CHAPTER 10

Investigating Build-Forward-Better Disaster Recovery Policies for Nepal 2015 Earthquake Recovery: An Approach Using a Recursive General Equilibrium Model

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10.1 Introduction

Two great earthquakes over magnitude 7.6 hit Nepal in April 2015 in the Gorkha district, 180 kilometers northwest of the capital city, Kathmandu. As of 2019, the losses of 8,970 lives and 22,303 casualties were confirmed, with 893,786 partially and fully collapsed buildings; economic losses of 706 billion Nepalese rupees (NRs) or $7 billion were estimated, and more than 800,000 people were displaced (Subedi and Chhetri 2019). The aftermath and reconstruction work faced adversity: the affected area, including the capital city, which had already been damaged severely, was hit by an energy crisis the next year, 2016. Several investigations have been conducted to analyze the building damages and losses (Government of Nepal 2015a, 2015b). The recovery was focused on build-back-better plans, prioritizing the repair of vulnerable nonengineered buildings that were earthquake hazards due to being constructions by uncertificated architects and engineers. Thereafter, the preliminary assessment for build-forward-better approaches was critical to adequate recovery with new development technology (Ulak 2016; Molden, Sharma, and Acharya 2016)

Nepal is abundant in resources for hydropower and solar energy, but its development only contributes 5% of the total renewable energy supply. While biomass accounts for most of the household energy use, imported energy sources like oil and coal are mainly utilized for industry (IRENA 2022). The initial infrastructure investment may be unaffordable among ordinary households, as Nepal's gross domestic product (GDP) per capita reached just $1,180 in 2020 (IMF 2022). However, due to technological development and declining costs, renewable energy has become an important solution in achieving environmental sustainability, energy for supply, and economic development (Aoshima and Asano 2017). Furthermore, while approximately 76% of the Nepalese population has access to electricity, many households rely solely on traditional biomass sources for cooking, resulting in heavy air pollution and life-threatening diseases. Therefore, as Nepal undergoes reconstruction activities, better resilience in critical sectors has become an essential element in effective risk reduction toward sustainable development.

A steady power supply could greatly help disaster preparedness, increase resilience, and reduce vulnerability. However, a comprehensive approach combining renewable energy and disaster recovery is rarely mentioned, partly due to the data inaccessibility and limited market scale. While most impact assessments of the Nepal earthquake of 2015 focused on direct physical impact, they seemed to have left gaps for indirect impact analyses of recovery policy as well as the roles of fiscal, international trade, or technology policy. This research aims to construct an evidence-based approach to establish a comprehensive framework to visualize the options for build-forward-better policies, their potential impact, and their costs to help policymakers make recovery decisions with sectoral compensation/subsidy policy for Nepal's 2015 earthquake.

In addition to international aid, government revenue is a primary source of funds for disaster recovery plans. The breakdown of Nepal's government revenue (Table 10.1) has changed significantly over time, especially in the category of customs tax, which indicates that the tariff reduction on imported sources facilitates the reconstruction process and speeds up the recovery. For a landlocked country like Nepal, growing trade volume may also help reduce the burden of domestic production during the aftermath, allowing more capital factors to be reallocated for reconstruction.

Table 10.1: Tax Revenue for the Government of Nepal, 2010 and 2020

Fiscal Year 2010			
Form of Taxes	Amount (NRs million)	Total Tax Revenue Ratio (%)	GDP Ratio (%)
VAT	61,680	29.4	4.4
Income tax	41,720	19.9	3.0
Excise duty	26,450	12.6	1.9
Customs duty	80,200	38.2	5.7
Total	210,050	100.0	14.9
Fiscal Year 2020			
Form of Taxes	Amount (NRs million)	Total Tax Revenue Ratio (%)	GDP Ratio (%)
VAT	263,750	37.7	7.0
Income tax	197,690	28.2	5.2
Excise duty	100,620	14.4	2.7
Customs duty	137,990	19.7	3.7
Total	700,050	100.0	18.6

GDP = gross domestic product, NRs = Nepalese rupees, VAT = value-added tax.

Note: The GDP of Nepal was NRs1,409,730 million in 2010 and NRs3,767,040 million in 2020.

Source: Nepal Annual Economic Report 2067–2068 [2010–2011 CE], published by the Inland Revenue Department, Government of Nepal.

To provide an evidence-based quantitative approach to investigate the cost-effectiveness of recovery policy for Nepal's 2015 earthquake, we developed a dynamic computable general equilibrium (CGE) model applying Nepal's 2010 input–output table to examine further the sectoral impact and the government's fiscal, trade, and technology policy for build-back-better and build-forward-better approaches.

