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POVERTY, VULNERABILITY, AND REFERENCE-DEPENDENT UTILITY

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The numerous proposed measures of multi-period poverty and vulnerability have until now not taken into account the insights from behavioral economics. In this paper we argue that recent evidence on individuals' decision making is of high relevance for the measurement of poverty when switching from a static and certain to a dynamic and uncertain framework. Building on reference-dependent utility we propose new measures of both (perceived) multi-period poverty and vulnerability, where the poverty status of an individual is a function not only of (expected) consumption levels but also of (expected) losses and gains in consumption. We demonstrate the implications of the proposed measures with a small illustrative example.

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> An object at a given temperature may be experienced as hot or cold to the touch depending on the temperature to which one has adapted. The same principle applies to non-sensory attributes such as health, prestige, and wealth. The same level of wealth, for example, may imply abject poverty for one person and great riches for another—depending on their current assets. (Kahneman and Tversky, 1979, p. 277)

1. INTRODUCTION

In recent years, the research agenda on poverty in developing countries has not only moved beyond money-metric to multidimensional measures of poverty (e.g., Sen, 1985, 1999) but has also increasingly noticed the importance of moving from a static to a dynamic and from a certain to an uncertain framework of well-being. This research acknowledges (i) that the currently observed well-being

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of a given individual might not necessarily be a good proxy of his future and/or past well-being, and (ii) that risk and uncertainty—which is particularly high in developing countries—should be incorporated into measures of poverty. This research has led to numerous definitions and measurements of vulnerability—incorporating the notion of uncertainty—and multi-period poverty—incorporating the notion of time.[1]

Despite conceptual differences between existing vulnerability and multi-period poverty measures, most approaches are based on, or can be interpreted within, a classical framework with a utility function that represents diminishing marginal utility of consumption. The classical framework has long been used not only to analyze individuals' decision making but also individuals' well-being; either based on the assumption that experienced utility is closely linked to decision utility or because desirable axioms for vulnerability and poverty analysis led to such measures. Over the last decades, experimental findings have, however, questioned whether diminishing marginal utility can sufficiently describe observed decisions under certainty and uncertainty. To improve traditional models of decision making, the insights of behavioral economics have long been incorporated, which might also provide new perspectives for poverty measures over time and under uncertainty (Dercon, 2005, 2007).

Concerning decisions under uncertainty, Kahneman and Tversky's (1979) prospect theory has become the most popular alternative to standard expected utility theory. Important features that distinguish it from the classical approach are "reference dependence," "loss aversion," "diminishing sensitivity," and "subjective decision weights." Reference dependence refers to the fact that an individual's perception of any outcome depends not only on the absolute evaluation of that outcome but also on the comparison of that outcome to a reference level. Loss aversion describes the phenomenon that individuals dislike losses to a specific reference level more than they like same sized gains to that reference level. Diminishing sensitivity means that the marginal impact of both, gains and losses, decreases with size. Last, subjective decision weights describe the tendency of people to perceive the probabilities of risky outcomes in a non-linear way. Tversky and Kahneman (1991) further applied their concept of reference-dependent preferences to risk-less decisions.

Reference dependence and loss aversion have been empirically verified in both industrialized and developing countries (e.g., Schechter, 2007; Yesuf and Bluffstone, 2009; Harrison *et al.*, 2010; Gheyssens and Günther, 2012). Moreover, reference dependence and loss aversion have been found for both decisions under certainty—typically in trading goods experiments (e.g., Kahneman *et al.*, 1990, 1991)—and decisions under uncertainty—typically in experiments on choice over risky gambles (e.g., Kahneman and Tversky, 1979; Barberis *et al.*, 2006). In contrast, diminishing sensitivity in losses (Gheyssens and Günther, 2012) and subjective decision weights (Humphrey and Verschoor, 2004; Delavande *et al.*, 2010) have not been experimentally verified for poor

[1]Empirical applications of vulnerability and multi-period poverty often lead to similar results, because past consumption experiences are used for both measures. Theoretically, however, vulnerability and multi-period poverty are distinct concepts. We therefore treat them separately throughout the paper.

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populations. Given its empirical underpinning, we argue that both reference dependence and loss aversion should be incorporated in measures of poverty over time and under uncertainty. If recent experimental studies have shown that preferences toward risky and certain outcomes can be better explained by reference-dependent utility models than by the classical approach, vulnerability and dynamic poverty measures should be extended by the insights from this latest evidence.

Moreover, from an axiomatic perspective, loss aversion nicely captures the broad consensus of policy makers and researchers that vulnerability measures should be specifically concerned about the impact of downside risks on individuals' well-being. For example, the *World Development Report* (World Bank, 2001) states that "vulnerability measures the resilience against a shock—the likelihood that a shock will result in a decline in well-being." Calvo and Dercon (2013) define vulnerability as "exposure to downside risks." Similarly, when moving from a static to a dynamic assessment of poverty, reference-dependent utility can capture *path dependency*, which has recently been proposed in various forms by several studies on multi-period poverty (e.g., Hojman and Kast, 2009; Hoy and Zheng, 2011; Bossert *et al.*, 2012; Mendola and Busetta, 2012). Reference-dependent utility models provide an empirically validated framework of how the *history* or *path* of consumption can be incorporated into dynamic poverty assessments.

Last, various empirical studies have already emphasized the importance of reference points and losses for individuals' (perceived) well-being. For example, D'Ambrosio and Frick (2012) find that current subjective well-being is dependent not only on current income but also on past incomes. They further find in a set of regressions that a previous income loss has a 15 times larger (negative) impact than a previous income gain on a person's reported current well-being. Kanbur (2001) notes that the often observed difference in measured *decreases* in poverty (by economists) and perceived *increases* in poverty (by local NGOs) might be due to aggregate improvements in poverty, but with decreasing incomes for some groups. A similar argument is brought forward by Herrera *et al.* (2006), who argue that the often observed difference between temporal measures of subjective and monetary poverty can partly be attributed to different aspiration levels and whether individuals' income is moving upward or downward.

Based on these different strands of literature and reasoning, we theoretically incorporate the experimental evidence on decision making under certainty and uncertainty into Chakravarty's (1983) utility-based static poverty measure to obtain new and simple measures of multi-period poverty and vulnerability. The suggested measure of (perceived) multi-period poverty allows the incorporation of path dependency, which seems particularly important when moving from a static to a dynamic framework. The proposed vulnerability measure will better reflect the negative impact of downside risks on individuals' (perceived) vulnerability. We suggest the term *perceived* to denote that our measure is built on a utility function that is based on experimental and empirical evidence on individuals' preferences. The proposed measures will be applied to various consumption trajectories and compared with a selected sample of other recently proposed dynamic poverty and vulnerability measures (Jalan and Ravallion, 1998; Pritchett *et al.*, 2000;

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Ligon and Schechter, 2003; Calvo and Dercon, 2009; Foster, 2009; Bossert *et al.*, 2012; Calvo and Dercon, 2013). In this paper we propose a measure of individual multi-period poverty and vulnerability and leave a discussion of an aggregate measure of poverty over time and under uncertainty incorporating reference dependence to other research (see, e.g., Dutta *et al.*, 2011; Jäntti *et al.*, 2013). In other words, we are interested in the extent of multi-period poverty and vulnerability of certain individuals (or households), and not of a group of individuals (or households).

The paper is structured as follows. In Section 2 we give a brief description of the concept of multi-period poverty and vulnerability and a selection of recently proposed approaches. Section 3 introduces a model of reference-dependent utility. Section 4 proposes new measures of multi-period poverty and vulnerability based on reference-dependent utility. Section 5 discusses the properties of our new measures and relates them to other measures of multi-period poverty and vulnerability. Last, the new measures will be illustrated with a small numerical example in Section 6. Section 7 concludes and gives an outlook for further research.

2. Multi-Period Poverty and Vulnerability

Until very recently, poverty of households has typically been measured using cross-sectional data on consumption expenditures over a relatively short period of time. This static picture of poverty has been regarded as a proxy for the well-being of households. A household's observed poverty status, which is a one-time measure of a household's well-being, is, however, not a convincing approach to a household's longer-term well-being for two main reasons. First, the current consumption level might be a bad indicator of past or future consumption and hence poverty. Second, traditional poverty assessments do not provide much information about the impact of risks and uncertainty on the welfare status of a household. It has, hence, been argued that it is critical to go beyond an assessment of who is currently poor to an assessment of the poverty dynamics of households.[2]

Two separate, but indeed very closely related, strands of literature have therefore emerged: the measurement of multi-period poverty and vulnerability. In contrast to static poverty measures, multi-period poverty measures incorporate a time dimension whereas vulnerability approaches aim to include the notion of future uncertainty into current poverty analysis. Since both concepts are rather new and have data requirements that go way beyond the data necessary to estimate static poverty, no consensus has yet emerged as to how to analyze multi-period poverty and vulnerability. In the following section, we will briefly review a (non-comprehensive) list of the most cited multi-period poverty and vulnerability indices that have been proposed in the last few years.

