Chapter 9
Managing Indirect Economic Consequences of Disaster Risk: The Case of Nepal

Reinhard Mechler, Stefan Hochrainer-Stigler, and Kazuyoshi Nakano

Abstract Natural disasters can exert significant economic and developmental impacts in countries that lack the economic resilience to bounce back post event. Yet, the brunt of these impacts often goes unrecorded and the information base for improving the financial and economic management of disaster risk in many instances is at best limited. Systematic disaster risk modeling can be a starting point for devising a comprehensive risk management approach. This chapter presents quantitative modeling analysis using the IIASA CATSIM framework for assessing economic natural disaster risk for the case of Nepal. We calculate country level direct disaster risk as well as the corresponding indirect effects using growth modeling and input-output analysis. We find the economic and fiscal risks posed by natural disasters in Nepal to be large and potentially long-lasting, particularly when they are triggered by earthquake risk. As well, disaster events ripple through the economy and may lead to important distributional effects. Given these results, we suggest there is a clear case for considering risk in economic and fiscal planning processes in Nepal and similar heavily disaster exposed countries.

Keywords Fiscal and economic risks • Disaster risk modeling • Multi-risk assessment • Extreme events • Nepal

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9.1 Assessing the Economic Impacts of Disasters in Nepal

Economic and developmental impacts of disasters in Nepal have been reported to be large and significant (Upreti 2006). Yet, as in many other heavily exposed, developing countries, the brunt of the impacts is hidden, very little quantitative data is available and there has not been systematic economic analysis of the repercussions of disaster risk. To tackle these issues and provide a more robust base for decisions, a consortium composed of the Asian Disaster Preparedness Centre (ADPC), the Norwegian Geological Institute (NGI) and IIASA developed an all-hazards risk model for Nepal to help inform effective risk management strategies (see ADPC, NGI and IIASA 2010). This chapter reports on one project element, the modeling of the indirect, economic risks of natural disasters in terms of potential fiscal and macroeconomic impacts using the IIASA Catastrophe Simulation Model (CATSIM) (for a model description see also Hochrainer-Stigler et al. 2012 in this volume). While estimates of direct risk based on an assessment of hazard, exposure, vulnerability and finally direct risk provide useful information, we argue – and demonstrate this for the case of Nepal – that information on economic risk, combining direct risk estimates with economic vulnerability and resilience, is key for informing decisions. In our analysis, we calculate country level direct disaster risk as well as the corresponding indirect effects using growth modeling and input-output analysis. We find the economic and fiscal risks triggered by natural disasters for Nepal to be large and potentially long-lasting, particularly when they are triggered by earthquake risk. Given these results, we suggest there is a clear case for considering risk in economic and fiscal planning processes in Nepal and similar heavily disaster exposed countries.

The chapter is organized as follows: In Sect. 9.2, we discuss the socio-economic context and the burdens imposed by disasters on Nepal. In Sect. 9.3, we introduce a number of options for better handling disasters, which may be informed by our modeling approach. Before we turn to discussing the application of CATSIM to the given case (Sect. 9.5), we introduce the main modeling steps in Sect. 9.4. We end with a discussion of results and some concluding remarks.

9.2 The Burden of Natural Disasters in Nepal

Natural hazards in Nepal are associated with large direct losses and significant burdens to development. While the direct impacts in theory can be readily observed (in practice they are often not systematically recorded), many indirect effects go unnoticed. These are difficult to observe and generally limited data is reported. In the following we discuss what is available in terms of data regarding socioeconomic characteristics of the country and information on direct and indirect observed impacts.

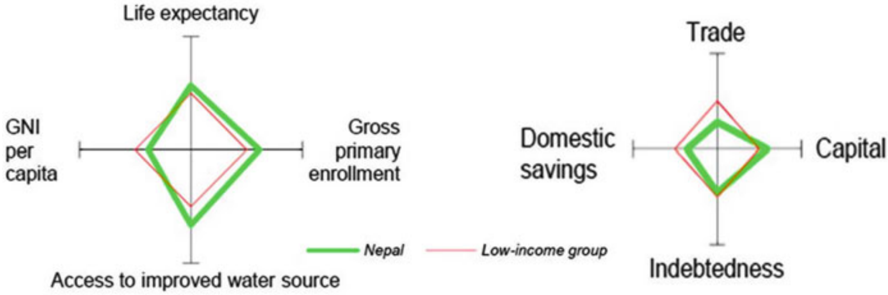

Fig. 9.1 Key development and economic indicators for Nepal as compared to the low-income group (Source: World Bank 2009)

9.2.1 Socioeconomic Context

Nepal is classified as a low income country with a high prevalence of poverty. Population under the poverty line recently exceeded 30%. Income per capita in 2008 was only about USD 250 (in constant 2000 USD) and is low even when compared to the low-income group of countries as defined by the World Bank. Also, domestic savings are low compared to the other countries classified by the World Bank as belonging to the low-income group (Fig. 9.1) (World Bank 2009).

Key socio-economic indicators and data for Nepal for the year 2008 are summarized in Table 9.1. While the World Bank classifies Nepal as a less indebted country, the level of external debt is high compared to the public budget. As one important indicator, the present value of external debt as measured against revenue excluding grants exceeded 247% in 2008. This means that the amount of debt which the government can additionally borrow from abroad is rather limited given that 250% for this indicator is often considered a threshold for debt sustainability (see HIPC 2002). Almost all of the external borrowing in Nepal is done by the central government. Most of the external debt is extended by multilaterals such as the World and Asian Development Banks. According to the World Development Indicators, external debt in the private sector was zero in 2008, and the private sector did not have access to international financial markets.

9.2.2 The Direct and Indirect Burden of Natural Disasters

Nepal is exposed to many different types of natural hazards, including earthquakes, floods, droughts, landslides and epidemics. Impact data, albeit with limited coverage, exists on the direct losses, fatalities and people affected. Looking back over the last 110 years (1901–2010) for which data exists, earthquakes and flooding can be

Table 9.1 Socio-economic indicators for Nepal (year 2008)

Social indicators	
Population	28 million
Surface area	147,180 km^2
Population density/km2	200
Population growth	1.8%
Life expectancy at birth	66
Infant mortality (per 1,000 live births)	40
Poverty (% of population below national poverty line)	31
Economic indicators	
GDP	7.3 billion USD
GDP per capita	253
GDP growth	5.3%
Fiscal revenue excluding grants	12.2% of GDP
Fiscal revenue including grants	15.8% of GDP
Inflation, consumer prices	10.9%
Present value of external debt (current USD)	2.2 billion USD
Present value of external debt	247% of revenue excluding grants

Source: World Bank (2009)
USD values in 2000 USD terms if not indicated otherwise

Table 9.2 Top 10 natural disasters in terms of people killed, affected and losses over the period 1901–2010

