Research Paper No. 2006/40

Vulnerability to Globalization in India

Relative Rankings of States Using Fuzzy Models

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April 2006

Abstract

The net impact of globalization on developing countries, and more specifically on the poorer sections of population in these countries, is complex and context dependent, and hence needs to be analysed empirically. This study in the context of globalization attempts to develop regional level indices of vulnerability with respect to welfare loss in India using a methodology based on fuzzy inference systems. The vulnerability of an entity is conceptualized (following the practice in global climate change literature) as a function of its exposure, sensitivity and adaptive capacity. Empirical analysis based on such multidimensional conceptualization demands use of indicator-based approach which is attempted in this study and uses fuzzy models that adequately capture vagueness inherent in such approaches.

The contribution of the study is three folds: conceptualization of vulnerability and linking it with formalization being attempted in other disciplines, development of a new methodology to measure vulnerability, and apply the methodology to rank Indian states

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in terms of their relative vulnerability to welfare loss. The economic reforms initiated in 1991 and set in motion a series of polices for trade liberalization in India. To capture the dynamic nature of vulnerability two time points representing 'pre' and 'post' reform period are chosen for analysis. The results show that vulnerability indices estimated are dynamic in the sense that an entity that is vulnerable today need not remain so in the next period and at the same time currently non-vulnerable may not enjoy that status in future.

Acknowledgements

1   Introduction

Globalization is one of the important issues confronting developing countries. While globalization means different things to different people, this study interprets it as that component which arises from trade liberalization. Some argue that the inability of countries to integrate into the global economy due to a complex set of factors, including domestic policies, institutions and infrastructure, can cause economies to contract and poverty to rise, while others say that trade liberalization could help developing countries in addressing poverty issues more effectively. But as Bardhan (2005) argues, the net impact of globalization on poor people is complex and context-dependent, making it an appropriate case for empirical analysis.

This study in the context of globalization attempts to develop state level indices of vulnerability with respect to welfare loss[1] in India using a methodology based on fuzzy set theory. The contribution of the study is three folds: conceptualization of vulnerability and linking it with formalization being attempted in other disciplines, development of a methodology to measure vulnerability, and apply the methodology to rank Indian states in terms of their relative vulnerability to globalization with respect to welfare loss. To capture the dynamic nature of vulnerability two time points—one in the early 1990s and the other in late 1990s—representing 'pre' and 'post' economic reforms (initiated in 1991), respectively are chosen for analysis. The period since the early 1990s saw the beginning of trade liberalization in India through dismantling of inward-looking economic policies in tune with the emerging WTO regime.

The paper is organized as follows: The first section provides a brief discussion on welfare implications of globalization with special focus on India and makes a case for vulnerability estimation which is a forward-looking assessment. The following section reviews literature on vulnerability assessment and develops the conceptual framework. The third section briefly discusses the fuzzy set theory and describes the methodological framework along with the data used. The fourth section presents the results of the empirical analysis and provides discussion on vulnerability ranking of states in India. Finally the fifth section gives concluding remarks and policy implications.

1.1   Trade liberalization and poverty in India

The jury is still out on the impact of trade liberalization on poverty and in particular rural poverty.[2] Two aspects on which there is widespread consensus are that: (i) openness has a long-run impact on growth and countries with inward-looking trade policies fare worse in the aggregate and long-run development; (ii) reduction of poverty in countries that have liberalized in the recent past depends on a host of institutional, political and regional factors leading to the understanding that trade liberalization though improves growth need not always be pro-poor.

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[1]   Though no specific indicator is chosen to represent welfare, for much of the discussion, the level of consumption expenditure is used as a proxy to represent welfare.

[2]   Detailed discussions on the causality between trade liberalization and poverty can be seen in Bardhan (2005); McCulloch, Winters and Cirera (2001); World Bank (2002).

Given wide spatial diversity in the level of development and sheer size of the country in terms of its area and population, India is an ideal case to analyse the impact of globalization. Given that India until very recently has pursued an inward-looking trade policy, the issue of impact of trade liberalization on the well-being of its people is widely debated within the country. In the wake of economic reforms started in 1991, India has undergone several non-agriculture related trade liberalization, while the agriculture related ones are yet to become operational. However, under the WTO regime greater importance is attached to trade than to pursue flexible domestic policies that aim at foodgrain self-sufficiency. Integration with world markets can bring in huge price volatility and possibly affect the purchasing power of the net buyers of staple cereals. Further there are serious apprehensions about the impact of WTO on the livelihood and sustenance of agriculture in the developing countries mainly because of the subsidy policies pursued by developed countries. In an open market the competitiveness of a country not only depends on exchange rate and domestic price policies but also policies of other exporting and importing countries. Gulati and Narayanan (2003) illustrate that when the world price of rice fell, countries like US (despite being less competitive in the world market) were able to stave it off due to domestic subsidy policies, while countries like Thailand, India and Vietnam not only accumulated their domestic stocks massively but also supposed to have exported at a loss during this period.

There are by far very few studies that have attempted to study the impact of trade policy on rural poor in India mainly due to the fact that the agriculture sector is not fully liberalized. Studies like Misra and Rao (2003) have highlighted the indirect impact of trade liberalization in the non-agricultural sector on the agricultural sector. The tariff reduction reduces the prices of manufacturing, resulting in the terms of trade moving in favour of agriculture, thereby improving the aggregate crop output and real wages of the unskilled agricultural workers in the following decade since 1991. This period has also seen a decline in agricultural employment and a rise in unemployment rate in rural areas, a slowing-down of agricultural growth rate and with slower rise in real wages. These two aspects would have countervailing effects on the rural poor, which is not addressed by Misra and Rao (2003). In earlier studies, Gulati and Kelley (1999) and Parikh *et al*. (1997) study the implications of various trade liberalization scenarios for Indian agriculture and argue that globalization could have welfare improving impacts. However, given the institutional rigidity and infrastructural shortcomings that exist in developing countries like India, many suspect that the beneficial impacts of globalization may not materialize in these countries. In general one could expect that winners and losers would emerge as different crops, farmers, and regions react differently to the changing incentive environment. Moreover, different regions would have different exposure and adaptive capacity to absorb external shocks. Under these circumstances, the required approach to study the impact of macro-level policy changes would be a micro-level analysis focusing on smaller regions. This is important in the Indian context because there are wide variations in the growth in value added from agriculture during the past decade and a half with significant increase in the proportion of casual labourers in agriculture constituting the dominant group among the rural poor. These are important concerns for policymaking and more so because the regional governments are increasingly in charge of such policy formulation and at the same time have to compete for funds from the central government.

Thus, a study of this kind enables one to focus on the regional effects of trade liberalization for an efficient allocation of funds not only for enhancing the capabilities of the agricultural sector to participate in the world trade but also designing intervention

measures to reduce impact of trade liberalization on those who are likely to be adversely affected. Since this involves assessing the impact of trade liberalization (risk) on not only on those who are currently at low levels of wellbeing, but also those likely to suffer welfare loss in the future, the present study uses the concept of vulnerability as against the conventional welfare criterion like poverty.