[2]Note that the welfare dynamics of the poor depend on two elements: the probability/frequency and severity of shocks, and the strength of the insurance mechanisms against those shocks. If households had recourse to perfect insurance it would be sufficient to measure static poverty. But several studies (see, e.g., Townsend, 1995; Udry, 1995) have shown that households in developing countries are only imperfectly insured, which leads to high income and consumption fluctuations.

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2.1. *Measures of Multi-Period Poverty*

Denote the experienced consumption stream by $\bar{x} = (x_1, x_2, \ldots, x_t, \ldots, x_T)$ with consumption in time period t $x_t \geq 0$ $\forall$ $t \in \{1, 2, \ldots, T\}$ and $T \in \mathbb{N}$. Multi-period poverty $M(\cdot)$ is measured in $T + 1$.

Among the first approaches to measuring multi-period poverty are measures of chronic and transient poverty. By analyzing historical consumption variability in and out of poverty, those measures distinguish between the chronically poor and the transient poor. The first two measures that have evolved are the "spells" approach (e.g., McKay and Lawson, 2003) and the "component" approach (e.g., Jalan and Ravallion, 1998).

The spells approach defines households as chronically poor who have always been poor, i.e. whose per capita household consumption has been below the poverty line in all observed points in time. The transient poor are those who have only temporarily been poor. In contrast, the component approach distinguishes permanent (average) consumption of a household from temporary variations in household consumption to derive a chronic and transient component of poverty for each single household. More formally, chronic poverty is defined as

$$(1) \qquad P^C(\bar{x}, z) = \left(\frac{z - \frac{1}{T}\sum_{t=1}^{T} x_t}{z} \right)^{\alpha},$$

where z is the poverty line, $\alpha > 1$ is a measure of "increasing cost of hardship" (Calvo and Dercon, 2009). The mean of consumption over all observed time periods T is set equal to the poverty line if $\frac{1}{T}\sum_{t=1}^{T} x_t > z$. Total multi-period poverty is defined as

$$(2) \qquad M_1(\bar{x}, z) = \frac{1}{T}\sum_{t=1}^{T} \left(\frac{z - \hat{x}_t}{z} \right)^{\alpha},$$

where $\hat{x}_t$ is consumption in time period t with all consumption $x_t > z$ set equal to the poverty line z. Transient poverty is the difference between total multi-period poverty and chronic poverty:

$$(3) \qquad P^T(\bar{x}, z) = M_1(\bar{x}, z) - P^C(\bar{x}, z).$$

Foster (2009) and Calvo and Dercon (2009) have developed further measures of (chronic) multi-period poverty, based on the Foster *et al.* (1984) measures of poverty (henceforth FGT) but extended to a time dimension. Foster (2009) proposes

$$(4) \qquad M_2(\bar{x}, z) = \frac{1}{T}\sum_{t=1}^{T} \left(\frac{z - \hat{x}_t}{z} \right)^{\alpha} \cdot 1_{\left[\left(\sum_{t=1}^{T} 1_{\{x_t < z\}}\right) \geq \beta\right]},$$

where the first part is equivalent to the FGT measures of poverty. The second term is an indicator function which takes the time dimension into account,

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introducing a "duration line" β in addition to a poverty line z. This term simply takes the value 1 whenever the household has been poor for at least β periods of time, else the term takes the value 0 and the household is not considered as poor.[3]

Calvo and Dercon (2009) suggest the following measure

$$M_3(\bar{x}, z) = \frac{1}{T}\sum_{t=1}^{T}\beta^{T-t}\left(\frac{z-\hat{x}_t}{z}\right)^{\alpha}, \tag{5}$$

where $\beta > 0$ allows for some time adjustment and represents a discounting parameter that values present time spells less (if $\beta > 1$), equally (if $\beta = 1$), or more (if $0 < \beta < 1$) than past time spells. Calvo and Dercon (2009) do not conclude which β should be preferred, i.e. whether all poverty time periods should be weighted equally or if current or past time periods should be more emphasized.

While Foster (2009) and Calvo and Dercon (2009) have added a time dimension, with Foster (2009) explicitly ruling out path dependency and Calvo and Dercon (2009) allowing for path dependency but without advocating a particular form, more recent studies have explicitly introduced path dependency into measures of longitudinal poverty (e.g., Hoy and Zheng, 2011; Bossert *et al.*, 2012; Mendola and Busetta, 2012). For example, Bossert *et al.* (2012) define multi-period poverty as

$$M_4(\bar{x}, z) = \frac{1}{T}\sum_{t=1}^{T}\beta^{t}\left(\frac{z-\hat{x}_t}{z}\right)^{\alpha}, \tag{6}$$

where β^t is the length of consecutive periods with positive (per-period) poverty, i.e. $\left(\frac{z-\hat{x}_t}{z}\right)^{\alpha} > 0$, to which period t belongs: poverty at time t is multiplied by the number of poverty spells around t. As a result, poverty spells that are part of persistent poverty are weighted higher than poverty spells that are separated by non-poor periods. An axiomatic foundation of a related measure has been proposed by Hoy and Zheng (2011) and a variant of (6) was considered by Mendola and Busetta (2012) and Dutta *et al.* (2013).

2.2. *Measures of Vulnerability*

In contrast to multi-period poverty measures, which aim to analyze poverty over a past time horizon, vulnerability measures aim to incorporate future consumption uncertainty into the well-being of individuals at time t. Let $\tilde{x}_{t+1}$ be the random future consumption variable where future consumption outcomes $\underline{x}_{t+1} = (x_{1t+1}, x_{2t+1}, \ldots, x_{it+1}, \ldots, x_{It+1})$, with $x_{it+1} \geq 0\ \forall\, i \in \{1, 2, \ldots, I\}$ states of the world and $I \in \mathbb{N}$, occur with corresponding probabilities $\underline{p}_{t+1} = (p_{1t+1}, p_{2t+1}, \ldots, p_{it+1}, \ldots, p_{It+1})$, with $p_{it+1} \in [0, 1]$ and $\sum_{i=1}^{I} p_{it+1} = 1$. Vulnerability $V(\cdot)$ is measured before period $t+1$, i.e. at t. In order to simplify notation in the context of vulnerability, we henceforth omit the time subscript so that $\tilde{x}$ denotes random future consumption.

[3]Throughout the paper we use α to capture diminishing marginal utility or "increasing cost of hardship" and β to capture different kinds of time sensitivity.

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The approach that has probably become most prominent is to define vulnerability as poverty risk, or the probability that a household's future consumption lies below the poverty line. Assuming that consumption is log-normally distributed, the probability of a household falling below the poverty line at any point in time can be estimated using the (expected) mean and variance of log consumption:

$$V_1(\tilde{x}, z) = P(\ln x < \ln z) = \Phi\left(\frac{\ln z - \mu_{\ln \underline{x}}}{\sqrt{\sigma^2_{\ln \underline{x}}}}\right), \tag{7}$$

where $\Phi(\cdot)$ denotes the cumulative density of the standard normal distribution function, z denotes the poverty line, $\mu_{\ln \underline{x}}$ is the mean of all possible log future consumption states, and $\sigma^2_{\ln \underline{x}}$ is their variance (Pritchett *et al.*, 2000; Chaudhuri, 2003). Although intuitively easy to understand, this measure ignores the potential downside impact of uncertainty on individuals' well-being. Moreover, this measure does not account for the magnitude of shortfalls below the poverty line (only for the "general risk" to fall below the poverty line). Small shortfalls below the poverty line are given the same weighting as large shortfalls below the poverty line. Christiaensen and Subbarao (2005) take into account this last critique and propose an improved measure.

An alternative approach is to define vulnerability as low expected utility. In contrast to expected poverty, such a utility framework explicitly takes into account the risk preferences of individuals and their impact on individuals' well-being. Within expected utility theory, risk aversion, i.e. an aversion to mean preserving spreads, corresponds to a concave utility function (Rothschild and Stiglitz, 1970). Based on this utility function, Ligon and Schechter (2003) propose to measure vulnerability with respect to the utility derived from some level of certain-equivalent consumption above which we would *not* consider households as vulnerable. We can then write vulnerability $V_2(\cdot)$ as

$$V_2(\tilde{x}, z) = u(z) - \mathbb{E}[u(\tilde{x})], \tag{8}$$

where $u(z)$ is the utility derived from a certain-equivalent minimum consumption and $\mathbb{E}[u(\tilde{x})]$ is the expected utility from uncertain future consumption $\tilde{x}$. Note that z is analogous to the choice of a poverty line in poverty measures. The utility function $u(\cdot)$ is weakly concave with $u'(\cdot) > 0$ and $u''(\cdot) \leq 0$. We can further decompose vulnerability $V_2(\cdot)$ into

$$V_2(\tilde{x}, z) = [u(z) - u(\mathbb{E}[\tilde{x}])] + [u(\mathbb{E}[\tilde{x}]) - \mathbb{E}[u(\tilde{x})]], \tag{9}$$

where $u(\mathbb{E}[\tilde{x}])$ is the utility of expected consumption and $\mathbb{E}[u(\tilde{x})]$ the expected utility of consumption. The first part of equation (9) refers to poverty-induced vulnerability, i.e. the vulnerability that is caused by low expected consumption levels, and the second part to risk induced vulnerability, i.e. the vulnerability that is caused by high income uncertainty. This decomposition emphasizes that the predicament of the poor is not only about insufficient consumption, but also about insecurity and risk.

