for immunization and sanitation, civil works projects and, in some cases, price stabilization. Higher incomes and stable employment opportunities further enhance the ability to cope with risk. However, the primary purpose of these policies is not to reduce individual vulnerability and thus they are best judged by other criteria. Therefore, we focus below on several policies that could directly address vulnerability.

First, one can insure oneself by building assets and using them to smooth consumption. Therefore, the saving technology available to individuals is crucial for mitigating vulnerability. Relevant policies for promoting savings include ensuring long-term security of saving and improving convenience Morduch (1999). Providing households with access to more attractive and more diversified assets could improve the functioning of self-insurance Dercon (2002). Note, however, that large negative shocks cannot be easily insured by self-insurance.

Second, provision of microcredit can help those poor who are entrepreneurial but credit-constrained to increase the income and also diversify the sources of income. As a result, it may help them increase the mean income and reduce the variance of income. However, the results of recent randomized control trial studies suggest that the provision of microcredit will not benefit all poor individuals equally. Hence, it is also unlikely to be sufficient to eliminate vulnerability to poverty.

Third, employment-guarantee schemes such as rural public works programs can also help to reduce vulnerability (Morduch 1999). In this type of program, employment is offered to (ideally) anyone who is willing to work for a low wage rate. Under such a scheme, the program is self-targeted. That is, workers would participate only when there is no better option elsewhere. Hence, employment guarantee schemes essentially provide a self-targeted fallback option.

Finally, a well-designed social safety net is likely to help reduce vulnerability. For example, Devarajan and Jack (2007) argue that a simple public insurance scheme that pays a fixed benefit to all households that suffer a negative shock is an effective redistributive instrument of public policy even when there is a well-functioning private insurance market.

The experience in Indonesia during the Asian financial crisis also highlights the potential importance of a social safety net. Dhanani and Islam (2002) find that vulnerability could have worsened in the absence of government intervention, even though some of the social safety-net programs did not appear to work well. Despite its potential usefulness for addressing vulnerability, social protection policies have to be carefully crafted because they may crowd out the existing informal insurance.

To conclude, there are a number of policy options to address vulnerability. However, little is known about the policy impact of specific policies. Further research is needed to better understand the interplay between informal insurance and public policies as well as its impact on vulnerability.

NOTES

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2. Based on the author's search of Econlit on 6 September 2014.
3. In Ligon and Schechter (2003) and various other studies, vulnerability is defined for households and not individuals. Despite the fact that household is often the unit of measurement in surveys by which vulnerability is measured, we chose to use individual as the unit for which vulnerability is defined, because vulnerability may vary even within the household, at least in principle.
4. While Pritchett et al. (2000) require only a zero mean and not symmetry, but this is clearly inappropriate. If an individual at the poverty line receives a small negative shock with a high probability and a large positive shock with a low probability, the probability of falling below the poverty line is higher than 0.5 even when the shock has a zero mean.
5. Note that chronic and transient poverty are typically defined as *ex post* concepts. However, they are treated as *ex ante* concepts here as with vulnerability.
6. Using wage as a welfare variable, Bourguignon et al. (2004) compare the accuracy of estimation of expected poverty based on a repeated cross-sectional data against true-panel data. See also Jha and Dang (2010) discussed below.
7. Duclos et al. (2010) propose alternative measures of chronic poverty and transient poverty.
8. Then, if each period is an independent trial and the observation period is arbitrarily long, vulnerability and total poverty make no practical difference despite the fact that they are respectively *ex ante* and *ex post* concepts. Further, we can also obtain an arbitrarily accurate estimate of $E[c]$.
9. We require $1 - d \geq p' \geq 0$, which was not explicitly required in Calvo and Dercon (2005, 2013), to ensure that the probability for the l -th component after the transfer is still on a unit interval.
10. The possibility of equality was not included in Calvo and Dercon (2005, 2013) presumably because it is a trivial case. We include it here to be complete. It should be noted that \bar{c} can be a constant even when c is random. This occurs if consumption is always above the poverty line.
11. Dutta et al. (2011) use income instead of consumption. We use consumption to be consistent with the rest of the paper.
12. Using our notations, the axiom of independence requires $v(z, c_a, \mathbf{p}) \leq v(z, c_b, \mathbf{p}) \Rightarrow v(z, c_a + d1_k, \mathbf{p}) \leq v(z, c_b + d1_k, \mathbf{p})$ for $d > 0$ and $1 \leq k \leq K$.
13. It is also possible to argue that the additive decomposability is a desirable property for a social measure of vulnerability. Dutta and Mishra (2013) derive a social measure of vulnerability from a set of axioms that includes the axiom of decomposability.
14. See Parry et al. (2007) for a detailed description of the impacts that have already been observed and are likely to occur under various scenarios.
15. To the best of our knowledge, Fujii's Chapter 5 in this volume is currently the only study that directly links future climate change to vulnerability to poverty based on a household-level data set.
16. Incidentally, the Fifth Assessment Report by the Interregional Panel on Climate Change (IPCC) Working Group II, which focuses on vulnerability and adaptation, has a new chapter on 'livelihoods and poverty' (see IPCC 2014).
17. It may be useful to consider a composite index to describe vulnerability to climate change. Brooks et al. (2005) construct a vulnerability index as a combination of various health, education and governance indicators. According to their index, the most vulnerable countries are nearly all situated in sub-Saharan Africa.
18. See also Naudé et al. (2009) for additional discussion on vulnerability in non-monetary outcomes.

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