2   Vulnerability assessment—developing conceptual framework

As mentioned above, globalization brings with it winners and losers and even among the losers, varied experiences have emerged on who are the likely losers and the extent of loss in wellbeing (measured in various ways). Therefore while formulating the policies to alleviate the impact and making them more resilient to the shocks, it is very important to keep the current and the future poor in mind. As it is, policy prescriptions are for future purposes and if one were to focus on the characteristic of the currently poor, then possibly a significant proportion of the population would be out of the welfare measures devised to take care of their needs. Therefore, vulnerability assessment can be considered as an appropriate concept while studying the impact of globalization on the welfare of people.

2.1   Brief review of vulnerability literature

The vulnerability concept is defined in a variety of ways in different disciplines such as disaster management, food security and global climate change. The notion of risk is closely linked to the concept of vulnerability and thus vulnerability depicts a *forward-looking* measure. What varies across these disciplines is the formalization of the linkage between risk and future state of affairs and thereby its measurement. Consequently this influences not only the constitution of the set 'who are vulnerable' but also the intervention policies designed for the vulnerable.

The commonly understood notion of vulnerability as susceptibility or defencelessness applies to the disaster management literature and essentially deals with vulnerability to a natural disaster (an event). The risk here is the natural hazard and individuals, or households or communities, are less or more vulnerable depending on their ability to 'anticipate, cope with, resist and recover' from the impact of the disaster. The assessment of vulnerability or its quantification is weakest in this strand, as what constitutes an outcome of the disaster is not clearly spelt and different studies focus on the impact on poor, malnourished, etc., without identifying who the vulnerable are on its own.

Among the social science literature though sociology and anthropology have discussed vulnerability extensively, the attempt at its quantification is distinctly visible only in economics. As Alwang, Siegel and Jorgensen (2001) argue, the vulnerability literature across different disciplines can be broadly classified as either conceptually strong and empirically weak or conceptually weak and empirically strong. Much of the literature on issues related to food security falls into the second category. The development of conceptual basis for vulnerability followed empirical investigation in food security literature and Dercon (2001) suggests a causal chain of 'asset-income-outcome' to describe vulnerability. Since risks are likely to be experienced at each stage of this

causal chain, the vulnerability in this literature stays away from risk specification and deals with 'vulnerability to outcome such as poverty' as against the conventional notion of 'vulnerability to risk' (like a disaster or global climate change) (Lovendal and Knowles 2005).

Thus, the concept of vulnerability in economics mainly looks at outcome which is usually poverty, arising from accumulated 'responses to risks' of a household (the usual unit of analysis in this literature). Vulnerability would be the propensity to fall below the (consumption) threshold and its assessment thereby deals not only with those who are *currently* poor but also those who are *likely to be* poor in the future (Chaudhuri, Jalan and Suryahadi 2002). More specifically as Dercon (2001) argues, the focus of vulnerability assessment should be on at least four groups: (i) those who are currently poor and permanently poor (also referred as chronic poor); (ii) those who are likely to become poor in future due to some trend evolution; (iii) those who are likely to become poor due to *predictable* events such as seasonality; and (iv) those who are likely to become poor due to risk and shocks. The outcome of interest is typically poverty in this literature, but other indicators like health, education, crime and social exclusion have also been analysed separately. However, composite measures of vulnerability are few as identification of a threshold for each outcome as well as aggregation across different outcomes is rather difficult. Thus, the focus has usually been on consumption or income poverty with some studies bringing in a time dimension more effectively and a few also highlighting the degree of shortfall from the threshold (Jalan and Ravallion 1998).

Further variations to this strand of assessing vulnerability deal with issues like the role of assets in managing or coping with risk. The assets are invested to reap benefits in future and during periods of stress a household can draw upon its assets, making it less vulnerable compared to that which does not have access to different assets. These two aspects are in turn analysed based on 'extended entitlements' which include social and environmental assets as well as aspects like market structure and property rights and how sensitivity and resilience[3] change over time. The empirical evidence is mainly based on case studies, as the emphasis is more on 'asset/livelihood' as against the 'outcome'.

Vulnerability in global change literature (the most recent among the three strands of literature mentioned above) is defined by Intergovernmental Panel on Climate Change (Ahmad *et al.* 2001) as a function of exposure, sensitivity and adaptive capacity of the entity, which in turn are defined as:

i) *Exposure* represents the magnitude and frequency of the stress experienced by the entity;

ii) *Sensitivity* describes the impact of stress that may result in the reduction of wellbeing due to a cross over of a threshold (below which the entity experiences lower wellbeing); and

iii) *Adaptive capacity* represents the extent to which an entity can modify the impact of a stress to reduce its vulnerability.

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3 These concepts are elaborated further in the context of literature on vulnerability to global change.

Such a framework when adopted for poverty issues presents scope for assessing vulnerability from a broader perspective than what has been the practice so far in the food security literature. Of course, such framework also poses a challenge for empirical methodology, as focus is not on any specific outcome. Most studies in the global change literature attempting to measure vulnerability in this framework have adopted indicator-based approach (Moss, Brenkert and Malone 2001; Acosta-Michlik *et al.* 2004; O'Brien *et al.* 2004; Brenkert and Malone 2004), but there are also some studies that go beyond indicators[4] (Lures *et al.* 2003). Inherent vagueness associated with use of the linguistic statements in quantitative analysis is one of the limitations of the indicator-based approaches.

Following Ionescu *et al.* (2005), for any conceptualization of vulnerability to be meaningful, it must be able to capture the following three dimensions:

- *Who are vulnerable?* This is the entity under consideration. Examples include households, geographical regions and demographic groups.

- *Vulnerable to what?* This is the trigger or exogenous input that causes the entity under consideration to face the threat of undesirable outcomes. Examples include globalization, price fluctuations, weather extremes (e.g., cyclones) and climate change.

- *Vulnerable with respect to what?* This is the outcome with regard to which certain preference criterion exists in the society. Non-attainment of outcome levels that correspond with society's preference criterion means that the entity under consideration is vulnerable. Examples include break-even level of crop yield, poverty line based on consumption expenditure or other threshold levels.

Thus, informative statements about vulnerability consider the vulnerability of an entity to an exogenous input, with respect to an undesirable outcome. The present study in the empirical analysis defines the above basic ingredients of vulnerability as follows: the geographic regions (viz., states) are considered as the entities,[5] globalization as represented by trade liberalization is taken as the exogenous input (or trigger) causing vulnerability, and welfare (proxied by consumption in various arguments) is used as the outcome of interest with well-defined preference order on the same (namely, higher consumption level is always preferred over lower consumption level).