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Last, Calvo and Dercon (2013) have proposed to measure vulnerability as one minus the expected value of the (risk attitude-weighted) ratio of a household's consumption to the poverty line:

$$V_3(\tilde{x}, z) = 1 - \mathbb{E}\left[\left(\frac{\hat{\tilde{x}}}{z}\right)^{\alpha}\right], \tag{10}$$

where $\hat{\tilde{x}}$ is a random consumption variable, which is set equal to the poverty line z whenever its realization $x_i > z$, and α is a parameter of risk aversion with $0 < \alpha < 1$. $V_3(\cdot)$ thus takes any value between zero and one. Whereas the approach of Calvo and Dercon (2013) is axiomatic and the approach of Ligon and Schechter (2003) is explicitly based on a utility framework, both measures are built on expected utility theory. The major difference between the two measures is that Calvo and Dercon (2013) equalize any consumption above the poverty line z to the poverty line to focus on downside risks and Ligon and Schechter (2003) allow outcomes above the poverty line to compensate for consumption outcomes below the poverty line.

Neither the theoretical nor the empirical literature has yet settled on a preferred measure to analyze multi-period poverty and/or vulnerability, although some preliminary research has been undertaken to compare the different approaches to measure multi-period poverty (Calvo and Dercon, 2009) and vulnerability (Hoddinott and Quisumbing, 2003; Calvo and Dercon, 2013). We argue that it might be instructive to extend both concepts, multi-period poverty and vulnerability, with the insights from prospect theory with regard to reference dependence and loss aversion.

3. Reference-Dependent Utility

Starting with Kahneman and Tversky's (1979) prospect theory, models of reference-dependent utility have been extended and modified over the last decades. In the following we draw on the reference-dependent utility model of Köszegi and Rabin (2006, 2007) in which overall utility $RU(\cdot)$ depends on pure consumption utility $u(\cdot)$ as well as on gain–loss utility $\mu(\cdot)$, which captures how the consumption utility $u(\cdot)$ compares to the utility of a reference consumption level $u(r)$:

$$RU(F|G) = \int u(x) + \iint \mu(u(x) - u(r))dF(x)dG(r). \tag{11}$$

The consumption outcome $x \in \mathbb{R}^+$ and the reference point of consumption $r \in \mathbb{R}^+$ are independently drawn from the probability distributions F and G, respectively. This captures the notion that the evaluation of all possible consumption outcomes is based on comparing each of them to all possibilities of the reference point. The comparison itself is evaluated by the gain–loss function $\mu(\cdot)$. Setting $u(x) - u(r) \equiv y \in \mathbb{R}$, we impose the following functional form assumptions on $u(\cdot)$ and $\mu(\cdot)$:

A1 ***Consumption utility is weakly concave and normalized:***
$u'(x) > 0$ and $u''(x) \leq 0$ $\forall x \in \mathbb{R}^+$ and $u(0) = 0$.

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A2 ***Gain–loss utility is piecewise linear:***
$\mu(y) = \eta y$ *if* $y \geq 0$ *and* $\mu(y) = \lambda\eta y$ *if* $y < 0$, *with* $\eta \geq 0$ *and* $\lambda \geq 1$.

A1 imposes the standard assumption of weakly concave consumption utility. The specification of piecewise linear gain–loss utility in A2 is common in the literature on reference-dependent preferences. The phenomenon of loss aversion is captured by the loss aversion parameter λ ($\lambda = 1$ means no loss aversion). η can be interpreted as the weight attached to the gain–loss utility (with $\eta = 0$, or $\lambda = 1$ and fixed r, equation (11) reduces to expected utility theory).

Note that A2 abstracts from the prospect theory feature of diminishing sensitivity in the gain–loss function. The specification of reference-dependent utility in (11) further abstracts from non-linear probability weighting. While the empirical evidence on reference dependence and loss aversion is overwhelming, neither diminishing sensitivity nor non-linear probability weighting has been empirically shown for developing countries (Humphrey and Verschoor, 2004; Delavande *et al*., 2010; Gheyssens and Günther, 2012). Since utility is determined by comparing possible outcomes to a reference point, it is crucial how this point of comparison is defined. Probably the best-known reference point assumption in risky and certain choice environments is the status quo (e.g., Kahneman and Tversky, 1979; Tversky and Kahneman, 1991).

A3 ***The reference point is the status quo:***
For utility in period t denoted $RU(F_t|G_t)$, $G_t = F_{t-1}$ *with* $t \in \mathbb{N}$.

In a dynamic context, A3 is reminiscent of assumptions made in the literature on habit formation or, its psychological counterpart, adaptation level theory. It is argued that current consumption is compared to the pre-period's consumption level because individuals get used to a certain level of consumption over time. Hence, any change in consumption to that level is perceived as a gain or a loss. Although this assumption might be relaxed either by an aspiration level that is shaped by more than just one past period (see, e.g., Gilboa and Schmeidler, 2001) or by different strengths of habit formation, it is an assumption that has previously been used (see, e.g., Easterlin, 2001; Rayo and Becker, 2007).[4,5]

A3 induces path dependency over multiple periods, which has recently been emphasized as a desirable property for multi-period poverty analysis (see, e.g., Hoy and Zheng, 2011; Bossert *et al*., 2012; Mendola and Busetta, 2012). When measuring vulnerability, A3 provides a utility-based foundation for the importance of the current state for the evaluation of a risky consumption prospect as emphasized by Dutta *et al*. (2011, p. 747): "A richer person, who has never experienced poverty, may also find it much harder to cope once they are in poverty than someone who has experienced poverty before. Hence for similar levels of future

[4]In addition, one could also think of a reference point that is not only intra- but also interdependent among individuals within a reference group (see, e.g., Vendrik and Woltjer, 2007).

[5]As in Köszegi and Rabin (2006, 2007), another popular specification assumes recent expectations as the reference point. This is equivalent to the status quo assumption if an individual expects to maintain the status quo and consumption changes come as a surprise. However, if these changes are rationally expected, the reference distribution is equal to the outcome distribution. With rational expectations as the reference point, i.e. $G_t = F_t$, we would obtain the same multi-period poverty measurement as with standard utility theory and any form of path dependency would be eliminated. Similarly, for vulnerability the importance of the current state would disappear. Given that we consider both properties as desirable, we propose the status quo as a reference point.

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income below the poverty line, a richer person may be relatively more vulnerable." In combination with loss aversion A3 incorporates the negative impact of downside risk into measures of vulnerability in a natural way.

4. A New Measure

In this section we propose new multi-period as well as vulnerability measures that build upon the well-known static poverty measure of Chakravarty (1983). He defines poverty as $P = A\frac{1}{n}\left[\sum_{i=1}^{q} U(z) - U(y_i)\right]$, where n is the number of individuals, $A = 1/(U(z) - U(0)) > 0$ is the coefficient of normalization, and $U(z) - U(y_i)$ is the utility gap which is positive for the poor (q individuals) and non-positive for the non-poor ($n - q$). Transformed into an individual measure we obtain:

$$P_i = A[U(z) - U(y_i)], \tag{12}$$

where $U(z) - U(y_i)$ is the utility gap between the utility from individual i's actual consumption y_i and the utility derived from consumption at the poverty line z. This utility gap is positive for the poor ($U(z) > U(y_i)$) and set at zero otherwise. Instead of using the standard utility function $U(\cdot)$, we base our proposed measures on the reference-dependent utility function $RU(\cdot)$ as described in the previous section and extend equation (12) to a multi-period poverty and vulnerability setting.