Disaster	Date	Killed	Disaster	Date	Affected	Disaster	Date	Losses[a]
Earthquake	1934	9,040	Drought	1979	3,500,000	Flood	1987	728
Epidemic	1991	1,334	Drought	1972	900,000	Earthquake	1980	246
Flood	1993	1,048	Flood	2004	800,015	Flood	1993	200
Epidemic	1950	1,000	Flood	2007	640,706	Earthquake	1988	60
Flood	1996	768	Flood	1993	553,268	Flood	2009	60
Earthquake	1988	709	Flood	1987	351,000	Flood	1998	22
Flood	1981	650	Earthquake	1988	301,016	Drought	1972	10
Epidemic	1992	640	Landslide	2002	265,865	Flood	1983	10
Landslide	2002	472	Earthquake	1980	240,600	Flood	2000	6.3
Flood	1970	350	Flood	1983	200,050	Wildfire	1992	6.2

Source: CRED (2010)
Note: Economic losses in this table means direct asset losses, which is not the same as the indirect, economic impacts discussed further below
[a]In million current USD

said to represent the largest threats to human life and economic assets. We focus on these two hazard types in the following model-based analysis. Table 9.2 summarizes the top ten disasters in terms of people killed, affected and direct losses over that time period.

Disasters are unevenly spread out over Nepal, and the highest impacts in terms of loss of life and loss of assets have been reported for Eastern Nepal, where a large part of the economic assets and the population is located (Upreti 2006).

As indicated above, there is little reported quantitative evidence regarding the full burden imposed by disasters in Nepal (see Upreti 2006), and next to nothing is known

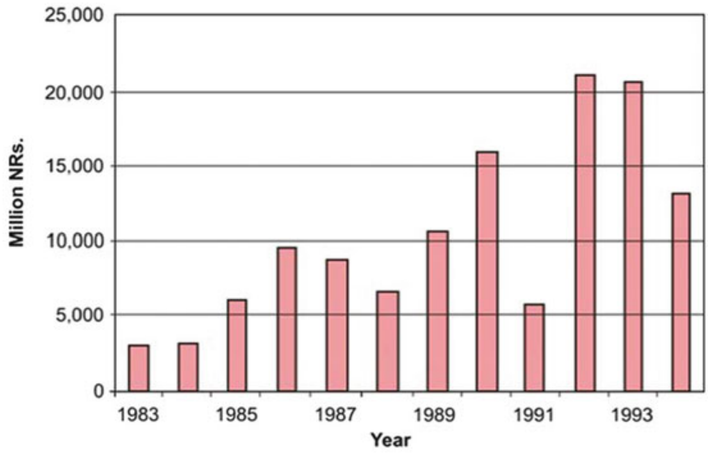

Fig. 9.2 Foreign assistance for disaster relief spending from 1983 to 1994 (Source: Upreti 2006). Note: In million Nepalí rupees. In 1994, 49.4 Nepalí rupees were equivalent to 1 USD (World Bank 2012)

about the economic implications including the macroeconomic impacts. It is known, however, that being a resource-constrained and least developed country (LDC), Nepal has been suffering disaster losses in the range of several billion rupees annually over the last few years. Also, the government of Nepal is already highly dependent on foreign assistance and lending, and about a third of the country's income stems from foreign aid with 64% of development spending disbursed by multilaterals (Bhattarai and Chhetri 2001). It comes as no surprise that foreign assistance for disasters has been large and rising as documented in Fig. 9.2 for the period 1983–1994, for which data was available.

Given a fragile economy exposed to substantial disaster risk, the government of Nepal is faced with developing far-reaching strategies, programmes and projects in order to ensure that key development and poverty alleviation objectives are achieved. It seems important to inform such planning by estimates of natural disaster risk and its potential economic repercussions. A number of entry points for better planning and managing risk exist, and in the following we discuss important disaster policy options, and particularly refer to those which our modeling approach may inform.

9.3 Policy Options for Managing Disaster Risk

9.3.1 Overview

Many options for reducing and managing disaster risk are available, in principle. After the fact (*ex post*) efforts such as providing relief and reconstruction are ever important and still dominate the field. Yet, as resources post-disaster are often very limited and risks are increasing, there is a critical need for stronger implementation of *ex ante* measures, which can be subsumed under the headings of risk assessment, risk prevention, preparedness and risk financing (see Table 9.3). All options need robust input from various sources, and those measures that are shaded in grey can be informed by our model-based analysis presented in this chapter.

In terms of ex ante approaches involving an estimate of risk, impact/risk assessment and planning can be informed using economic risk analysis; importantly, if risk is considered to be large, it should be mainstreamed into development. For risk prevention, economic incentives play a role, which can be informed by estimates of the developmental cost of disasters as well as the benefits of reducing those; education and awareness-raising is another important category for ensuring risk prevention. Risk sharing and financing options need to be based on economic analysis in order to properly identify which risks to keep, finance or transfer. In terms of ex post approaches, often involving an (deterministic) analysis of impacts, response options can be informed by economic loss assessments, consequently leading to the mobilization of financial and other recovery resources from sources such as the public sector, multilaterals or the insurance sector. For matters of reconstruction and rehabilitation, economic modeling can be helpful for designing options for revitalizing affected sectors such as tourism, agriculture, exports etc., as well as for sound macroeconomic and budget management in order to stabilize and protect social expenditures.

9.3.2 Planning Economic Risk

Our analysis focuses to a large extent on risk assessment and planning aspects of risk management. As one entry point, disaster risk can be incorporated into development plans and mainstreamed into strategies, plans, the budget, policies, regulations, programs and finally projects as shown in Fig. 9.3.

This analysis refers to integrating disaster risk with budget planning; the associated planning problem is one of contingency liability planning with fiscal disaster risk resulting from explicit and implicit contingent public sector liabilities. Before explaining in Sect. 9.4 how this problem is operationalized in CATSIM, we shortly discuss the relevance of risk for this as well as other problems in the context of decision making under risk.