3   Methodology

Quantifying vulnerability is difficult due to several reasons: (i) Many factors may contribute towards the vulnerability and also in complex ways; (ii) Knowledge about the determinants of vulnerability is typically vague; (iii) Possibility of non-linear

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[4] This study attempts to develop a vulnerability metric that links wheat yield (outcome) to climate variability and change and market fluctuations (stress) dynamically in the presence of varying degrees of adaptive capability.

[5] While much of the vulnerability discussion in economic literature focuses on households as the entities, literature in other disciplines, especially geography, considers geographical regions as the fundamental unit of vulnerability analysis (Cutter 1996).

relationships between the determinants and vulnerability (for example, while a very high level of income inequality in the society can be associated with vulnerability, a small decline in the inequality may not lead to corresponding decline in the vulnerability); and (iv) Lack of knowledge on weights to be attached to these determinants.

For these reasons, the methodology adopted in this paper focuses on a range of determinants of vulnerability and makes use of linguistic models of vulnerability. Use of different factors for capturing vulnerability is not new, but identification and use of different factors as per the conceptualization of the vulnerability outlined in the previous section are not very common (see Acosta-Michlik *et al.* 2004; O'Brien *et al.* 2004, and Brenkert and Malone 2004). Further, application of fuzzy set theory to translate the inexact linguistic statements into quantitative estimates is relatively limited in the vulnerability literature. Thus, combination of the conceptualization of vulnerability to globalization (similar to global climate change literature) and application of fuzzy set theory to make quantitative inference from linguistic statements makes the methodology of this paper unique. The rest of this section describes the approach adopted for allocating various indicators chosen for analysis among the broad dimensions of exposure, sensitivity and adaptive capacity of the entity; and the tool used for quantitative analysis, namely fuzzy inference system.

3.1 Indicators of vulnerability

As mentioned above, vulnerability of an entity is hypothesized to be a function of its exposure (to the external stressor causing the vulnerability), sensitivity of the entity's outcome to the external stressor, and its adaptive capacity in overcoming the adverse impact of the stressor on its outcome. While identifying the determinants of exposure could be relatively easy[6] (provided the cause of entity's vulnerability is unambiguously identified), categorizing the determinants of entity's vulnerability among the sensitivity and adaptive capacity subgroups could be more daunting.

Since it is relatively easy to understand the notion of sensitivity and adaptive capacity with reference to natural systems, this subsection describes the same using a simple example and extends the concept to social systems. Considering the example of vulnerability of agricultural system on rainfall fluctuations, the choice of a crop variety and seed commits the farmer to certain impact on the farm yield due to rainfall fluctuation (knowledge about which is not available to the farmer at the time of planting). This could be described as the sensitivity of the entity to rainfall fluctuation. More precisely, sensitivity of the entity is determined by its intrinsic characteristics on which the entity has no direct control. The extent to which the entity could protect itself from the adverse impacts caused by the external stressor can be described as its adaptation potential. The control that the entity has over all the options, which are helpful in ameliorating the adverse impacts caused by the external stressor defines its adaptive capacity. In the present example, once faced with the prospect of adverse yield change the farmer could employ a range of options at his/her disposal—both before and after experiencing the yield loss, in order to protect him/herself from the implications of

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[6] Which incidentally in this study proved to be very difficult as region level data on trade liberalization were not easily available.

the output change. Examples include use of irrigation, subscribing to crop insurance and resorting to behavioural changes (say, reducing a component of current consumption due to fall in income). Naturally by definition the entity has more control over the factors determining its adaptive capacity.

The insights from the above discussion could be translated into guiding principles for allocating various factors among sensitivity and adaptive capacity categories in social systems:

i)   Both sensitivity and adaptive capacity deal with the outcome;

ii)   Sensitivity is captured by indicators that represent the intrinsic features of the system which define the impact of the external stressor on the entity's output. The intrinsic features are those characteristics of the system that cannot be changed by the entity at least in the short and medium term. Adaptive capacity, on the other hand, is captured by indicators that can be modified by the entity even in the short and medium term and hence can influence the shortfall in outcome caused by the external stressor;

iii) Indicators capturing adaptive capacity can contribute either towards compensating adverse impacts caused by the external stressor, or strengthening the entity's capacity to absorb the adverse implications of output change; and

iv)   While sensitivity is represented by indicators that reflect the state of the system, adaptive capacity indicators are more like policy (or, control) variables.

In the empirical analysis presented in the next section these guiding principles are used in allocating various indicators across sensitivity and adaptive capacity categories.[7]

3.2   Fuzzy inference system

Fuzzy set theory is useful in translating linguistic statements such as 'high' or 'low' into numerical values. Use of fuzzy set theory in poverty analysis in economics is not new and studies by Cerioli and Zani (1990) and Cheli and Lemmi (1995) provide fuzzy set theoretic measures of poverty. Qizilbash (2002) extends the application of fuzzy set theory to capture the notion of vulnerability to poverty. Use of fuzzy set theory in poverty is centred around the idea that an individual could be considered definitely poor if his income is below a lower threshold, and definitely non-poor if his income is above a higher threshold, with ambiguity associated with income lying in between these two thresholds as with such income the individual belongs to the set of poor people to *some degree*.[8] These studies essentially carry out what is described below as 'fuzzification' to translate a crisp value into fuzzy number that falls in the interval [0,1]. Qizilbash (2002) interprets such fuzzy numbers as the individual's level of vulnerability to poverty, i.e.,

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[7]   It is often difficult to explicitly identify whether a particular indicator represents sensitivity or adaptive capacity of the entity. As many other studies have pointed out (see www://hero.geog.psu.edu), it is often a choice by the researcher between emphasizing present (current sensitivities) and past (historic adaptive strength or lack thereof).

[8]   It is not necessary to define fuzzy set theoretic poverty measures on income dimension alone and the studies cited considered multiple dimensions of poverty.

to indicate how close one is to being labelled as definitely poor.[9] The analysis presented in this study, on the other hand, while trying to assess welfare loss due to globalization focuses on several dimensions (not just consumption or income) and hence requires aggregation involving a set of crisp inputs going through a fuzzification-defuzzification process to generate a crisp output. Martinetti (2006) has proposed a similar approach for assessing multidimensional well-being of individuals. The following paragraphs describe the elements of fuzzy inference system—namely, fuzzification, fuzzy inference and defuzzification—using an illustrative example.

Fuzzification

This involves translation of propositions into quantitative values using membership functions. For instance consider the proposition: 'if literacy rate is high, the vulnerability is low'. In binary logic, levels such as 'high' and 'low' are assigned sharp boundaries, whereas in fuzzy logic it is possible to assign non-sharp (or fuzzy) boundaries. As shown in Figure 1, the membership functions defined in a fuzzy model describe the 'degree of belief' of a particular value of a variable.