4.1. *Perceived Multi-Period Poverty*

Building on Chakravarty (1983) and reference-dependent utility (see Section 3), two possible measures of multi-period poverty can be derived, which we discuss in turn: in each period t, and given the reference point of previous period consumption x_{t-1}, per-period poverty $M_t^1(\cdot)$ is the normalized utility gap of consuming $x_t \geq 0$ instead of consuming at the poverty line $z > 0$. The relevant comparison for an evaluation of gains and losses for both these utilities is the consumption prior to experiencing x_t which is the consumption level of the previous period x_{t-1} (see A3). Since $t = 1, 2, \ldots, T$ we further assume $x_0 = z$ as the reference point for the first period.[6] In other words, the utility gap in each period is measured by comparing consumption in that period to being hypothetically lifted to the poverty line in that period. More formally, $M_t^1(x_t, x_{t-1}, z) = N[RU(z|x_{t-1}) - RU(x_t|x_{t-1})]$ where $RU(z|x_{t-1}) = u(z) + \mu(u(z) - u(x_{t-1}))$ and $RU(x_t|x_{t-1}) = u(x_t) + \mu(u(x_t) - u(x_{t-1}))$. $N = 1/[RU(z|z) - RU(0|0)] = 1/u(z) > 0$ is the coefficient of normalization and is a simple reference-dependent extension of Chakravarty's (1983) normalization. Multi-period poverty is then defined as the average of all per-period poverty measures, i.e. $M^1(\cdot) = \frac{1}{T}\sum_{t=1}^{T} M_t^1$. This leads us to an individual's (perceived) multi-period poverty of

[6]Alternatively, the reference point for the first period could be set at the consumption level of the first period, i.e. $x_0 = x_1$. Using this assumption instead would generate similar but not identical properties as the ones discussed in Section 5. More specifically, monotonicity would hold under $M^1(\cdot)$ if $1 \geq \eta(\lambda - 1)$ and under $M^2(\cdot)$ if $1 \geq \eta\lambda$. Downward path sensitivity would hold unconditionally under $M^2(\cdot)$ and for sufficiently small T under $M^1(\cdot)$ (see Section 5 for a comparison).

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(13) $$M^1(\bar{x}, z) = N\frac{1}{T}\sum_{t=1}^{T}[RU(z|x_{t-1}) - RU(x_t|x_{t-1})],$$

which can be interpreted as the normalized multi-period utility gap.

Instead of determining the utility gap for each period and then averaging it across periods, an alternative is to measure multi-period poverty as the difference between the utility of experienced consumption across all periods and the utility of hypothetically consuming at the poverty line z in all periods. Hence, we compare the utility derived from the actual consumption stream to the utility of the hypothetical consumption stream of always consuming a fixed z, i.e. $z_{t-1} = z_t = z$. Again, the reference point for the gain–loss utility in each period is the consumption of the previous period. We obtain:

(14) $$M^2(\bar{x}, z) = N\frac{1}{T}\sum_{t=1}^{T}[RU(z|z) - RU(x_t|x_{t-1})]$$

(15) $$= 1 - \frac{1}{T}\sum_{t=1}^{T}\frac{RU(x_t|x_{t-1})}{RU(z|z)},$$

which again can be interpreted as a normalized multi-period utility gap. In both measures, having a lower consumption in a certain period increases the utility gap of that period but decreases the utility gap of the next period since the reference point for the next period has decreased. However, in $M^1(\cdot)$ a lower consumption in period t not only decreases $RU(x_t|x_{t-1})$ and increases $RU(x_{t+1}|x_t)$ (as in $M^2(\cdot)$ as well) but additionally increases $RU(z|x_t)$. This effect mitigates the decreasing utility gap effect for the next period.[7]

Based on Chakravarty (1983) we furthermore impose the following focus assumption on both measures:

A4 ***Focus on the multi-period poor:***

(*i*) *Under* $M^1(\cdot)$*: If* $\sum_{t=1}^{T} RU(x_t|x_{t-1}) > \sum_{t=1}^{T} RU(z|x_{t-1})$*, consumption outcomes in all periods are equalized to the poverty line so that* $\bar{x} \equiv (z, z, \ldots, z)$*. Otherwise* $\bar{x} = (x_1, x_2, \ldots, x_T)$.

(*ii*) *Under* $M^2(\cdot)$*: If* $\sum_{t=1}^{T} RU(x_t|x_{t-1}) > \sum_{t=1}^{T} RU(z|z)$*, consumption outcomes in all periods are equalized to the poverty line so that* $\bar{x} \equiv (z, z, \ldots, z)$*. Otherwise* $\bar{x} = (x_1, x_2, \ldots, x_T)$.

A4 equates every consumption outcome to the poverty line if utility from consuming at the poverty line is smaller than the utility from experienced consumption *over all periods*. This assumption (together with $N > 0$) assures that $M^{1,2}(\cdot) = 0$ for the non-poor and $M^{1,2}(\cdot) > 0$ for the poor. Hence, instead of applying "per-period"

[7]As a result, and as discussed in more detail in Section 5.1, for monotonicity to hold, the sufficient condition on the parameter values of loss aversion, i.e. λ, and the weight attached to the gain–loss utility, i.e. η, is stronger for $M^2(\cdot)$ than for $M^1(\cdot)$.

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focus (as, for example, Calvo and Dercon, 2009) we apply an "over-all-periods" focus assumption. However, in the static case (i.e., $T = 1$) A4 is equivalent to the usual focus assumption as proposed by Chakravarty (1983) where consumption is equalized to the poverty line if $x > z$.

Without gain–loss utility, i.e. $\eta = 0$, our proposed measures reduce to existing approaches in the literature. Per-period poverty reduces to $M_t^{1,2}(x_t, z) = 1 - \frac{u(x_t)}{u(z)}$ which is equal to the static Chakravarty (1983) measure given that he imposes $U(0) = 0$. Multi-period poverty reduces to $M^{1,2}(\bar{x}, z) = 1 - \frac{1}{T}\sum_{t=1}^{T} \frac{u(x_t)}{u(z)}$, which is equal to Calvo and Dercon's (2009) intertemporal poverty extensions (with $\beta = 1$) of Chakravarty's (1983) static poverty measure given that we impose $u(x) = x^{\alpha}$ with $0 < \alpha < 1$.

4.2. *Perceived Vulnerability*

Again following Chakravarty (1983), we define individual vulnerability as the normalized utility gap between the utility of consuming at the poverty line $z > 0$ and the utility of risky future consumption $\tilde{x}_{t+1} \equiv \tilde{x}$. As indicated in A3, the reference point is current consumption $x_t \equiv x^0$. Similar to multi-period poverty, there are two approaches as to how to proceed, which we discuss in turn.

For each state of the world $i = 1, 2, \ldots, I$, and given the reference point of current consumption x^0, per-state vulnerability $V_i^1(\cdot)$ measures the normalized utility gap of consuming x_i instead of consuming at the poverty line z, so that $V_i^1(x_i, x^0, z) = N[RU(z|x^0) - RU(x_i|x^0)]$, where $RU(z|x^0) = u(z) + \mu(u(z) - u(x^0))$ and $RU(x_i|x^0) = u(x_i) + \mu(u(x_i) - u(x^0))$. Vulnerability is then further defined as the weighted average of all per-state vulnerability measures, namely $V^1(\cdot) = \sum_{i=1}^{I} p_i V_i^1$. This yields:

$$V^1(\tilde{x}, x^0, z) = N\sum_{i=1}^{I} p_i[RU(z|x^0) - RU(x_i|x^0)] \tag{16}$$

$$= N[RU(z|x^0) - RU(\tilde{x}|x^0)], \tag{17}$$

where $RU(\tilde{x}|x^0) = \sum_{i=1}^{I} p_i u(x_i) + \sum_{i=1}^{I} p_i \mu(u(x_i) - u(x^0))$. A second possible approach is to measure the normalized utility gap over all states of the world of consuming $\tilde{x}$ (and given the current state x^0) as compared to hypothetically consuming z in all states of the world, and given that the current state was also equal to z. Vulnerability is then defined as:

$$V^2(\tilde{x}, x^0, z) = N[RU(z|z) - RU(\tilde{x}|x^0)] \tag{18}$$

$$= 1 - \frac{RU(\tilde{x}|x^0)}{RU(z|z)}. \tag{19}$$

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For a given consumption prospect, a higher current state significantly increases the utility gap under $V^2(\cdot)$, since only $RU(x_i|x^0)$ decreases, whereas this effect is partly mitigated under $V^1(\cdot)$ where both $RU(z|x^0)$ and $RU(x_i|x^0)$ decrease.

Our next assumption equates each future consumption outcome to the poverty line if utility from consuming at the poverty line is smaller than the expected utility from the risky consumption prospect.

A5 ***Focus on the vulnerable:***

(i) Under $V^1(\cdot)$: If $RU(\tilde{x}|x^0) > RU(z|x^0)$, future consumption outcomes in all possible states of the world are equalized to the poverty line so that $\underline{x} \equiv (z, z, \ldots, z)$. Otherwise $\underline{x} = (x_1, x_2, \ldots, x_I)$.

(ii) Under $V^2(\cdot)$: If $RU(\tilde{x}|x^0) > RU(z|z)$, future consumption outcomes in all possible states of the world are equalized to the poverty line so that $\underline{x} \equiv (z, z, \ldots, z)$. Otherwise $\underline{x} = (x_1, x_2, \ldots, x_I)$.

A5 (together with $N > 0$) assures that $V^{1,2}(\cdot) \geq 0$ with $V^{1,2}(\cdot) = 0$ for the non-vulnerable and $V^{1,2}(\cdot) > 0$ for the vulnerable. With deterministic future consumption and without gain–loss utility (i.e., $\eta = 0$), our focus assumption is equivalent to the one already used by Chakravarty (1983).