9.3.3 Relevance of Risk for Assessing Options

Determining how much should be invested in risk reduction and how much in risk financing is not a straightforward proposition. It ultimately depends on the wider costs and benefits of both types of activities, on their interaction (e.g., financial instruments, through incentives, can influence prevention activities, see

Table 9.3 Overview of disaster risk management measures

Type	Ex ante risk management				Ex post disaster management	
	Risk assessment and planning	Prevention	Preparedness	Risk sharing and financing	Response	Reconstruction and rehabilitating
Effect	Assessing risk	Reducing risk by addressing underlying factors	Reducing risk in the onset of an event	Transferring risk by reducing variability and longer term consequences	Responding to an event	Rebuilding and rehabilitating post event
Key options	Hazard assessment and monitoring	Physical and structural risk reduction works (e.g. irrigation, embankments)	Early warning systems, communication systems	Risk transfer (by means of (re-) insurance) for public infra-structure and private assets, microinsurance	Humanitarian assistance	Rehabilitation/ reconstruction of damaged critical infrastructure
	Vulnerability assessment (population and assets exposed)	Land-use planning and building codes	Emergency response	Alternative risk transfer	Clean-up, temporary repairs and restoration of services	Revitalization for affected sectors (tourism, agriculture, exports etc.)
	Risk assessment as a function of hazard, exposure and vulnerability	Economic incentives for proactive risk management	Networks of emergency responders	National and local reserve funds	Loss assessments	Macroeconomic and budget management (stabilization, protection of social expenditures)
	Mainstreaming risk into development planning	Education, training and awareness raising about risks and prevention	Shelter facilities and evacuation plans	Calamity Funds (national or local level)	Mobilization of recovery resources (public/ multilateral/ insurance)	Incorporation of disaster mitigation components in reconstruction activities

Note: options marked in grey can be informed by the present analysis

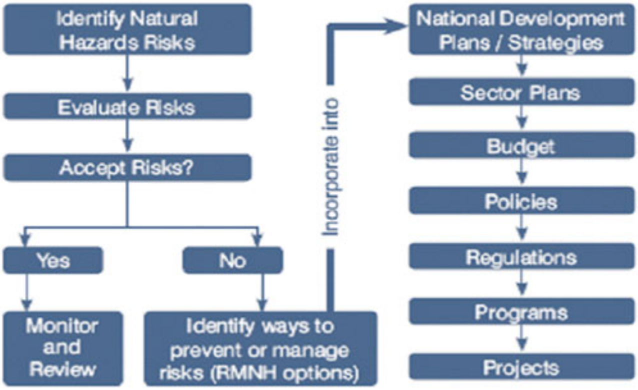

Fig. 9.3 Planning for disaster risks (Source: Bettencourt et al. 2006)

Linnerooth-Bayer et al. 2011) and their acceptability. Cost and benefits, in turn, depend on the nature of the hazard and risk. One way to think about the interaction and effectiveness of prevention and risk financing is by taking a layering approach shown in Fig. 9.4 (see also Chap. 16 in this book by Hochrainer-Stigler et al.).

For the low – to medium-sized loss events, which happen relatively frequently, prevention is likely to be more cost effective in reducing burdens. The reason is that the costs of prevention often increase disproportionately with the severity of the consequences. Moreover, individuals and governments are generally well able to finance lower consequence disaster events from their own means, for instance, savings or calamity reserve funds, and including international assistance. The opposite is generally the case for risk-financing instruments, including reserve funds, catastrophe bonds and contingent credit arrangements. These instruments do not reduce losses, but the variability around the losses, and thus only become cost-effective at higher costs associated with lower probability (e.g., at 100 year events). For this reason, it is generally advisable to use risk based instruments mainly for lower probability events that may have debilitating consequences (catastrophes). Finally, as shown in the uppermost layer of Fig. 9.4, individuals and governments will generally find it too costly to use risk financing (or risk reduction) instruments against very extreme risks occurring less frequently than, say, every 500 years. Overall, by taking a probabilistic approach, we can inform the full spectrum of options across the continuum of risk measures. As described below, our analysis which is based on the CATSIM model, provides an illustration of a probabilistic analysis.

9.4 Assessing and Planning for Economic Risk: CATSIM

When applying CATSIM to the Nepal case, we generally follow the approach discussed in Hochrainer-Stigler et al. (2013), but add a sectoral impact analysis module based on a Social Accounting Matrix (SAM) approach in order to represent

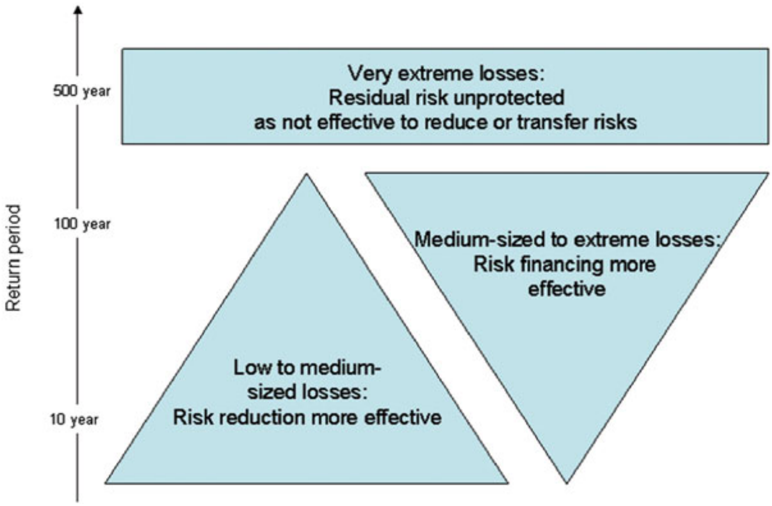

Fig. 9.4 The layering approach for risk reduction and risk financing

the distributional impacts of disasters. To properly introduce the analysis, we shortly describe the CATSIM methodology, which is organized around five steps, and we then give more emphasis to the analysis of aggregate and sectoral impacts as essential for step 4.

9.4.1 Methodological Steps of CATSIM

Step 1: Assessing asset risk

In the first step, risk is assessed in terms of the probability of asset losses (also called direct losses) in a relevant country or region. Consistent with general practice, risk is modeled as a function of hazard (frequency and intensity), the elements exposed to those hazards and their physical vulnerability. We assume that in the case of a disaster event, the government of Nepal will need to take responsibility for the following: (i) reconstruction of public assets: roads, bridges, schools, hospitals; (ii) provide relief and reconstruction support to private households and businesses temporarily affected; (iii) provide relief to the poor. This step in the methodology of CATSIM involves devising loss-frequency distributions, which relate probabilities to loss of assets.

Step 2: Assessing economic and fiscal resilience

A key aspect in CATSIM is the operationalization of economic and fiscal resilience. The focus is on the availability of internal and external savings of a country or region to spread risks and refinance losses as well as increased post-disaster expenditure needs, e.g. for supporting the private sector with relief and recovery assistance. Fiscal resilience is determined by the general conditions prevailing in an economy, i.e., changes in tax revenue have important implications on a country's financial capacity to deal with disaster losses. Governments can raise resources ex post or after a disaster by diverting funds from other budget items, imposing or raising taxes, taking credit from the Central Bank (which either prints money or depletes its foreign currency reserves), borrowing by issuing domestic bonds, borrowing from international institutions, issuing bonds on the international markets, and finally asking for outside assistance (Benson and Clay 2004; Fisher and Easterly 1990).