10.2 Methodology

The purpose of this research is to develop a practical framework of disaster policy analysis for Nepal's earthquake recovery through a macroeconomic scope, focusing on the disaster impact assessments and with an effective compensation/subsidy policy to help the damaged sectors to recover with resilience, an approach that is often called "build forward better." The macroeconomic framework developed in this research will enable us to combine the estimates of the direct physical impact of a disaster from an engineering viewpoint with an economic model. More specifically, the research aims to develop a method to estimate loss production factors (e.g., capital, labor) and a new composite of power generation invested in the new technology infrastructure. Compared with conventional disaster studies from engineering viewpoints of physical losses, the research aims to demonstrate the disaster impact assessment and the recovery framework by constructing a recursive multi-sector CGE model based on the optimization behavior of individual households and firms and their market competition (Hosoe, Gasawa, and Hashimoto 2010; Rose and Guha 2004) to analyze the earthquake's economic impact on Nepal. In addition, the CGE models to be used in the research would help analyze the aggregate welfare and distributional impacts of policies through multiple markets for various types of fiscal measures (e.g., taxation and subsidy) by the government (Adam 2013).

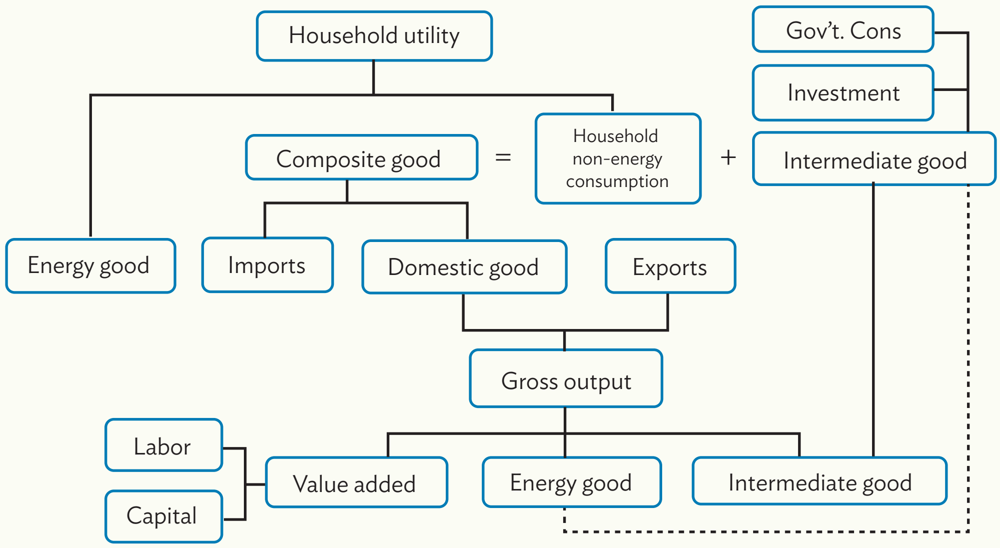
In addition to the statistics surveyed by the disaster recovery agency, the research focuses on designing a survey question and index method for collecting the most informative data (Kajitani and Tatano 2009). An input–output table on the selected region and key sectors were used to construct the empirical model. The government mechanisms and policy practices were grounded for making plausible policy instruments for simulations with the calibration of collected data. Constructing a framework to demonstrate the economic impact and recovery policy in various disaster scenarios could enable the quantification of the sectoral disaster impact and provide recovery policy options (Huang and Hosoe 2016, 2017; Tanaka and Huang 2021).

The research was conducted using general equilibrium analysis to construct a disaster impact assessment and recovery framework through various policy simulations. The Nepalese 2010 input–output table (Paudel 2014) was applied and aggregated from 38 to 10 sectors to obtain the realistic coefficient to examine sectoral interdependence (details in Table A10.1). To better capture the international economy feature, we extended Nepal's input–output table by including the tariff rates based on the trade policy review (WTO 2014). This framework is expected to assist policymakers in better managing disaster risks and developing industrial recovery plans based on quantitative assessments. In addition, such a synergic instrument could describe how disaster shocks are propagated in an economy and how indirect loss amounts are generated. The implementation of a recovery policy by providing compensation/subsidies was made in policy simulations using the CGE model following the capacity and estimated construction cost. The framework was used to simulate different policy options on the investment amount in renewable sectors and examine the sectoral impact.

10.2.1 Analytical Process

The disaster impact assessments and the input–output table for renewable energy made it possible to construct a recursive CGE model for the disaster recovery policy simulations (Figure 10.1). In all scenarios, a 10-year compensation for (i) capital-use subsidy as renovation for manufacturing facilities, (ii) production subsidy as an incentive for production, and (iii) tariff removal as trade liberalization was made for all sectors to examine its cost-effectiveness and recovery resilience. Thanks to data availability, technical assistance, and collaboration between Nepal and Japan, we were able to calibrate the energy technology improvement parameter from Japan (Huang and Kuroda 2021) to scrutinize its application in the recovery process with higher energy efficiency in Nepal. This allowed us to observe its impact in the build-forward-better recovery process. This technological parameter is for macroeconomic simulations and is thus not limited to the products from a certain country in sectors of machinery or energy. Finally, this recursive CGE model was applied to examine the fiscal cost of compensation/subsidy recovery policy and the consequences of welfare change. The simulation results provide quantified information on the recovery speed and fiscal and social benefits/costs as consequences.