Without gain–loss utility, i.e. $\eta = 0$, our proposed measures are reminiscent of existing approaches. First, they can be seen as a risk extension of the static and deterministic Chakravarty (1983) poverty measure since then $V^{1,2}(\tilde{x}, z) = 1 - \frac{\mathbb{E}[u(\tilde{x}_t)]}{u(z)}$. Moreover, setting $u(x) = x^\alpha$, $V^{1,2}(\cdot)$ further reduces to $V^{1,2}(\tilde{x}, z) = 1 - \mathbb{E}\left[\left(\frac{\tilde{x}}{z}\right)^\alpha\right]$ which is almost equal to the individual vulnerability measure of Calvo and Dercon (2013). The only difference is the applied focus assumption. While A5 applies focus after the expected utility aggregation over all states of the world, Calvo and Dercon's (2013) measure applies the focus assumption *before*, so that all consumption outcomes in $\tilde{x}$ are equalized to the poverty line in those states of the world where they exceed z. Last, under A5 our proposed vulnerability measures can also be interpreted as normalized versions of the measure of Ligon and Schechter (2003), since the utility gap reduces to $u(z) - \mathbb{E}[u(\tilde{x})]$.

5. Properties of the Proposed Measures

Before turning to a small empirical illustration, we will discuss some properties of our proposed measures. Multi-period poverty and vulnerability measures are a time and risk extension of poverty measures in a static and certain environment. We therefore relate our proposed measures to a set of properties that are generally accepted for static poverty measures: monotonicity, scale invariance, anonymity, transfer, and focus. In the following, we extend these properties to include a time dimension (for multi-period poverty) and a risk dimension (for vulnerability). Proofs for all properties are presented in the Appendix.

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5.1. *Perceived Multi-Period Poverty*

Monotonicity. Monotonicity requires that an increase (decrease) in consumption in a given time period leads to a decrease (increase) of multi-period poverty. The consumption change in period t has two effects on multi-period poverty $M^{1,2}$. First, $M_t^{1,2}$ changes directly, and second, $M_{t+1}^{1,2}$ changes since the reference point has changed. An increase (decrease) of x_t reduces (increases) $M_t^{1,2}$ but it also increases (reduces) $M_{t+1}^{1,2}$. A sufficient condition for monotonicity to hold is that the smallest possible gain (loss) in t is not lower than the largest possible loss (gain) in $t + 1$. With reference-dependent utility, this condition restricts the values of η and λ as expressed in the following.

P1 ***Monotonicity (multi-period poverty):***

(i) Under $M^1(\cdot)$*: For* $\delta > 0$ *and* $t \in \{1, \ldots, T\}$ *we have* $M^1(x_1, \ldots, x_t + \delta, \ldots, x_T; z) \leq M^1(x_1, \ldots, x_t, \ldots, x_T; z)$ *if* $1 \geq \eta(\lambda - 2)$.

(ii) Under $M^2(\cdot)$*: For* $\delta > 0$ *and* $t \in \{1, \ldots, T\}$ *we have* $M^2(x_1, \ldots, x_t + \delta, \ldots, x_T; z) \leq M^2(x_1, \ldots, x_t, \ldots, x_T; z)$ *if* $1 \geq \eta(\lambda - 1)$.

The common experimental finding of "two-to-one loss aversion," i.e. losses looming twice as large as gains (e.g., Kahneman *et al.*, 1991; Tversky and Kahneman, 1991), can be attained in case (*i*). With our specification of reference-dependent utility, overall loss aversion is $L \equiv \frac{1+\lambda\eta}{1+\eta}$. Setting $L \leq 2$ yields $1 \geq \eta(\lambda - 2)$. Hence, the condition for monotonicity to hold under $M^1(\cdot)$ is equivalent to the condition $L \leq 2$. For monotonicity to hold under $M^2(\cdot)$ we need a stronger condition on overall loss aversion since $1 \geq \eta(\lambda - 1) \Rightarrow 1 \geq \eta(\lambda - 2)$. Despite its stronger parameter requirements, other applications of reference-dependent preferences also apply this stronger condition of $1 \geq \eta(\lambda - 1)$ in order to rule out first-order stochastic dominance problems (see, e.g., Herweg *et al.*, 2010; Herweg and Mierendorff, 2013).

Given that our measures satisfy monotonicity, the upper bound of multi-period poverty is reached with zero consumption in every period. Under $M^1(\cdot)$ an individual who always consumes nothing has a multi-period poverty of $\frac{1}{T}[1+\lambda\eta+(T-1)(1+\eta)]$ so that $0 \leq M^1(\cdot) \leq \frac{1}{T}[\eta(\lambda-1)]+1+\eta$ holds. As T goes to infinity the upper bound of $M^1(\cdot)$ converges to $1 + \eta$. Under $M^2(\cdot)$ having always zero consumption leads to a multi-period poverty of $\frac{1}{T}[1+\lambda\eta+T-1]$ so that $0 \leq M^2(\cdot) \leq \frac{1}{T}\lambda\eta+1$. As T goes to infinity the upper bound of $M^2(\cdot)$ converges to 1.

Scale Invariance. Scale invariance specifies that if both the poverty line z and consumption in every single time period $x_t\ \forall\ t \in \{1, \ldots, T\}$, are scaled up or down by a certain factor, the measured multi-period poverty should not change. Due to our utility-based approach, a restriction on $u(\cdot)$ to belong to a specific parametric family of utility functions is needed for scale invariance to hold.

P2 ***Scale invariance (multi-period poverty):*** *For* $\delta > 0$ *and* $t \in \{1, \ldots, T\}$ *we have* $M^{1,2}(x_1, \ldots, x_t, \ldots, x_T; z) = M^{1,2}(\delta x_1, \ldots, \delta x_t, \ldots, \delta x_T; \delta z)$ *if* $u(x) = x^\alpha$ *(with* $0 < \alpha \leq 1$*).*

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The applied restriction on the class of u functions for scale invariance to hold is similar to Chakravarty (1983) and Calvo and Dercon (2009). Further note that $u(x) = x^{\alpha}$ is a special case of A1. $\alpha = 1$ refers to the extreme case where consumption utility is linear instead of concave (i.e. $0 < \alpha < 1$).

Anonymity. With respect to static poverty measures, anonymity means that poverty should be invariant to a permutation of consumption across persons. Similarly, some multi-period poverty measures are invariant to a permutation of consumption across time periods. A multi-period poverty measure based on reference-dependent utility does not satisfy the anonymity property, since each outcome is compared to a status quo reference point which may well be different at different points in time. Although we agree that it should not matter *which* person has a certain consumption level within a society, we think that it matters *when* a certain consumption level occurs for a specific person in a dynamic framework. Moreover, loss aversion can lead to a specific form of path dependency which is described next.

> **P3** ***Downward path sensitivity:*** *With* $x_t < x_{t+1}\ \forall\ t \in \{1, \ldots, T-1\}$ *we have* $M^1(x_1, x_2, \ldots, x_t, \ldots, x_T; z) = M^1(x_T, x_{T-1}, \ldots, x_{T-(t-1)}, \ldots, x_1; z)$ *independently of T, but* $M^2(x_1, x_2, \ldots, x_t, \ldots, x_T; z) \leq M^2(x_T, x_{T-1}, \ldots, x_{T-(t-1)}, \ldots, x_1; z)$ *if T is sufficiently large.*

Because of the asymmetric evaluation of gains and losses, downward consumption paths generate lower utility than corresponding reflective upward paths if T is sufficiently large. This effect leads to downward path sensitivity of $M^2(\cdot)$, but not of $M^1(\cdot)$.[8] $M^2(\cdot)$ is therefore our preferred measure.

Transfer. For static poverty measures, transfer holds if poverty increases when there is a consumption transfer from a poor to a less poor person. For intertemporal poverty measures this means that whenever there is a transfer from a poor time period to a less poor time period, poverty should increase. As already discussed in the context of anonymity and downward path sensitivity, reference-dependent utility crucially depends on how consumption in t compares to consumption in $t-1$. Generally, it is therefore undetermined how a transfer from a poor to a less poor time period changes multi-period poverty. However, for the special case of transfer where, coming from a flat consumption path with the same consumption in every period, some time periods gain and others lose in consumption—without changing the total consumption over all periods—transfer holds strictly in the presence of loss aversion (i.e. $\lambda > 1$ and $\eta > 0$) even if $u''(\cdot) = 0$.[9]

[8]Given that $x_0 \equiv z$, a loss in the first period can occur even for an upward consumption path. By reversing the order of consumption, this loss turns into a lower loss or even gain. The more periods there are, the more advantageous an upward path becomes compared to a downward path. Which T in fact is sufficiently large for downward path sensitivity to hold under $M^2(\cdot)$ heavily depends on the differences in consumption between time periods. Under $M^1(\cdot)$ and independently of T, the described effect is exactly offset by the effect of comparing each consumption outcome to the poverty line (see Appendix, Proof [P3]).