In addition to accessing ex post sources, a government can arrange for financial provisions before a disaster occurs (ex ante). Ex ante financing options include reserve funds, credit lines, traditional insurance instruments (public or private), or alternative insurance instruments, such as catastrophe bonds. These ex ante options can involve substantial annual payments and opportunity costs. Each of these financing sources is characterized by costs to the government as well as factors that constrain their availability, which are assessed by the CATSIM module. Sources not considered feasible are not included in the module. As an example, disaster taxes are expensive to administer and generally are not part of the public sector financing portfolio. Borrowing to finance deficits in the budget is heavily constrained by existing deficits and debt. To provide detail regarding the debt constraints, we employ a debt threshold for the present value of debt of 250% of revenue, which is often considered a critical debt threshold not to be exceeded (see HIPC 2002).

Step 3: Measuring financial and fiscal vulnerability by the "resource gap"
Using the information on direct risks and fiscal resilience, financial (or fiscal) vulnerability can be evaluated. Financial vulnerability is thus defined as the lack of access of a government to domestic and foreign savings for financing reconstruction investment and relief post-disaster. The shortfall in financing is measured by the term resource gap (or fiscal/financing gap). The resource gap is understood as the lack of financial resources to restore assets lost due to natural disasters and to continue with development as planned.

Step 4: Mainstreaming disaster risk into development planning
Ultimately the implications of disaster risk on economic development and other "flow variables" is of major interest when mainstreaming disaster risks into development planning and macroeconomic analysis. For that matter, direct risk, fiscal vulnerability and the prevalent economic conditions in Nepal are combined in order to derive an estimate of potential fiscal and macroeconomic impacts, such as in terms of GDP effects.

Step 5:Reducing risk and building resilience
CATSIM can illustrate the pros and cons of strategies for building economic and fiscal resilience using ex-ante financial instruments. Vulnerability and resilience are understood as properties of dynamic economic and social systems, which can adapt and manage shocks and surprises. As discussed, there are two broad types of risk based policy interventions: those that reduce the risks of disasters by reducing exposure and physical vulnerability, and those that build resilience of the responding agencies, e.g. by using financial risk management options. As CATSIM for the case of Nepal was used to examine and document disaster risk rather than test and examine options, for the present case we do not go into further detail on this model feature.

9.4.2 Modeling Aggregate Impacts

This analysis focusses on step 1 of CATSIM, or risk assessment, and in the following section we provide more detail regarding some technical aspects of modeling economic disaster risk. For the aggregate impacts, a production function approach is utilized for assessing GDP losses. As is standard practice in macroeconomics, a Cobb-Douglas type production function specification is used to project GDP based on inputs of capital and labor.

$$Y = AK^{\alpha}L^{\beta} \tag{9.1}$$

where K is capital, L is labor, Y represents GDP, and α, β are the production coefficients. For Nepal, parameters of the production function are estimated using data on GDP, capital and total labor force from 1980 to 2004 as given by the World Bank Development Indicators (World Bank 2012). Table 9.4 shows the results for the estimation of these parameters.

In a next step, GDP is "shocked" by reducing capital by a fraction ΔK lost in a disaster event

$$\Delta Y = AK^{\alpha}L^{\beta} - A\Delta K^{\alpha}L^{\beta} \tag{9.2}$$

The fraction of capital destroyed is determined by the asset loss distributions determined in Step 1. The decrease in capital stock in each event scenario can be obtained from random draws from the loss distribution used in CATSIM.

9.4.3 Modeling Sectoral Impacts

A disruption of one industrial sector can affect other economic agents through interdependencies within an economy. This is called a higher order effect. Disruption in one factory, for example, would lead to reduced orders for needed components. It would cause its suppliers to decrease their production and, in turn, to reduce their orders for inputs. This would continue up the supply chain. In a similar vein, the shutdown of a factory leads to decreases of demand for labor. This decreases the income of households, which in turn reduces final consumption of products leading to multiplier effects within the economy.

Table 9.4 Parameters of the aggregate production function for Nepal

	Coefficient	S.E	t value	P-value
Constant	4.64	2.02	2.295	0.0316
Capital	0.46	0.06	7.149	0.001
Labor	0.60	0.20	3.005	0.007

R square: 0.996

Multipliers and sectoral impacts can be estimated employing Input-output (I-O) analysis. I-O analysis is a standard method to study the interlinkages between economic sectors and the interconnectedness within an economy. An I-O table displays the flows of transaction within an economy. A Social Accounting Matrix (SAM) is an extension of an I-O model and additionally summarizes the distribution of income across certain types of households (see Stone 1961; Pyatt and Thorbecke 1976; Pyatt and Roe 1977). I-O and SAM analyses are common tools for the estimation of economic losses from natural disasters (see for example Okuyama 2008).

Figure 9.5 illustrates the logic of the SAM approach as employed in this study for Nepal. It starts from defining a so-called primary loss for each industry at first, which is the loss in output caused by the loss of capital stock discussed above and distributed over the economic sectors.

Based on the information of the primary loss, higher-order effects can be calculated using the SAM multiplier matrix. Because a SAM is a demand-driven model, the input data must be indicated in terms of change in demand. A change in demand is calculated by dividing the primary loss by the diagonal elements of the multiplier matrix (see Okuyama and Sahin 2009). Economic losses are then calculated by multiplying the demand change to the multiplier matrix.

For the Nepal analysis, we employ the Social Accounting Matrix as calibrated by Acharya (2007) for Nepal. Based on the loss distributions estimated with CATSIM and the aggregate GDP estimates presented above, we calculate sector specific losses and income impacts for household groups taking into account higher-order effects. The characteristics of the SAM approach for the given case are as follows (see also Appendix for the multiplier matrix): (i) Three economic sectors are considered, (ii) the inputs to production are capital, low-skilled labor and high-skilled labor; (iii) there are four population groups earning income: urban households, large rural households, small rural households, and landless rural households.

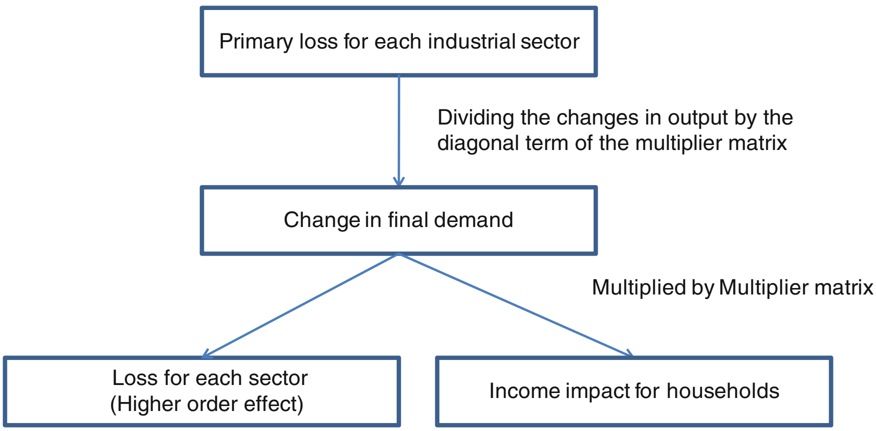

Fig. 9.5 Outline of the social accounting matrix approach

9.5 Results

We report results in terms of direct risk estimates, assessments of the economic risks as well as distributional impacts.