Figure 10.1: The Computable General Equilibrium Model Structure



Source: Compiled from Huang and Hosoe (2016).

10.2.2 Scenarios

Nepal's 2015 earthquake. There has been no specific quantitative analysis on the losses of sectors in the Nepal earthquake of 2015. To recreate the scenario of the earthquake, we used the sectoral impact estimated by the Government of Nepal (2015b) divided by the pre-disaster stock sourced from the 2014–2015 national accounts (Ministry of Finance 2015). To estimate the loss in the capital stock, we multiplied the sectoral output reduction by the capital ratio to determine the damage in sectors and the labor endowment loss. The sectoral damage and labor endowment are stated in Table 10.2.

Table 10.2: Sectoral Damage from the 2015 Earthquake

Sector	2014 Output (NRs million)	2015 Loss (NRs million)	Capital Ratio (%)	Damage (%)
Agriculture	831,007	62,387	50.7	3.8
Energy	62,863	6,529	82.8	8.6
Food*	452,400	121,696	80.3	21.6
Metals*			79.8	21.5
Machinery*			76.4	20.6
Manufacturing*			76.4	20.6
Trade	354,858	16,593	57.5	2.7
Tourism	123,683	76,522	48.4	29.9
Transportation	287,807	35,533	67.9	8.4
Service	744,408	105,707	62.9	8.9
Labor endowment (million people)	26.5	5.6	49.3	10.4

* These four sectors are aggregated in the same sector in Government of Nepal (2015b).

Source: Estimated by authors based on Government of Nepal (2015b) and Ministry of Finance (2015).

Based on the recursive CGE model structure of recovery policy (Huang and Hosoe 2017; Tanaka and Huang 2021), the capital factor is immobile and sector specific. This indicates that the capital stock would not increase as time passed unless the surplus occurred as an investment. By contrast, the labor factor is mobile among production sectors, allowing the flow from sectors upon their optimal rationales. The labor losses do not necessarily imply mortality, but may reflect the temporary shortage, displacement, or unavailability in damaged facilities due to the earthquake. Based on the large-scale disaster recovery process, employment was assumed to resume within 5 years (Huang and Hosoe 2017; Tanaka and Huang 2021). Finally, social welfare was determined as equivalent variations of the household utility change affected by the price changes triggered by the policies.

Ten-year recovery policy for building back better. To examine the effective compensation and recovery policy toward the target year—the 11th year after the disaster—we designed three types of subsidies as incentives to be implemented for 10 years to stimulate the sectoral output to rebound to its pre-disaster business-as-usual level and further investigate the welfare change for the tariff removal policy. In the model structure, the policy should be financed from a lump-sum tax, and it also could be referable as the budget needed to reach the recovery target. These policy simulations demonstrate a numerical approach for build-back-better policy analysis. The required subsidy rates are stated in Table 10.3 for the following recovery policies:

- **Capital-use subsidy:** Provide a subsidy to reconstruct the damaged buildings, factories, or facilities such as machines for production operation.
- **Production subsidy:** Provide a subsidy as an incentive for firms to produce more.
- **Tariff removal:** Remove the current sectoral tariff as trade liberalization.

Table 10.3: Sectoral Subsidy Rates for Recovery Policies
(%)