[9]More formally, with $x_1 > x_A \equiv \frac{1}{T}\sum_{t=1}^{T} x_t$ we have $M^{1,2}(x_A, \ldots, x_A; z) \leq M^{1,2}(x_1, \ldots, x_T; z)$. The assumption $x_1 > x_A$ assures that there is at least one consumption loss over time.

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Without reference dependent utility, transfer only holds under strictly decreasing marginal utility, even for this special case.

Focus. For static poverty measures, the focus axiom requires that a consumption change for *individuals* above the poverty line should not have an impact on the level of poverty within a society. Similarly, Foster (2009) or Calvo and Dercon (2009) argue that an increase (decrease) in consumption in a *time period* where consumption is above the poverty line should not have an impact on the measured multi-period poverty of an individual. Our proposed measures of multi-period poverty do not satisfy this property. We argue that, whereas it is straightforward that the measured poverty level within a population should not be affected by the consumption status of the non-poor, the well-being of an individual over time should be affected by the consumption level in all poor and non-poor time periods. Hence, instead of a focus axiom for each period, A4 applies a focus axiom over all periods. This means that the focus axiom still holds at the identification stage, i.e. identifying who is poor and who is not. Hence, the chosen focus axiom retains the original sense of the focus: it was meant as an effort to pay attention to poor individuals, not as a focus on specific periods of their lives. As such our focus assumption can be interpreted as a reference-dependent and multi-period extension of the one proposed by Chakravarty (1983) or as a reference-dependent extension of chronic poverty of the component approach by Jalan and Ravallion (1998).

5.2. *Perceived Vulnerability*

Monotonicity. Monotonicity requires that an increase (decrease) in consumption in any state of the world (weakly) leads to a decrease (increase) of vulnerability. This property is fulfilled by our proposed vulnerability measures.

> **P4** ***Monotonicity (vulnerability):*** *For* $\delta > 0$ *and* $i \in \{1, \ldots, I\}$ *we have* $V^{1,2}(x_1, \ldots, x_i + \delta, \ldots, x_I; \underline{p}; x^0; z) \leq V^{1,2}(x_1, \ldots, x_i, \ldots, x_I; \underline{p}; x^0; z)$.

Since each possible consumption outcome is compared to a fixed reference consumption point and probabilities are not altered, either the loss is strictly reduced (increased) or the gain is strictly increased (reduced) or a loss (gain) becomes a gain (loss). In contrast to our proposed multi-period poverty measures we do not need further requirements on λ and η in order to satisfy monotonicity for $V^{1,2}(\cdot)$. However, the upper bound of the two vulnerability measures differs as well. With monotonicity being satisfied, upper bounds are reached with zero consumption in all states of the world. For $V^1(\cdot)$ an individual with zero consumption in all states of the world (and therefore with probability 1) has a vulnerability of $1 + \eta + \frac{1}{u(z)}\eta[u(x^0)(\lambda - 1)]$ if current consumption is strictly below the poverty line so that $0 \leq V^1(\cdot) \leq 1 + \eta + \frac{1}{u(z)}\eta[u(x^0)(\lambda - 1)]$ if $x^0 < z$. The upper bound is increasing in current consumption, since for a given consumption prospect, the comparison to a higher reference point increases vulnerability. The upper bound of $V^1(\cdot)$ is independent of current consumption if x^0 is (weakly) above the poverty line z.

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$0 \leq V^1(\cdot) \leq 1 + \lambda\eta$ holds if $x^0 \geq z$. In other words, if an individual's consumption is currently already above the poverty line, vulnerability cannot increase for increases in the current state. In contrast, the upper bound of $V^2(\cdot)$ is increasing in the current state throughout, with $0 \leq V^2(\cdot) \leq 1 + \lambda\eta \frac{u(x^0)}{u(z)}$.

Scale Invariance. Scale invariance specifies that if all relevant outcomes, namely current consumption x^0, the poverty line z, and future consumption in each possible state of the world x_i $\forall$ $i = 1, \ldots, I$, are scaled up or down by a certain factor, the measured vulnerability level should not change. This requires a sensible choice of $u(\cdot)$.

> **P5** ***Scale invariance (vulnerability):*** *For $\delta > 0$ and $i \in \{1, \ldots, I\}$ we have $V^{1,2}(x_1, \ldots, x_i, \ldots, x_I; \underline{p}; x^0; z) = V^{1,2}(\delta x_1, \ldots, \delta x_i, \ldots, \delta x_I; \underline{p}; \delta x^0; \delta z)$ if $u(x) = x^\alpha$ (with $0 < \alpha \leq 1$).*

$u(x) = x^\alpha$ is a special case of A1 with $\alpha = 1$ referring to linear consumption utility and with $0 < \alpha < 1$ referring to concave consumption utility. Note that all utility-based vulnerability measures require a restriction on $u(\cdot)$ in order to satisfy scale invariance. Therefore, all measures based on Chakravarty (1983) explicitly or implicitly impose a similar assumption (see, e.g., Calvo and Dercon, 2013; Ligon and Schechter, 2003 use $u(x) = \ln x$ instead).

Anonymity. For static poverty measures, anonymity means that it does not matter which person has a certain consumption level when analyzing poverty: poverty is not sensitive to permutations of personal labels. For vulnerability measures anonymity indicates that it does not matter which state of the world is altered as long as outcomes and probabilities are identical. In other words, it does not matter why a certain consumption prospect might occur.

> **P6** ***Anonymity (vulnerability):*** *For $\delta > 0$, $i, j \in \{1, \ldots, I\}$, $x_i = x_j$, and $p_i = p_j$ we have $V^{1,2}(x_1, \ldots, x_i + \delta, \ldots, x_I; \underline{p}; x^0; z) = V^{1,2}(x_1, \ldots, x_j + \delta, \ldots, x_I; \underline{p}; x^0; z)$.*

Our measure of perceived vulnerability satisfies anonymity since changes in vulnerability can only be caused by changes in the outcome distribution, the reference point, or the poverty line.

Transfer/Risk Sensitivity. For static poverty measures transfer specifies that whenever there is a transfer from a poor person to a less poor person, poverty should increase. In a vulnerability framework, transfer translates into two distinct properties, probability transfer and outcome transfer. In the following we consider each of them in turn. Both are related to risk sensitivity (see Rothschild and Stiglitz, 1970).

Outcome transfer specifies that vulnerability should increase if there is a transfer from a lower to a higher outcome given that the probability of the lower outcome is not smaller than the larger outcome's probability.

> **P7** ***Outcome transfer:*** *For $\delta > 0$, $i, j \in \{1, \ldots, I\}$, $x_i \leq x_j$, and $p_i \geq p_j$ we have $V^{1,2}(x_1, \ldots, x_I; \underline{p}; x^0; z) \leq V^{1,2}(x_1, \ldots, x_i - \delta, \ldots, x_j + \delta, \ldots, x_I; \underline{p}; x^0; z)$.*

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With $u''(\cdot) < 0$, we have $u(x_j + \delta) - u(x_j) < u(x_i) - u(x_i - \delta)$. Compared to an unaltered reference point, this means that the utility gap increase (decrease) in gains (losses) is strictly less than the utility gap decrease (increase) in gains (losses). The asymmetry of the gain–loss function $\mu(\cdot)$ amplifies this effect. So, with a strictly concave u function, outcome transfer holds strictly. With $u''(\cdot) = 0$, we have $u(x_j + \delta) - u(x_j) = u(x_i) - u(x_i - \delta)$. Compared to an unaltered reference point, the utility gap increase is equivalent to the decrease within gains and losses. Then, outcome transfer holds strictly only if $p_i > p_j$. However, if domains change (i.e., moving from gains to losses or vice versa), loss aversion (i.e. $\lambda > 1$ and $\eta > 0$) leads our vulnerability measure to strictly satisfy outcome transfer, even with a linear u function.

Instead of altering outcomes and holding probabilities constant as under the outcome transfer, we can also alter probabilities while holding outcomes constant.

P8 ***Probability transfer:*** *For* $0 < \delta < 1$*,* $i, j \in \{1, \ldots, I\}$*, and* $x_i \leq x_j$ *we have* $V^{1,2}(\underline{x}; p_1, \ldots, p_I; x^0; z) \leq V^{1,2}(\underline{x}; p_1, \ldots, p_i + \delta, \ldots, p_j - \delta, \ldots, p_I; x^0; z)$.

Since probabilities enter linearly into the expected reference-dependent utility evaluation and probability mass increases (decreases) for the worse (better) income, the weight for the smaller (larger) gain (loss) increases so that vulnerability increases. This relationship holds only weakly because if $x_i = x_j$ there is no change in vulnerability.

P7 and P8 considered a transfer with the probability and outcome distribution being fixed, respectively. Allowing both distributions to vary at the same time, we can additionally consider a special case of transfer that is at the heart of measuring vulnerability, comparing a risk-less with a risky situation with the same expected consumption. Making the consumption prospect risky but holding the mean constant strictly increases vulnerability if loss aversion is present (i.e., $\lambda > 1$ and $\eta > 0$).[10] Without reference-dependent utility vulnerability strictly increases in this case if and only if $u''(\cdot) < 0$.