Figure 1
An example of membership functions in fuzzy model
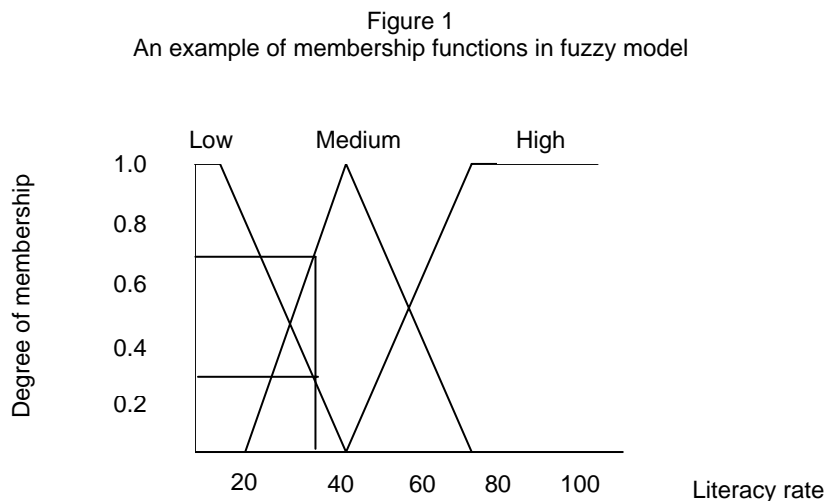
As shown in the figure, a literacy rate of, say, 35 per cent need not be assigned to either 'low' or 'medium' literate category, but can be a member of both categories, having a certain degree of membership in each category.

Fuzzy inference

The variables are related to each other with a knowledge-based rule system. A statement about the resulting variable has to be made for all possible combinations of the categories of all variables. Suppose the model consists of two variables: literacy and percentage share of educational expenditure in the total state expenditure. If each of these variables is defined in two states (i.e., 'low' and 'high'), then four rules are required to describe the resulting output variable (say, human capability index). The rules describing the system can be:

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9   Clark and Hulme (2005) propose a unified framework that extends Qizilbash's approach to capture vagueness in depth, breadth and duration of poverty.

Rule 1: If literacy is low and share of educational expenditure is low, then the human capability is low.

Rule 2: If literacy is low and share of educational expenditure is high, then the human capability is medium.

Rule 3: If literacy is high and share of educational expenditure is low, then the human capability is medium.

Rule 4: If literacy is high and share of educational expenditure is high, then the human capability is high.

For example, assume that the literacy rate and percentage share of educational expenditure in the total expenditure in a region are such that the degree of membership to the 'low' and 'high' states are 0.7 and 0.3 (for literacy), and 0.4 and 0.6 (for share of educational expenditure) respectively. Then using the above rule-base along with the intersection operation (since the rules use 'and' condition) the output variable (namely, human capacity index) attains the following degrees of certainty under each rule:

Rule 1: Human capability is low = min (0.7, 0.4) = 0.4

Rule 2: Human capability is medium = min (0.7, 0.6) = 0.6

Rule 3: Human capability is medium = min (0.3, 0.4) = 0.3

Rule 4: Human capability is high = min (0.4, 0.6) = 0.4.

Figure 2
Rule strength and defuzzification – illustration
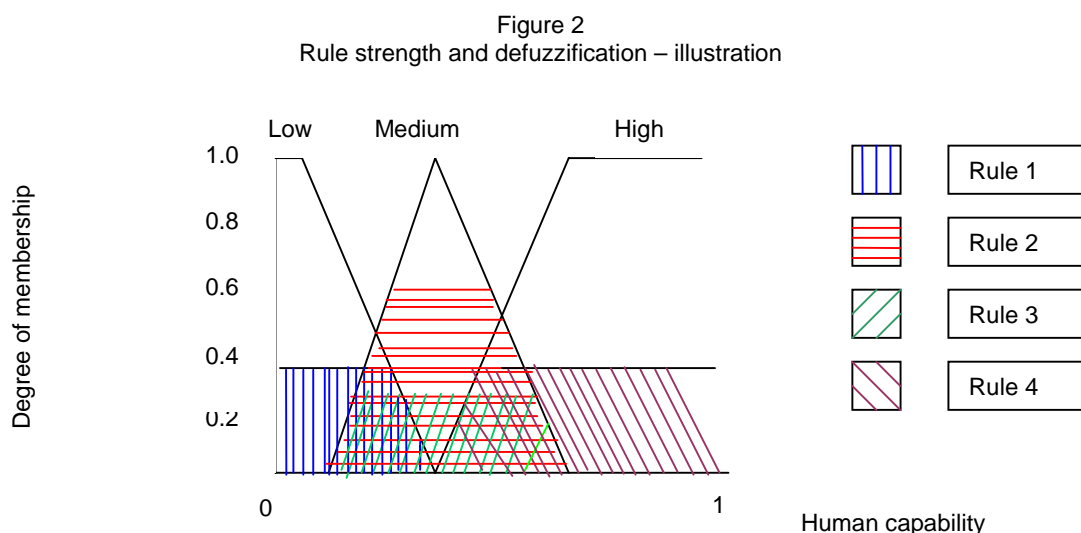
Defuzzification

This final step of the fuzzy inference system is necessary for combining the results of each rule into a single unique result. Although there are several mathematical approaches for defuzzification, the most commonly used approach is the 'centre of gravity' method. A defuzzification diagram (Figure 2) containing membership functions for every category of the output variable is used and the certainty of each inference result is represented as the area below the corresponding membership function of the output variable. The final result is obtained as the centre of gravity of the joined areas of all membership functions.

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In the empirical analysis presented in the next section, two or three indicators at several stages are clubbed together to generate various indices. In terms of procedure described here, this involved translating the input indicators into fuzzy numbers using fuzzification procedure, fuzzy inference is then applied to relate the input indicators and output index, and finally defuzzification is used to translate fuzzy index to crisp index.

4 Vulnerability estimation: an application to Indian states

The units of analysis are sixteen large federal states of India, namely Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajastan, Tamil Nadu, Uttar Pradesh and West Bengal. While there has been further subdivision of some of the states[10] in 2000, the analysis has been carried out for the sixteen undivided states mentioned above. The choice of these sixteen states is made keeping in mind (i) the availability of reliable data, (ii) large geographical coverage, and (iii) large population coverage.

As explained above, the framework for vulnerability estimation incorporates the notion of exposure, sensitivity, and adaptive capacity and indicators to represent each of these system characteristics are selected on the basis of (i) representativeness, (ii) data availability, and (iii) forward-looking nature. Figure 3 shows the overall framework of the analysis.

Vulnerability (to external shock) of a system is hypothesized to increase with exposure and sensitivity, but decline with adaptive capacity. Exposure is captured through two indicators: instability in cereal production and share of investment in manufacturing sector. Sensitivity is assessed through three broad indices: agricultural, demographic and health which, in turn, are assessed through six indicators, namely share of agricultural GDP, per capita calorie consumption, population density, population growth rate, percentage of malnourished children, and share of health expenditure in total expenditure. Adaptive capacity is measured through three broad indices: economic, human, and infrastructure which, in turn, are assessed through six indicators, namely per capita income, inequality measure, literacy rate, share of educational expenditure in total expenditure, infrastructure development index, and share of rural development expenditure in total expenditure.