9.5.1 Assessment of Direct Asset Risks (Step 1)

In the first step, probabilistic asset risks for earthquake and flooding as well as the combined risks are estimated. Using information available on assets in Nepal as calculated for the project (see ADPC, NGI and IIASA 2010), a total value of capital stock of USD 75.3 billion is computed. As shown in Table 9.5, the values at risk for which the government is liable (contingent liabilities) are approximated overall at USD 37.7 billion. The calculation is made as follows: because little information is available on public sector capital stock in Nepal, it is assumed (in line with global averages) that approximately 30% of the total capital stock is public. Since one third of the population of Nepal is poor, the government will additionally absorb a large extra burden in the case of a disaster. Consistent with average figures (see Burby 1991; Freeman et al. 2002), it is further assumed that the government will have to spend an amount equivalent to another 20% of the total asset losses in order to provide relief.

The exposure information is combined with vulnerability and hazard data, and leads to individual loss distributions for flood and earthquake risk (see ADPC, NGI and IIASA 2010). These estimates are broadly based on the 1833 and 1934 earthquake events (estimated to have been 500 – and 100-year events, respectively) as well as 10-, 50 – and 100-year flood events (see Tables 9.6 and 9.7).

Table 9.5 Assets and government liabilities

Type	Billion USD
Private capital	52.8
Public capital	22.5
Total capital	75.3
Government contingent liabilities (public assets and assistance to private sector and households)	37.7

Table 9.6 Return periods and losses for flooding

Return Period	Probability	Losses(Million Nepali Rupee)	Losses(Million USD)
10	0.9	6,464	92
50	0.98	7,580	108
100	0.99	8,132	116

Table 9.7 Return periods and losses for earthquake risk

Return Period	Probability	Losses(Million Nepali Rupee)	Losses(Million USD)
100	0.99	1,017,827	14,540
500	0.998	1,102,685	15,752

Table 9.8 Potential joint losses associated with combined flood and earthquake risk

	Low estimate (Billion USD)	Central estimate (Billion USD)	High estimate (Billion USD)
20-year event loss	4.5	5.3	8.0
50-year event loss	7.0	9.7	10.5
100-year event loss	8.7	12.2	13.9
250-year event loss	12.0	16.8	17.6
500 year event loss	12.1	17.0	30.8

For our model-based economic risk assessment, a continuum of possible future risk scenarios is necessary, which requires fitting a whole distribution to these point estimates. Also, a convolution of flood and earthquake risk is required. Due to the small number of loss return periods available for the estimation of the extreme value distribution, past loss observations from the EM-DAT databases are also used to parametrize the distributions. Extreme value distributions were chosen from the broad class of the Generalized Extreme Value (GEV) distribution as well as the Generalized Pareto (GPD) and Weibull distributions. The GEV distribution performed best and was ultimately selected. This distribution is defined as:

$$H_{\xi(x)} = \begin{cases} \exp(-(1+\xi x)^{-1/\xi} & if\ \xi \neq 0 \\ \exp(-\exp(-x)) & if \xi = 0 \end{cases} \tag{9.3}$$

where$1 + \xi x > 0$

In order to account for the uncertainty associated with the estimation procedure, uncertainty bounds in the form of a central estimate (most probable case) as well as low and high estimates are examined. It is reasonable to assume that earthquakes and floods will occur independently, and we perform a convolution to get a joint loss distribution for Nepal. Convoluting two independent distributions with densities "f" and "g" is defined as:

$$(f * g)(x) = \int_{R^d} f(y)g(x-y)dy \tag{9.4}$$

We arrive at a joint distribution including low, central and high estimates with the following estimated losses (Table 9.8, Fig. 9.6).

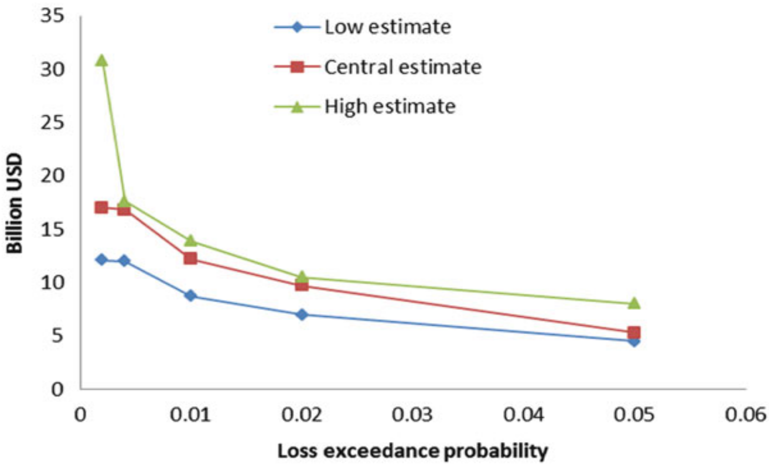

Fig. 9.6 Joint flood and earthquake risk distribution

9.5.2 *Estimation of Fiscal Resilience of the Public Sector (Step 2)*

An understanding of the sources for financing disasters in Nepal, including the costs and constraints, is crucial for planning a sound disaster risk management strategy. Concerning ex-post sources, Nepal is constrained by its fiscal inflexibility and low revenue base. Diversion from the budget is considered highly constrained, and therefore we assume that, as a maximum, 10% of the budget can be diverted. In line with empirical estimates across a sample of events, international assistance is assumed to be up to 10.4% of the total losses (see Freeman et al. 2002). Also, Nepal has very limited access to international capital markets, and thus it is assumed that Nepal can borrow only from multilateral sources at concessional rates and cannot issue any bonds in the international capital markets post disaster. The present value of external debt is over 240% of revenue in 2008. This means that the amount of debt which the government can additionally borrow from abroad is quite limited if a debt of 250% of revenue is considered a binding threshold for debt sustainability (see Table 9.9).

9.5.3 *Fiscal Vulnerability and the "Resource Gap" (Step 3)*

Summarizing all potential sources, the CATSIM model can provide an estimate of the government's fiscal vulnerability. It is most meaningful to assess the fiscal and economic consequences of exposure to both hazards jointly, as those are independent and thus may coincide in a short time span.