Focus. For static poverty measures, the focus axiom requires that an increase (decrease) in consumption for *individuals* above the poverty line should not have an impact on the level of poverty within a society. In other words, increasing the consumption of non-poor individuals should not alter the poverty of a society. With the focus assumption proposed in A5 this property is satisfied by our proposed vulnerability measures. We think that non-vulnerable individuals should not be able to compensate for vulnerable individuals. However, and in contrast to Calvo and Dercon (2013) and Dutta *et al.* (2011), we think that individual vulnerability should be affected by the consumption level of all, poor *and* non-poor, states, so that an increase (decrease) in consumption in a state of the world where consumption is above the poverty line should decrease (increase) the measured vulnerability of an individual.

[10]More formally, for some $x_i \neq \mathbb{E}[\tilde{x}]$ and $\underline{p}, \underline{p}'$ we have $V^{1,2}(\mathbb{E}[\tilde{x}], \ldots, \mathbb{E}[\tilde{x}]; \underline{p}'; x^0; z) \leq V^{1,2}(x_1, \ldots, x_I; \underline{p}; x^0; z)$. A similar mean-preserving spread is considered by Calvo and Dercon (2013). Dutta *et al.* (2011) use the special case of $p_i = p_j$ in P7 as another mean-preserving spread.

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5.3. *Comparison to Existing Measures*

Table 1 gives an overview of the discussed multi-period poverty and vulnerability measures and the properties they satisfy. Apart from the conventional poverty axioms we add the properties path dependency (second to last column) and reference dependence (last column).

Since our measures are the only ones that are based on reference-dependent utility, reference dependence is only fulfilled by our measures of multi-period poverty and vulnerability. Although not being based on reference-dependent utility, the non-utility based multi-period measure of Hojman and Kast (2009) and vulnerability measure of Dutta *et al.* (2011) also assume some kind of reference dependence, the former in order to obtain downward path sensitivity and the latter in order to emphasize the importance of the current state.

In the context of multi-period poverty, path dependency can take various forms. Calvo and Dercon (2009) induce path dependency via discounting. Bossert *et al.* (2012) achieve path dependency by assuming that consecutive periods of poverty loom larger than non-consecutive periods. In our case, loss aversion implies the specific form of downward path sensitivity for M^2 (and a non-specific form for M^1). Since consumption drops have a higher impact on utility than consumption gains, decreasing consumption over time leads to higher poverty than an increasing consumption path. Table 1 also shows that path dependency in multi-period poverty measures leads to the inability to satisfy the transfer and anonymity axiom. All multi-period measures apply some kind of focus axiom. However, in contrast to all other measures of multi-period poverty in Table 1, our measures apply focus across individuals and not across periods.

With respect to vulnerability, all vulnerability measures satisfy anonymity and transfer (except Pritchett *et al.*, 2000). Except Calvo and Dercon (2013), none of the vulnerability measures satisfies the focus assumption: this enables high consumption states to compensate for low consumption states without ignoring the risk involved. Note that all multi-period poverty and vulnerability measures fulfill scale invariance and monotonicity (under specific parameter restrictions).

6. Empirical Application

Before applying our proposed measures, we need to fully parameterize reference-dependent utility such that monotonicity and scale invariance holds. For this illustrative example we show our proposed multi-period poverty measure M^2 and vulnerability measure V^2. Both measures show the implications of reference-dependent utility and loss aversion more clearly than M^1 and V^1 and are therefore our preferred measures. For simplicity, we assume linear consumption utility, i.e. $u(x) = x$. This means that transfer (for multi-period poverty) and risk sensitivity (for vulnerability) are purely driven by the gain–loss utility function $\mu(\cdot)$. We set $\eta = 1$, giving the same weight to gain–loss utility $\mu(\cdot)$ as to consumption utility $u(\cdot)$. We set $\lambda = 2$ which is the highest possible loss aversion for monotonicity to hold under $\eta = 1$ in a multi-period poverty framework.

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TABLE 1

Properties of Poverty and Vulnerability Measures

	Monotonicity	Scale	Anonymity	Transfer	Focus	Path	Reference
Multi-period poverty measures							
Jalan and Ravallion (1998)	Yes	Yes	Yes	No/Yes[4]	Yes	No	No
Foster (2009)	No/Yes[1]	Yes	Yes	No/Yes[4]	Yes	No	No
Calvo and Dercon (2009)	Yes	Yes	Yes/No[6]	Yes/No[6]	Yes	No/Yes[6]	No
Bossert *et al*. (2012)	Yes	Yes	No	No	Yes	Yes	No
$M^1(\cdot)$	No/Yes[2]	Yes	No	No	No/Yes[5]	Yes	Yes
$M^2(\cdot)$	No/Yes[3]	Yes	No	No	No/Yes[5]	Yes	Yes
Vulnerability measures							
Pritchett *et al*. (2000)	Yes	Yes	Yes	No	No/Yes[5]	–	No
Ligon and Schechter (2003)	Yes	Yes	Yes	Yes	No/Yes[5]	–	No
Calvo and Dercon (2013)	Yes	Yes	Yes	Yes	Yes	–	No
$V^1(\cdot)$	Yes	Yes	Yes	Yes	No/Yes[5]	–	Yes
$V^2(\cdot)$	Yes	Yes	Yes	Yes	No/Yes[5]	–	Yes

Notes: [1]if $\beta \geq 1$; [2]if $1 \geq \eta(\lambda - 2)$; [3]if $1 \geq \eta(\lambda - 1)$; [4]if $\alpha > 1$; [5]across individuals; [6]if $\beta \neq 1$.

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6.1. *Multi-Period Poverty*

In a first step we apply the proposed measure of (perceived) multi-period poverty to various consumption paths over time and compare it with other recently proposed measures of multi-period poverty. Table 2 shows illustrative consumption trajectories for five households over a four-year period. The consumption paths are normalized to the poverty line z, so that z is equal to 100 and consumption levels can be read as a percentage of the poverty line. Household 1 shows the lowest mean in consumption, but is on an increasing consumption path. Households 2 and 3 have the same mean in consumption (and higher than household 1), but household 2 is on a decreasing consumption path, whereas household 3 has the same consumption level over all periods. Households 4 and 5 show the highest mean in consumption, which is for household 4 mainly driven by consumption levels above the poverty line.

The upper panel of Table 3 displays the numerical results of the various proposed measures of multi-period poverty. For each measure, the first three rows display the parameterizations for α (transfer), β (time sensitivity), λ (loss aversion), and η (weight on gain–loss utility). Note that, whereas α expresses diminishing marginal utility of consumption in our measure, it represents "increasing cost of hardship" in other measures. Besides our proposed measure of (perceived) multi-period poverty, Foster (2009), Calvo and Dercon (2009), and Bossert *et al.* (2012) also incorporate a measure of "time." Foster (2009) specifies a "duration line," which indicates the least number of time spells a household has to be below the poverty line to be considered poor (in this example 3). Calvo and Dercon (2009) apply a "time multiplier" that gives more weight to either current ($\beta < 1$) or past ($\beta > 1$) time spells. The introduction of a gain–loss utility function ($\eta = 1$) that incorporates loss aversion ($\lambda = 2$) leads to an even stronger version of "time sensitivity," namely path dependency. Bossert *et al.* (2012) propose another version of path dependency. Each poverty spell is weighted with the number of consecutive poor periods to which a certain poverty spell belongs, for example for a time period of four years, β varies between one and four. Based on the numerical results of the upper panel of Table 3, the ranking from the poorest (1) to the wealthiest (5) household over time is shown for each measure in the lower panel of Table 3. This ranking differs considerably across the analyzed measures, which we discuss below.

TABLE 2

CONSUMPTION HISTORY MATRIX

	Year x_1	Year x_2	Year x_3	Year x_4	Mean($\bar{x}$)	SD($\bar{x}$)
HH1	50	70	80	90	72.5	17.078
HH2	100	80	70	50	75	20.816
HH3	75	75	75	75	75	0.000
HH4	50	50	120	120	85	40.414
HH5	100	70	100	70	85	17.320

Notes: year x_1–year x_4 denote yearly per capita consumption. SD denotes standard deviation. HH denotes household.