Table 1 summarizes the rationale for the use of these indicators under each dimension of vulnerability by describing what each indicator represents and the expected functional relationship with the respective component. Even though the analysis does not define specific outcome, implicitly impact of globalization shock on consumption (and hence poverty in that dimension) is used as outcome of interest. Choice of sensitivity and adaptive capacity indicators reflects this aspect.

Agricultural sensitivity

Sensitivity of agriculture is considered important, given its role as livelihood provider for a large section of the population. Extent of agricultural sensitivity is measured through the

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[10] Bihar is divided into Bihar and Jharkhand; Madhya Pradesh is divided into Madhya Pradesh and Chattisgarh; and Uttar Pradesh is divided into Uttar Pradesh and Uttaranchal,

dependency of a region on agriculture (share of agricultural GDP in overall GDP of the region) and access to agricultural markets and public food distribution mechanisms (with the per capita calorie consumption of a region acting as a proxy). Both these indicators reflect the state of the system which cannot be changed in the short to medium term by the entity. It may be noted that per capital calorie consumption is determined among other things by the infrastructure and institutions in a region and these cannot be modified by the individual in the short run.

Demographic sensitivity

This sensitivity is included in the overall sensitivity measurement, given varied population characteristics of Indian states. Population density is used as a proxy to represent access to resources and also opportunities. Annual population growth rate, on the other hand, is a forward-looking indicator and is included to capture the ability of a region to effectively allocate resources over time. Again, both these indicators reflect the state of the system and hence could be viewed as sensitivity measures.

Health sensitivity

The third sensitivity measure used in the analysis captures a dimension of social well-being, namely health. The percentage of malnourished children among the children below 4 years of age acts as a proxy for life-cycle measure of health and human capital because undernourishment leads to slow growth and lower level of cognitive development. The proportion of health expenditure in total public expenditure reflects the concern for healthy and productive society, as such expenditure results in improvement of human capital.[11]

Economic capacity

Economic capacity is an important determinant of adaptive capacity as it represents the availability of resources and scope of resource mobilization. The extent of economic capacity is measured through per capita income which represents the ability to access resources that are useful for adaptation, and inequality measure (Gini coefficient) which represents the degree of cohesiveness of society for adaptation. Both these indicators reflect entity's control on influencing the outcome (or shortfall in outcome induced by the shock) and hence capture its adaptive capacity on economic dimension.

Human capacity

Human capacity is used as the second dimension of adaptive capacity, as it captures the inherent adaptive capacity of the vulnerable population. The degree of human capacity is assessed through the percentage of literate population in the society which indicates the adaptability of the population to both adverse impacts caused by shocks and the opportunities created, and the proportion of expenditure on education in total public expenditure which represents the investment in human capital. Again, both indicators reflect the extent of influence that an entity can exercise on its outcome and hence qualify as adaptive capacity indicators.

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[11] There is a case for this indicator to be labeled as adaptive capacity indicator (see discussion below on other expenditure indicators). However to effectively capture health sensitivity, this expenditure indicator is used as sensitivity indicator.

Infrastructure capacity

The third and final dimension of adaptive capacity is the infrastructure capacity, as it reflects the availability of physical resources that enables adaptation. The infrastructure capacity is measured through infrastructure development index which is developed on the basis of a range of physical resources and hence represents the accessibility of the same to the vulnerable population, and proportion of expenditure on rural development in total public expenditure which captures the investment into the relatively backward sector of the society (compared to the urban sector) that also provides livelihood for large proportion of population.

In sum, the three dimensions of sensitivity capture the influence of shock on outcome through economic, demographic and social lenses. The three adaptive capacity dimensions on the other hand reflect entity's influence on outcome (or shortfall in the outcome caused by the shock) through economic, human and physical resources at its disposal.

Exposure to external shock (namely, globalization) is difficult to capture because contingent upon the stakeholder under consideration, it could be argued to contribute positively or negatively to vulnerability. For instance, if one looks from the perspective of agriculture, globalization leading to price fluctuations (along with natural factors such as climate variability) could cause instability in agricultural production. Increase in such an indicator of exposure could increase vulnerability. On the other hand, if one looks from the perspective of manufacturing sector, globalization would provide opportunities for entry into new markets and also could give scope for greater investment. Increase in such an indicator of exposure would decrease vulnerability, as higher exposure indicates the ability to make use of new opportunities. The exposure index constructed in the analysis captures these two conflicting aspects through instability in cereal production and percentage share of investment in manufacturing sector, respectively.

The data on all the indicators are collected for the sixteen states for two specific time points: 1990-91 and 1999-2000.[12] The two points chosen belong to the pre-reform and post-reform periods, respectively, and a comparison of the results across these two periods is expected to provide an idea about the dynamic nature of the vulnerability measure. The sources of data include various Reserve Bank of India Bulletins, CMIE reports, Central Statistical Organization reports, and Census reports. The data on per capita calorie intake are collected from Ray and Lancaster (2005), per capita foreign direct investment (FDI) is from Singh and Srinivasan (2002), inequality index (Gini) is from GoI (2001) and Datt *et al.* (1996), relative infrastructure index is from Ahluwalia (2001), the percentage of malnourished children is from IIPS (1994, 2000), and share of manufacturing investment is from Thomas (2002).

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[12] The data on certain indicators, such as population growth rate, instability in cereal production, percentage share of investment in the manufacturing sector, correspond to the decades prior to 1990-91 and 1999-2000. Data on malnourished children correspond to 1993 and 1998-99. Similarly, data on infrastructure development index correspond to 1990-91 and 1996-97.