Table 9.9 Sources for financing disaster losses in Nepal

Source	Parameter value used
International donor assistance	10.4%
Diversion from budget	10%
Domestic bonds and credit	0
Multilateral borrowing	Very limited
Reserve fund	0
International borrowing	0

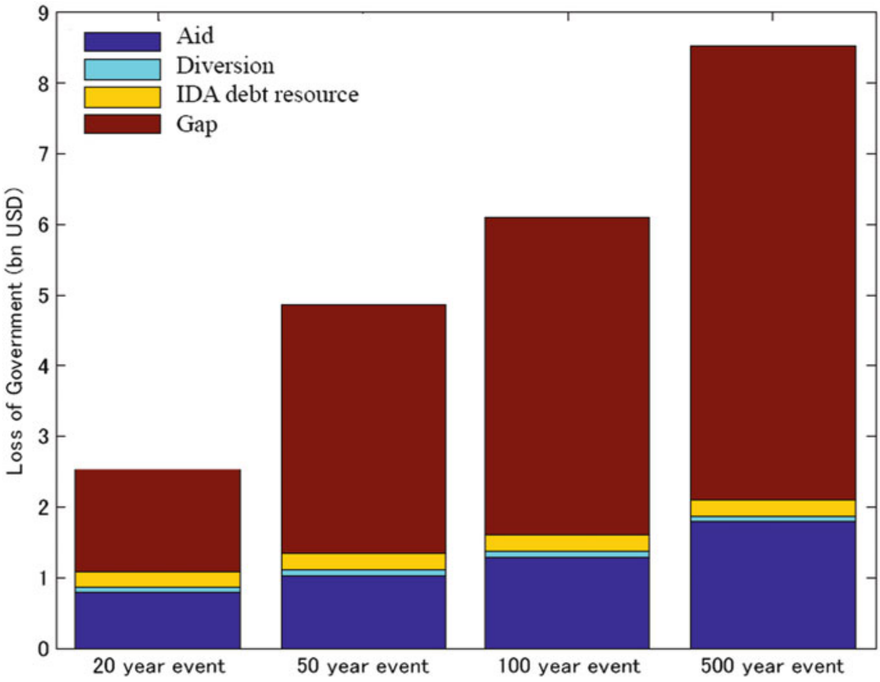

Fig. 9.7 Fiscal vulnerability and resource gap for the joint risk distribution (central estimate)

Given the assumptions and data as described above, Nepal's fiscal vulnerability to the combined risk is shown in Fig. 9.7 for the central estimate (we do not further show results for the low and high estimates in order to simplify the discussions and results generally are similar for these uncertainty ranges).

Fiscal vulnerability is considerably high and already for an event as frequent as a 20-year return period, the public authorities in Nepal would face difficulties raising sufficient funding. Here, the resource gap could amount to more than USD 1.3 billion, given our analysis. Available funding for this event includes aid inflows, which could amount to as much as USD 800 million, USD 50 million may be diverted from the budget, and another USD 150 million could be borrowed on highly concessional terms, such as offered by the World Bank through the International Development Bank (IDA). Keeping data limitations and restrictive

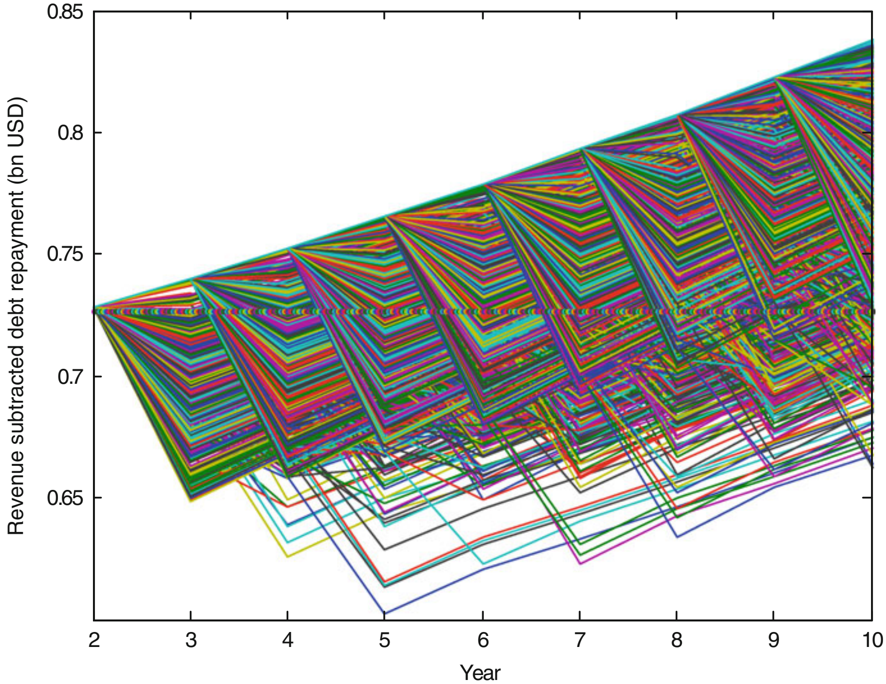

Fig. 9.8 Potential fiscal impacts due to the joint risk of flood and earthquake

assumptions in mind, this analysis shows that the government of Nepal has vastly insufficient financing resources available for tackling a relatively frequent 20-year event. The key driver behind the losses is earthquake risk, which is almost two magnitudes higher in terms of losses than flood risk.

9.5.4 Mainstreaming Disaster Risk into Macroeconomic and Development Planning (Step 4)

As a next step, risk and fiscal vulnerability is integrated with a model of the economic system in order to assess aggregate fiscal and economic effects.

9.5.4.1 Aggregate Analysis

As discussed, in order to mainstream and assess risk, a production function is established relating assets to flow variables (consequences of business interruptions etc.). Now using stochastic sampling approaches, fiscal and macroeconomic projections taking account of risk can be performed. Figures 9.8 and 9.9 show a

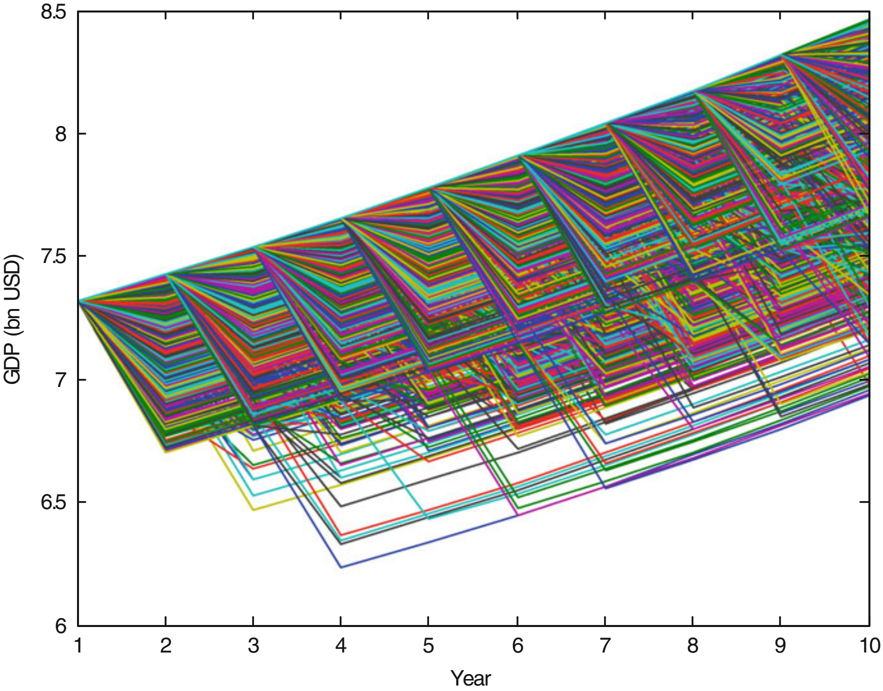

Fig. 9.9 Potential GDP impacts due to joint risk of flood and earthquake. Note: the time period considered is 2011–2020