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TABLE 3

Multi-Period Poverty Measures Applied

	Jalan/Ravallion (M_1)	Foster (M_2)	Calvo/Dercon (M_3)	Bossert *et al.* (M_4)	Günther/Maier (M^2)
α	1.2	1.2	1.2	1.2	1
β	–	3	0.8	–	–
λ	–	–	–	–	2
η	–	–	–	–	1
HH1	0.220	0.220	0.138	0.879	0.425
HH2	0.204	0.204	0.179	0.612	0.500
HH3	0.189	0.189	0.140	0.758	0.375
HH4	0.218	0.000	0.125	0.435	0.225
HH5	0.118	0.000	0.097	0.118	0.375
HH1	1	1	3	1	2
HH2	3	2	1	3	1
HH3	4	3	2	2	4
HH4	2	non-poor	4	4	5
HH5	5	non-poor	5	5	3

Foster (2009) and Jalan and Ravallion (1998) show very similar results. The major difference is that Foster (2009) is very sensitive to the specified duration line, so that Foster (2009) comes to the conclusion that households 2 and 3 are poorer than household 4, which is non-poor, whereas households 2 and 3 are wealthier (but still poor) than household 4 according to Jalan and Ravallion (1998). Neither Jalan and Ravallion (1998) nor Foster (2009) incorporate a notion of path dependency, that is, make a difference between increasing and decreasing income trajectories. Thus, Foster (2009) and Jalan and Ravallion (1998) consider household 1 (increasing consumption path) poorer than household 2 (decreasing consumption path), whereas Calvo and Dercon (2009) and our measure evaluate household 2 poorer than household 1. With our measure, path dependency is even stronger: we are the only measure that ranks household 5 poorer than household 3. Even if household 5 has a higher mean in consumption and is non-poor in two periods, it shows a highly fluctuating consumption path, whereas consumption of household 3 is very stable over time. Bossert *et al.* (2012) is the only measure that ranks household 3 poorer than household 2, even though both have the same mean in consumption and household 3 a lower variance in consumption. The reason is that Bossert *et al.* (2012) is very sensitive to the number of consecutive poverty spells, which is higher for household 3 than for household 2.

Last, comparing household 4 and household 5, we see that all existing multi-period poverty measures consider household 4 poorer than household 5, even though both households have the same mean in consumption and household 4 has been significantly above the poverty line for the last two years. In contrast, our measure suggests that household 5 is poorer than household 4. The major reason is that a strong focus axiom does not pay any attention to consumption levels above the poverty line. Even though we recognize the importance of the focus axiom across households, we argue that when aggregating consumption across time (for one household) the focus axiom should be dropped. Whereas an increase in wealth of a non-poor household can certainly not compensate for a poor

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household, a poor time period of one household may be compensated by an increase in the wealth of another non-poor time period of the same household.

6.2. *Vulnerability*

Similar to the previous section, we apply our proposed measure of (perceived) vulnerability to various future consumption prospects and compare it with other recently proposed measures of vulnerability. Table 4 shows consumption prospects for four households. In addition, current consumption x^0 (i.e., the reference point) is stated for each household. Again, consumption is normalized to the poverty line z.

Table 5 displays the numerical results of existing as well as of our proposed measure of vulnerability V^2. For each measure, the first row displays the parameterization for α (risk sensitivity). η (weight on gain–loss utility) and λ (loss aversion) are only relevant for our proposed measure. In contrast to other measures, in our measure risk sensitivity is not solely captured by α, but also by η and λ.

The numerical values in Table 5 are interpreted as follows: Pritchett *et al.* (2000) measure the probability to fall below the poverty line. Calvo and Dercon (2013) can be interpreted within the framework of the expected poverty gap if we set $\alpha = 1$ (linear consumption utility). The same is true for our measure if we

TABLE 4

Consumption Prospect Matrix

	x^0	State x_1	State x_2	State x_3	State x_4	Mean($\tilde{x}$)	SD($\tilde{x}$)
HH1	70	75	80	80	85	80	4.082
HH2	100	70	80	80	90	80	8.164
HH3	130	110	100	110	100	105	5.773
HH4	100	50	60	130	130	92.5	43.493

Notes: x^0 denotes current consumption. state x_1–state x_4 denote possible future consumption outcomes that occur with probability $p_1 = p_2 = p_3 = p_4 = 0.25$. SD denotes standard deviation. HH denotes household.

TABLE 5

Vulnerability Measures Applied

	Pritchett *et al.* (V_1)	Ligon/Schechter (V_2)	Calvo/Dercon (V_3)	Günther/Maier (V^2)
α	–	0.5	0.5	1
λ	–	–	–	2
η	–	–	–	1
HH1	1.000	1.058	0.106	0.100
HH2	0.986	1.065	0.106	0.600
HH3	0.193	0.000	0.000	0.450
HH4	0.632	0.595	0.130	0.375
HH1	1	2	3	4
HH2	2	1	2	1
HH3	4	non-vulnerable	non-vulnerable	2
HH4	3	3	1	3

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additionally set $\eta = 0$. For the case of $\alpha = 1$, our measure V^2 is, hence, the expected poverty gap with the addition that possible losses (gains) in consumption increase (decrease) the expected poverty gap. The numerical value of Ligon and Schechter (2003) does not allow for a direct interpretation.

For each measure the ranking from the most vulnerable (1) to the least vulnerable (4) household is shown in the second panel of Table 5. The first observation is that different measures do not agree on the ranking of households—even if we exclude our proposed vulnerability measure. Assuming that vulnerability measures should be sensitive to risks, we would expect that all measures evaluate household 2 as more vulnerable than household 1. Household 2 shows the same mean but twice the standard deviation in consumption compared to household 1 (see Table 4). However, the measure of Pritchett *et al.* (2000) suggests that household 1 is more vulnerable than household 2. Poverty risk, as proposed by Pritchett *et al.* (2000), implies higher vulnerability with lower expected variance in consumption if the expected mean of consumption lies below the poverty line: in this case higher variance in consumption means a higher probability of escaping poverty. All other measures (including ours) suggest that household 2 is more vulnerable than household 1. Calvo and Dercon's (2013) ranking differs in the sense that household 4 is much more vulnerable than indicated by all competing measures. The reason is that Calvo and Dercon (2013) apply the focus axiom to individual consumption states. This means that households' consumption states above the poverty line do not decrease vulnerability. Other measures assume that compensation for low consumption states is possible through high consumption states.

Probably the most striking point of a vulnerability measure based on reference-dependent utility and loss aversion is that household 1 is less vulnerable than household 3, contradicting all other measures. Household 1 shows a lower expected mean in consumption and an equal relative variance in consumption compared to household 3. But household 1 faces a risky gain in consumption whereas household 3 faces a risky loss in consumption—in relation to current consumption. All existing vulnerability measures assume that only the expected *level* and *variance* of consumption are of relevance for vulnerability, and do not explicitly take into account downside risks. Our measure also takes into account the expected *change* in consumption (relative to current levels of consumption), where expected losses have an additional (negative) impact on measured vulnerability.

7. Critical Discussion and Further Research

In this paper we suggest that the insights from behavioral economics might enrich existing measures of poverty over time and under uncertainty. We base our new proposed measure on reference-dependent utility and thereby incorporate one of the most important behavioral phenomena found in numerous experimental studies on decisions under certainty and uncertainty: loss aversion. We try to show that instead of using a conventional utility function for the measurement of expected and experienced utility it might be desirable to incorporate the effect of loss aversion induced by a value function with a kink at the reference point. Such a reference-dependent utility function provides alternative measures that are able

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to incorporate path dependency for multi-period poverty and downside risk sensitivity for vulnerability measures. We think that it is reasonable to extend individual well-being measures with the insights from behavioral economics if they have been shown to systematically influence the utility of individuals. Only if the downside impact of (certain and uncertain) consumption losses on current and life-time individuals' well-being is properly understood, are reasonable policy recommendations—e.g. with regard to insurance mechanisms and/or social transfers—possible. That being said, four critical points need to be discussed:

First, since the model we use (Köszegi and Rabin, 2006, 2007) was originally modeled for *choice* under certainty and uncertainty, for our measure of multi-period poverty we implicitly assume that decision utility equals experienced utility. Although we note that this is a strong assumption, "economists tend to assume that decision utility and experienced utility are the same" (Easterlin, 2001, p. 474). But more empirical evidence like the study by D'Ambrosio and Frick (2012) would certainly be needed.

Second, one might argue that the level of individual multi-period poverty and vulnerability should only be dependent on a fixed reference point (the poverty line) and not on a varying reference point of previous individual consumption/income. We think that if we measure well-being over time, single periods in time cannot be analyzed in isolation of other periods, i.e. neglecting history. Otherwise, we simply construct a measure of accumulated static poverty instead of a dynamic poverty measure. Moreover, vulnerability is explicitly concerned with the exposure to "downside risks" (Calvo and Dercon, 2013), which naturally depends on the current state of consumption.

Third, and linked to the previous argument, policy recommendations solely based on the grounds of *perceived* poverty and/or vulnerability might be problematic. For example, political acceptance of programs, which give less support to the currently poor either because their future prospects looks very promising compared to the present or because they are on an historical upward trend in consumption, might be low. We think that making policy recommendations solely based on perceived measures is not warranted and more objective principles should also be adhered to. Still, our proposed measures may help to evaluate perceptions of poverty which should also be taken into account when designing policies.

Last, the data requirements for multi-period poverty, but especially for vulnerability, are currently not being met by most developing countries. For an empirical analysis of poverty over time and under uncertainty there is an urgent need to increase the availability of long-term panel data in order to reasonably apply the proposed measures.

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Appendix: Proofs

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