Figure 3
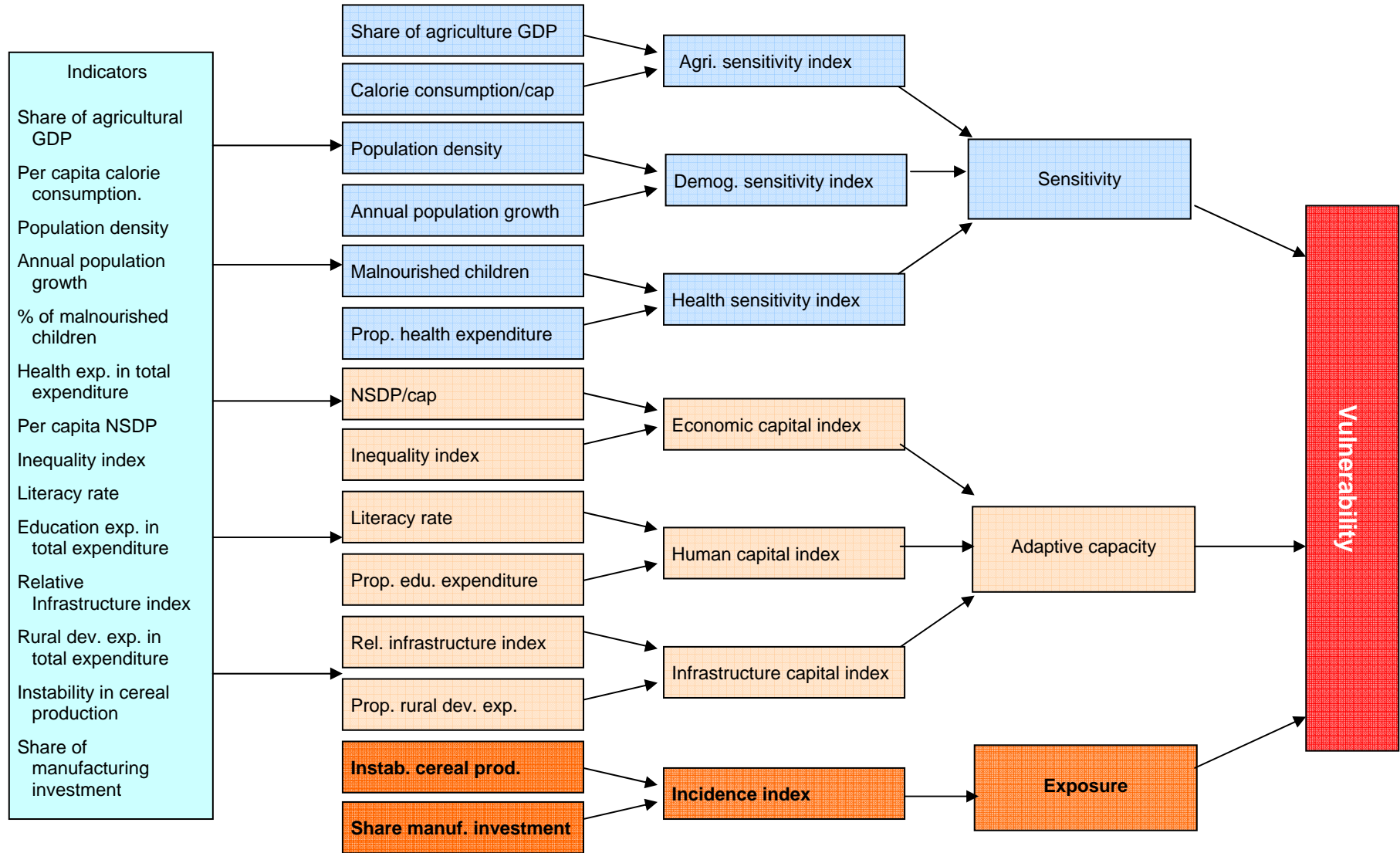Framework for vulnerability analysis

Table 1
Sensitivity, adaptive capacity and exposure—indicators and functional relationship

	Sector	Indicator	Represents	Functional Relationship
Sensitivity	Agriculture	Share of agricultural GDP	Dependency on agriculture: the livelihood provider for majority population	Sensitivity increases as share of agricultural GDP increases
		Per capita calorie consumption	Access to agricultural markets and other food distribution mechanisms	Sensitivity decreases as per capita calorie consumption increases
	Demography	Population density	Access to resources and opportunities	Sensitivity increases as population density increases
		Annual population growth rate	Resource allocation from dynamic perspective: a forward-looking indicator	Sensitivity increases as population growth rate increases
	Health	Percentage of malnourished children	Life-cycle measure of health and human capital	Sensitivity increases as proportion of malnourished children among children increases
		Proportion of health expenditure in total expenditure	Concern for healthy and productive society	Sensitivity decreases as health expenditure increases
Adaptive capacity	Economic	Per capita net state domestic product	Access to resources useful for adaptation	Adaptive capacity increases as per capital net state domestic product increases
		Gini coefficient	Degree of cohesiveness of society for adaptation	Adaptive capacity increases as inequity decreases
	Human	Literacy rate	Human capital and adaptability of labour force	Adaptive capacity increases as literacy increases
		Proportion of educational expenditure in total expenditure	Investment in human capital	Adaptive capacity increases as expenditure on education increases
Adaptive capacity	Infrastructure	Infrastructure development index	Physical resource capital for adaptation	Adaptive capacity increases with higher attainment of infrastructure development
		Proportion of rural development expenditure in total expenditure	Investment in rural sector: backward sector with larger proportion of population	Adaptive capacity increases as rural development expenditure increases
Exposure	Incidence	Instability in cereal production	Exogenous shock from market and physical (such as climatic) forces on agriculture	Exposure increases as instability in cereal production increases
		Percentage share of investment in manufacturing sector	Ability to make use of opportunity	Exposure decreases as share of investment in manufacturing sector increases

4.1 Results

At the outset, the use of the word 'vulnerability' needs clarification. The index calculated is being interpreted as the propensity of an individual to low welfare status when subjected to external stressors. Also, the vulnerability notion here is a relative one and not absolute.

The analysis involves carrying out three levels of aggregation: (i) at the first level, two indicators from each category are aggregated to arrive at various sensitivity, adaptive capacity and incidence indices; (ii) at the second level, three sensitivity indices are combined to form sensitivity index, and three adaptive capacity indices are aggregated to form adaptive capacity index; and (iii) at the third and final level sensitivity, adaptive capacity and incidence indices are combined to form overall vulnerability index. Table 2 shows the total aggregations carried out at each level of aggregation as well as the information on membership functions and the number of rules used.

Figure 4 shows the performance of each state in terms of sensitivity, adaptive capacity and exposure indices for before and after the 'reform' periods. Table 3 shows the relative vulnerability rankings of Indian states before and after the 'reforms'. The table also shows the state-wise rankings of sensitivity, adaptive capacity and exposure for the two time points of the analysis.

It may be noted that the analysis accounts for globalization and poverty only implicitly. Moreover, by no means it is implied that vulnerability is captured only through the selected set of indicators and the aggregation procedure followed. However, the proposed framework is believed to capture a forward-looking measure of wellbeing of the entity (viz., states of India) subjected to stressors that could be attributed to the globalization phenomenon.

In the pre-reform period, Orissa, Bihar, Rajasthan, Karnataka, Himachal Pradesh, Haryana and Gujarat were the six most vulnerable states, whereas Kerala, Punjab, Maharastra, Andhra Pradesh, Tamil Nadu and West Bengal were the six least vulnerable

Table 2
Characteristics of different levels of aggregation

Aggregation level	No. of inputs	Membership functions		No. of rules
		Input	Output	
I: Seven aggregations to generate seven indices	2	3 – low, medium, high	4 – low, medium, high, very high	9 (for each index)
II: Two aggregations to generate two indices	3	4 – low, medium, high, very high	6 – very low, low, fair, medium, high, very high	64 (for each index)
III: One aggregation to generate one index	3	6 – very low, low, fair, medium, high, very high	8 – lowest, very low, low, fair, medium, high, very high, highest	144

Note: At the third level of aggregation while two inputs (sensitivity and adaptive capacity) are characterized by six membership functions each, the third input (exposure) is represented by four membership functions, resulting in a total of 144 rules.