selection of trajectories for fiscal and macroeconomic impacts for Nepal.[1] In Fig. 9.8, potential trajectories for government revenue (less repayments for debt) are outlined. This variable is a useful indicator representing budget flexibility (*fiscal space*) after mainstreaming disaster losses and government relief requirements into the projections. The graph shows that in the cases without disasters, budget flexibility would increase; yet in many instance, there is a potential for disasters seriously affecting budget flexibility, which in a number of scenarios would be highly reduced over the 10 year modeling time horizon.

We can further investigate fiscal space under disaster risk using the present value of government resources, discounted over time, and compare this to a baseline case without including disaster risk (see Table 9.10). In year 10, fiscal space as measured by the present value of budgetary resources would decrease on average by about 30% when explicitly factoring in disaster risk, and the standard deviation would equal about 36%. Considering another indicator for fiscal risk, the probability of a

[1] In the calculation, it is assumed that the private sector invests a certain ratio of GDP to capital if no disaster happens. If a disaster happens, the private sector does not get external funding for recovery (as it does not have access to the financial markets), so that the damaged capital cannot be restored immediately.

Table 9.10 Indicators for fiscal risk (in year 10 of the modeling time horizon)

Key variable	Decrease in PV of budget revenue (mean)	Decrease in PV of budget revenue (standard deviation)	Probability of resource gap
Joint earthquake and flood (central estimate)	29.7%	36.2%	57.8%

Note: PV is present value

resource gap, which is estimated at close to 60%, it seems very likely that events may occur in the near future that deteriorate public finances and cause longer term adverse macroeconomic impacts.

In a next step, aggregate economic risk is modeled and Fig. 9.9 identifies aggregate impacts on GDP based on risk, very limited resilience of the private sector and limited resilience of public authorities to respond. The GDP indicator shows that given limited resilience, disaster events may result in a lower economic growth trajectory. As with the fiscal impacts, the occurrence of such trajectories is stochastic and depends on the probability distribution of the losses (about 10,000 trajectories are calculated in this analysis). In a number of cases, GDP would be significantly reduced compared to the business-as-usual case.

9.5.4.2 Intersectoral Linkages

In a next step, we calculate the intersectoral impacts of disaster risk. Due to computational complexities involved in running the stochastic scenarios, the SAM approach cannot easily be reconciled with the risk analytical methodology, and we thus focus on a scenario earthquake event with a 100-year return period, which is roughly equal in intensity to the devastating event of 1934. The disastrous event of 1934, the so called Bihar/Nepal Earthquake, heavily affected the capital region of the Kathmandu Valley, killed about 9,000 people, destroyed 20% of the valley's assets and severely damaged another 40%. For such an event, asset losses of about USD 14.5 billion have been estimated for today as documented in Table 9.2. The primary affected sectors are housing, education, health, transportation, industry (manufacturing), and power infrastructure. Among them, the shutdown of the manufacturing sector would most seriously decrease its purchases of intermediate input. This study, therefore, focuses on the ripple effect due to a shutdown of the manufacturing sector. Table 9.11 and Fig. 9.10 summarize the primary loss and calculated loss as well as income impact of households for this scenario earthquake as one example. It can be observed that the primary GDP loss (about USD 730 million) is doubled (about USD 1,420 million) by the multiplier effect as economic interdependencies reduce demand for agricultural goods as well as commercial and public services. The total value of the higher order loss would thus amount to as much as approximately 19% of current GDP, which seems reasonable for such a catastrophic event destroying a fifth of the total assets in Nepal.

Table 9.11 Primary and higher order losses of a scenario earthquake of the severity of the 1934 earthquake (current million USD)

Sector	Primary GDP loss	Higher order GDP loss	Income loss
Agriculture	–	383.3	–
Industry	731.5	731.5	–
Commercial service	–	228.6	–
Public service	–	80.7	–
Urban household	–	–	201.4
Large rural household	–	–	143.0
Small Rural household	–	–	181.9
Landless rural household	–	–	97.3
Total	731.5	1,424.1	624.5
% GDP	10%	19%	

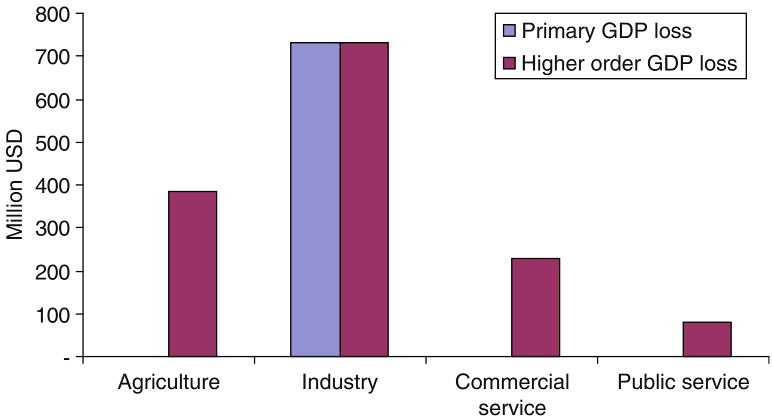

Fig. 9.10 Primary and higher order losses for a 1934 scenario earthquake (in absolute USD terms)

As to the distribution of the shock, income losses may spread from urban areas to the countryside due to reduced demand for agricultural commodities by those directly affected. Consequently income for rural households, which are not directly affected by such an event, would ultimately also be reduced (Fig. 9.11).