Figure 4
State level performance on sensitivity, adaptive capacity and exposure indices

Pre-Reform

Post-Reform
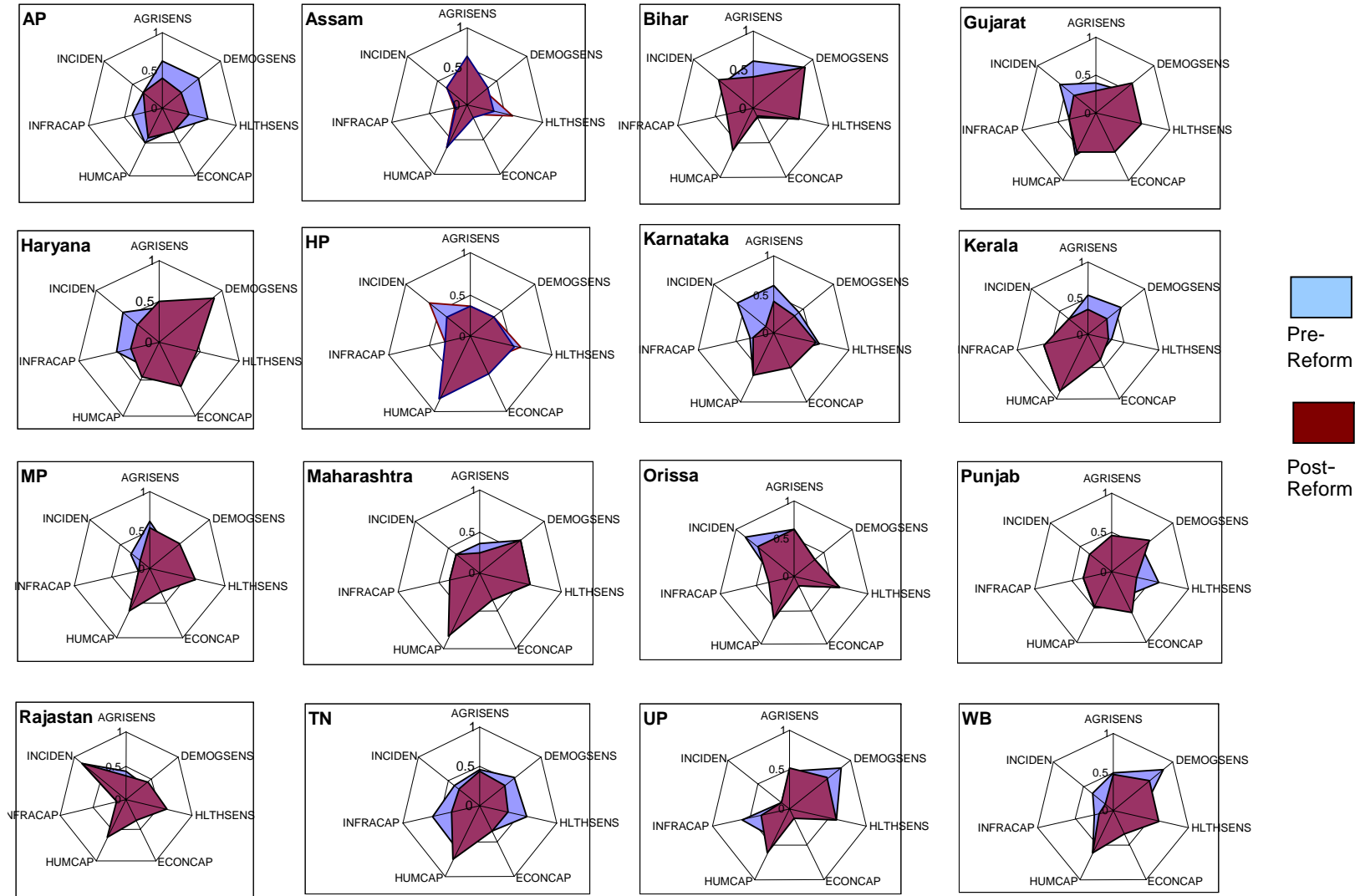
Source: Author's computations.

Table 3
Relative vulnerability ranking of Indian states

State	Vulnerability		Vulnerability		Sensitivity		Adaptive capacity		Exposure	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Andhra Pradesh	0.45	0.39	4	3	13	2	3	9	3	5
Assam	0.52	0.46	7	10	7	4	12	11	5	7
Bihar	0.68	0.65	15	14	15	16	16	15	10	14
Gujarat	0.55	0.44	10	8	3	11	5	3	12	13
Haryana	0.55	0.48	11	13	5	15	6	6	11	8
Himachal Pradesh	0.59	0.41	12	4	1	3	8	2	13	9
Karnata	0.62	0.38	13	2	12	5	9	8	14	2
Kerala	0.36	0.32	1	1	4	1	1	1	6	10
Maharastra	0.44	0.42	3	7	11	9	4	4	7	11
Madhya Pradesh	0.53	0.47	9	12	9	10	13	14	2	4
Orissa	0.70	0.68	16	16	10	12	14	16	16	15
Punjab	0.43	0.42	2	6	6	8	7	5	4	12
Rajasthan	0.67	0.66	14	15	2	7	15	13	15	16
Tamil Nadu	0.45	0.42	5	5	8	6	2	7	9	6
Uttar Pradesh	0.53	0.45	8	9	16	13	10	12	1	1
West Bengal	0.51	0.46	6	11	14	14	11	10	8	3

Notes:　'Pre' and 'post' represent the two time periods for which the vulnerability analysis is carried out;

Low rank represents low vulnerability, low sensitivity, high adaptive capacity and low exposure.

Source:　Authors' calculations.

states. Factors contributing towards vulnerability (or lack of it) are, however, different across different states. For instance, Orissa and Bihar were both vulnerable due to poor performance on sensitivity, adaptive capacity and exposure, whereas despite relatively lower sensitivity and moderate adaptive capacity, high exposure makes Rajasthan third most vulnerable state. Similarly, Andhra Pradesh, despite having very high sensitivity, shows low vulnerability due to high adaptive capacity and low exposure. Factors contributing towards high sensitivity (and adaptive capacity) are also different across different states. Bihar and Orissa, while having similar levels of agricultural and health sensitivity, differ in terms of their demographic sensitivity, with Orissa faring relatively better on that front.

In the post-reform period, the six most vulnerable states were Orissa, Rajasthan, Bihar, Haryana, Madhya Pradesh and West Bengal, and the six least vulnerable states were Kerala, Karnataka, Andhra Pradesh, Himachal Pradesh, Tamil Nadu and Punjab.