Our analysis underlines the potentially large distributional effects of a catastrophe event, such as a 100-year earthquake, on overall GDP as well as associated linkage effects on the different households considered. It is worth noting that it would be desirable to crosscheck our results with recorded economic impacts associated with large disasters in Nepal, particularly impacts for the 1934 catastrophe. Yet, as outlined in the introduction, these effects are often hidden, and for the 1934 event, beyond discussions regarding the immense suffering, there is no public

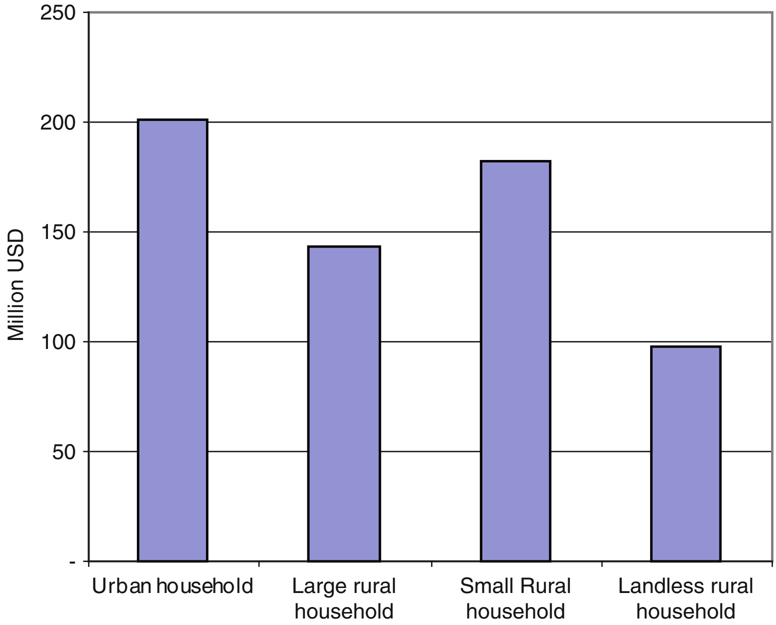

Fig. 9.11 Income effects for an earthquake of the size of the 1934 event

record of the economic effects. Also, it has to be noted here, that this analysis is of short term nature (1 year) and in the medium term response mechanisms facilitating a recovery would need to be considered. Using the CATSIM framework, risk and disaster management options may be identified and tested in this modeling framework, which, however, was not the purpose of the project, and had to be left as a potential consideration for further model applications.

9.6 Discussion and Conclusions

Disasters are considered a serious threat to lives and property in Nepal. The disaster burden imposed is considered heavy, yet little is known regarding the true economic impacts and losses. For this matter, economic risk analysis involving catastrophe modeling was undertaken and formed an important part of the project on developing an all-hazards model for Nepal.

The risk-based economic analysis reported here centered on examining the fiscal and economic effects of earthquake and flood risk across Nepal, which are often considered the key hazards leading to macroeconomic impacts. The analysis shows that the economic and fiscal risks posed by natural disasters are large for Nepal, and there is a clear case for considering these impacts in economic and fiscal planning. In particular, earthquake risk, for which a 100-year event of the size of the 1934 event may mean losses of about USD 15 billion, can lead to large fiscal and economic impacts. Yet, given limited fiscal resilience, an event as frequent as every 20 years may already lead to a resource gap, which is defined as the inability to provide key relief and reconstruction requirements post disaster. If disaster risk is explicitly considered in economic planning and a 10-year time horizon, we find fiscal space reduced by about 30% compared to a case without consideration of disaster risk. Finally, when using a social accounting matrix approach to derive intersectoral linkages, we estimate that a large disaster event, such as that of the size of the 1934 earthquake would lead to substantial (in the range of 20%) reductions in GDP due to linkages across primarily unaffected sectors, such as agriculture.

As a key application, the economic modeling presented may inform contingency liability planning in disaster exposed and vulnerable countries. As another application, CATSIM modeling may inform relief and reconstruction efforts post event. The analysis demonstrates that disasters like earthquakes and floods may ripple through an economy and indirectly affect sectors that were not impacted directly by the disaster event. As a consequence, it is worth considering important cross-sector linkages in any strategy that touches upon the consequences of disaster risk on the economy overall.

We conclude that in the face of massive disaster risk coupled with limited resilience, the Nepalese government should consider a position of risk aversion, and risks should be explicitly accounted for (*ex ante* approach). The need for taking a risk averse position can also be supported by looking at the empirical indicators related to disaster spending shown in Sect. 9.2. Even in the absence of major disasters, the government of Nepal is already highly dependent on foreign support, with about a third of the country's income from foreign aid and more than 60% of development spending financed by multilaterals. As disasters and the necessary spending for relief and reconstruction often lead to a significant loss of these scarce resources, implementing options for limiting such a drain on funding is important.

Finally, a word of caution has to be expressed regarding model calibration as well as the risk estimates. The results are necessarily associated with considerable uncertainties, which were captured by us where possible. For example, we used mean estimates and also incorporated uncertainty in terms of estimates of low and high risk. These often large uncertainties need to be factored into any analysis, and before attempting to derive very specific policy recommendations for risk management, there is a need for further investigations and discussion with key experts and stakeholders on policy priorities including disaster risk options. In Nepal, a process involving the Ministry of Home Affairs, donors and development banks has been initiated. We hope that the modeling presented here may ultimately contribute to better bolstering Nepal against disaster risk.

Appendix

SAM Multiplier Coefficients Table for Nepal Based on Acharya (2007)

	Agriculture	Industry	Commerce	Public sector	Wage to low-skilled labor	Wage to high-skilled labor	Capital	Urban household	Large rural household	Small rural household	Landless rural household	Firms
Agriculture	1.94	0.78	0.72	0.62	1.13	1.03	0.89	1.05	0.74	1.22	1.33	0
Industry	0.43	1.50	0.42	0.41	0.58	0.54	0.47	0.53	0.43	0.67	0.60	0
Commerce	0.64	0.47	1.65	0.53	0.74	0.74	0.63	0.90	0.54	0.71	0.72	0
Public sector	0.20	0.17	0.22	1.17	0.27	0.25	0.21	0.26	0.19	0.26	0.33	0
Wage to low-skilled labor	0.74	0.44	0.54	0.56	1.54	0.51	0.44	0.54	0.37	0.57	0.62	0
Wage to high-skilled labor	0.20	0.19	0.18	0.29	0.18	1.17	0.14	0.18	0.13	0.19	0.20	0
Capital	0.96	0.75	0.96	0.52	0.77	0.73	1.63	0.80	0.54	0.81	0.84	0
Urban household	0.56	0.41	0.50	0.42	0.71	0.81	0.66	1.45	0.31	0.46	0.49	0
Large rural household	0.39	0.29	0.36	0.28	0.45	0.57	0.49	0.32	1.22	0.33	0.34	0
Small rural household	0.53	0.37	0.45	0.38	0.76	0.60	0.57	0.42	0.28	1.43	0.46	0
Landless rural household	0.29	0.20	0.24	0.22	0.47	0.33	0.27	0.23	0.16	0.24	1.25	0
Firms	0.13	0.10	0.13	0.07	0.11	0.10	0.22	0.11	0.08	0.11	0.12	1

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