Comparison of the vulnerability and relative rankings highlight the following:

−　As expected, all states reduced their vulnerability in the 'post' reform period compared with their vulnerability in the 'pre' reform period. This could be attributed to a decline in exposure and sensitivity along with improvement in adaptive capacity.

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- Kerala remains the lowest vulnerable state, whereas Orissa retains its rank as the highest vulnerable state among the sixteen states. Bihar and Rajasthan also remain among the top vulnerable states.

- Karnataka and Himachal Pradesh showed significant improvement in their ranking, but due to different reasons. While Karnataka improved its ranking due to sharp decline in exposure (which is also captured in lower agricultural sensitivity), Himachal Pradesh moved up the ladder due to lower exposure as well as high adaptive capacity. Maharashtra also improved its ranking due to lower sensitivity and higher adaptive capacity.

- The tradeoff between sensitivity and exposure on one hand and adaptive capacity on the other, which leaves the rank unaltered, is best illustrated in the case of Gujarat and Haryana, where higher sensitivity is compensated by higher adaptive capacity and lower exposure. Similarly, the rank of Tamil Nadu remained same even though its adaptive capacity deteriorated because of lower sensitivity and exposure.

- It may also be noted that the focus on relative rankings masks other significant changes. For instance, the rank of Punjab deteriorated despite lower sensitivity and higher adaptive capacity. Similarly, the rank of West Bengal deteriorated despite marked decline in exposure.

The rank correlations between different indices in the 'pre' and 'post' reform period indicate that adaptive capacity rankings remained significantly similar (with correlation of about 0.82) across time, whereas the sensitivity rankings changed widely (with correlation of only about 0.4). The exposure rankings changed moderately over time (with correlation of about 0.52), to result in reasonably robust overall vulnerability ranking between the two periods (with correlation of about 0.6). However, the dynamic characteristic of vulnerability is reflected in the changing ranks of states—with the exception of three states, all other states showed rank changes between the two periods. This aspect of vulnerability measure is contrasted with other welfare indicators like human development index (HDI) in the following subsection.

4.2 Comparison of state rankings based on vulnerability and other indicators

Table 4 shows the state rankings based on vulnerability estimated in this study, along with the rankings based on various other indicators. The indicators used for comparison include other welfare indicators such the HDI and the share of 'below poverty line' (BPL) population, as well as such performance indicators as the flow of foreign direct investment (FDI) during the period 1991 to 2001 and an overall competitiveness index computed by National Productivity Council (2004) that takes into account the economic strength, business efficiency, governance quality, human resources and infrastructure.[13]

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[13] The comparison is by no means the most appropriate; for instance, HDI is assessed on the basis of only three indicators, namely per capita income, infant mortality and life expectancy as against fourteen indicators used in the construction of vulnerability index reported in this study. The comparison is made only to reflect the dynamic nature of vulnerability index.

State	Vulnerability		HDI		Share of BPL population		Per capita FDI flow	Competi-tiveness index
	Pre	Post	1991	2001	1987-88	1999-2000	1991-2001	2004
Andhra Pradesh	4	3	10	11	7	8	7	7
Assam	7	10	11	15	13	10	NA	15
Bihar	15	14	16	16	2	2	14	13
Gujarat	10	8	7	7	11	12	3	3
Haryana	11	13	6	6	14	14	6	8
Himachal Pradesh	12	4	3	3	NA	NA	NA	NA
Karnata	13	2	8	8	8	9	2	4
Kerala	1	1	1	1	12	13	12	5
Maharastra	3	7	5	5	3	4	1	1
Madhya Pradesh	9	12	14	13	5	3	8	10
Orissa	16	16	13	12	9	6	5	11
Punjab	2	6	2	2	15	15	10	2
Rajasthan	14	15	12	10	10	11	11	12
Tamil Nadu	5	5	4	4	6	7	4	6
Uttar Pradesh	8	9	15	14	1	1	13	14
West Bengal	6	11	9	9	4	5	9	9

Notes: 'Pre' and 'Post' represent the two time periods for which the vulnerability analysis is carried out;

FDI flow column shows the volume of per capita FDI flow during the period August 1991 to July 2001;

Low rank represents low vulnerability, high HDI, high FDI flows, high share of BPL population; high competitiveness index.

Sources: Own calculations for vulnerability rankings; GoI (2001) for HDI rankings; Singh and Srinivasan (2002) for FDI flows; NPL (2004) for competitiveness index.

The state rankings remained nearly constant in case of the welfare indicators HDI and share of BPL population (with a rank correlation of about 0.96 and 0.94, respectively), reflecting the static nature of such indicators. In contrast, the vulnerability rankings showed considerable variation across the two periods of analysis, indicating that vulnerability is a dynamic concept. That is, the entity that is vulnerable today need not remain so in the next period and at the same time, the currently non-vulnerable may not enjoy that status in future.

FDI flows to a state indicate the investor's assessment of its lower vulnerability status. Thus, higher FDI flows would always be to a low vulnerability region, while the vice versa need not hold. This can be seen from the FDI flows column in Table 4, where the FDI inflow into states like Kerala and Punjab is significantly low despite their low vulnerability ranks as estimated in this study. It may also be noted that the competitiveness index is fairly high for these states reflecting their lower vulnerable status. This contrast is mainly due to the nature of FDI flows, which are typically into the non-agricultural regions of developing countries.

5   Conclusions

This study proposed a framework for vulnerability assessment in the context of globalization and its impact on welfare. This framework is applied to study vulnerability with respect to welfare loss in sixteen major states of India. The vulnerability index is compared across two time periods—one corresponding to the pre-economic reform process initiated in 1991 in India and another representing the situation a decade later.

The vulnerability of an entity is conceptualized (following the practice in global climate change literature) as a function of its exposure, sensitivity and adaptive capacity. Empirical analysis based on such conceptualization demands the use of an indicator-based approach and the present study, while following indicator-based approach, uses fuzzy methodology that adequately captures the vagueness inherent in such approaches. The results show that the vulnerability indices estimated are dynamic in the sense that an entity that is vulnerable today need not remain so in the next period and, at the same time, currently non-vulnerable may not enjoy that status in future. The fact that other welfare indicators like HDI and proportion of population below poverty line fail to capture such forward-looking representation is clearly reflected in significantly stable relative rankings of states based on those indicators.

The choice of indicators used in the vulnerability assessment may need further refinement to best reflect the forward-looking nature of the overall index. Similarly, to capture the globalization more appropriately, the exposure index needs further strengthening. State-level data on openness is difficult to get. However, some recent studies (Marjit and Kar 2005) have attempted to construct such regional level indices, and it may be helpful to incorporate such data for constructing the exposure index. Some of the other indicators that could be included in the assessment are terms of trade, agricultural price volatility, and characteristics of the labour force in the informal sector in urban areas and the non-farm sector in rural areas.

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