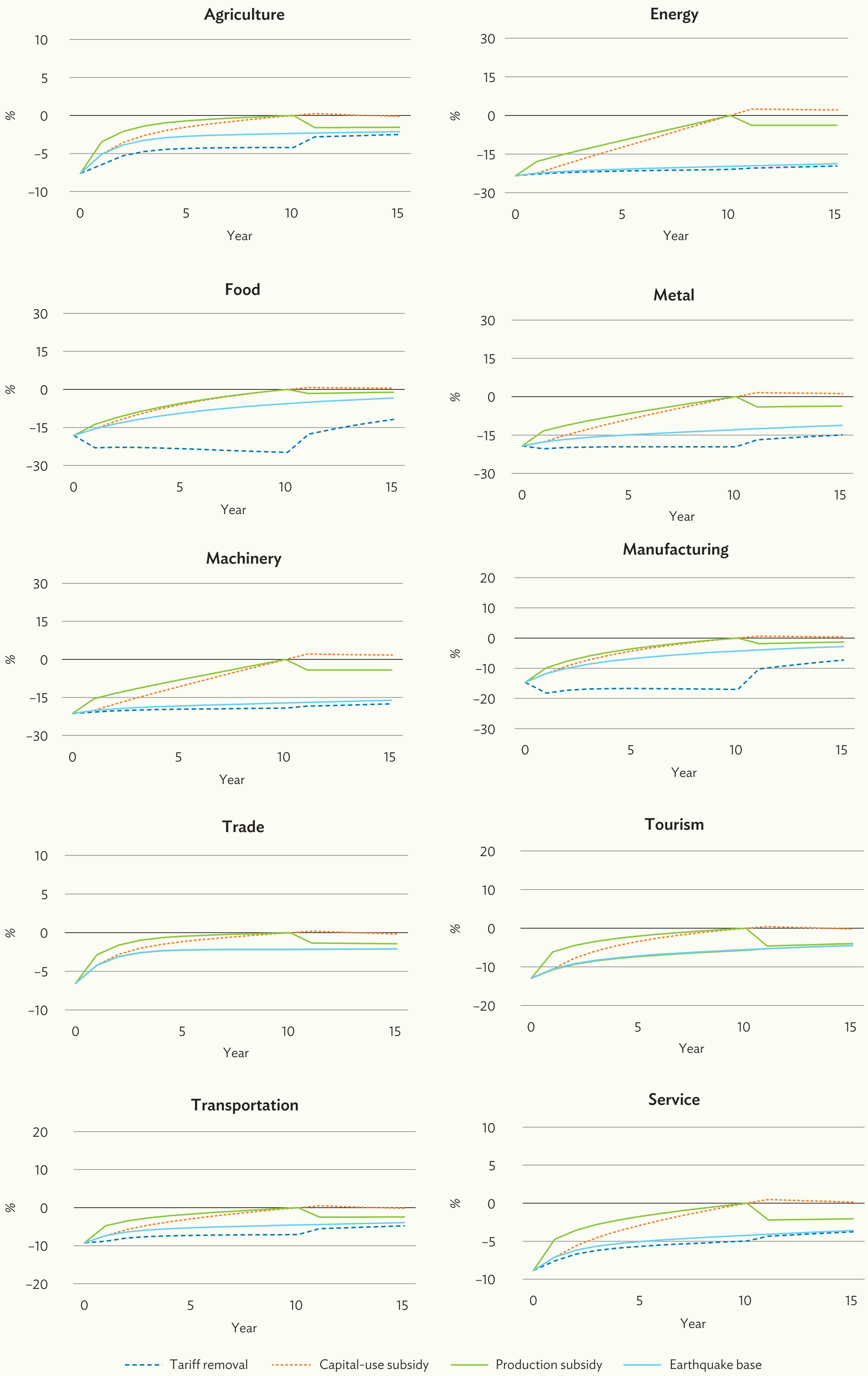
	Capital-Use Subsidy	Production Subsidy	Tariff Removal
Agriculture	20.0	5.2	69.7
Energy	36.0	22.6	17.5
Food	20.5	3.8	74.5
Metal	29.2	1.0	33.9
Machinery	32.6	44.2	30.3
Manufacturing	17.7	2.1	36.9
Trade	11.2	3.6	14.8
Tourism	55.5	10.4	14.8
Transportation	20.5	7.0	14.8
Service	25.2	7.3	13.4

10.3 Simulation Results

10.3.1 Sectoral Output Recovery Process

We demonstrate 10-year build-back-better recovery policies to be explicitly implemented with the earthquake impact baseline (thick line) in Figure 10.2. The policy targets of capital use and production subsidies are to return the sectoral output to the pre-disaster business-as-usual level in the 11th year, while the policy of tariff removal is implemented for 10 years regardless of output change.

Figure 10.2: Sectoral Recovery Process under Subsidy Policies



The baseline disaster scenario shows that no sector could recover without the support of a recovery policy, suggesting the indispensability of government intervention. In all sectors, the recovery path of the capital-use subsidy is more sustainable than the production subsidy, which shows a dip right after the termination of the program. For the production subsidy policy, we see that the output drops by 3%–4% after the termination of the subsidy policy, implying that the production was distorted from the free market rule. Moreover, the tariff removal policy does not appear to affect production recovery; its impact needs reference with the perspective of social benefits.

10.3.2 Fiscal Cost and Social Benefit/Cost

In addition to observing the output path, we looked further into the consequences of annual fiscal cost and the social benefit/cost at the present price of the policies (Figure 10.3). The visualized comparison may give stakeholders a clearer picture of policy options. The social benefit/cost is determined by the sum of household utility in the equivalent variations between the status before and after the policy intervention. The social benefit represents social welfare improvement, providing policymakers with a positive sign to proceed with the policy, while the social cost may raise caution that the policy may worsen social welfare in addition to the fiscal costs.

Figure 10.3: Comparison of Fiscal and Social Benefit/Cost (NRs million)

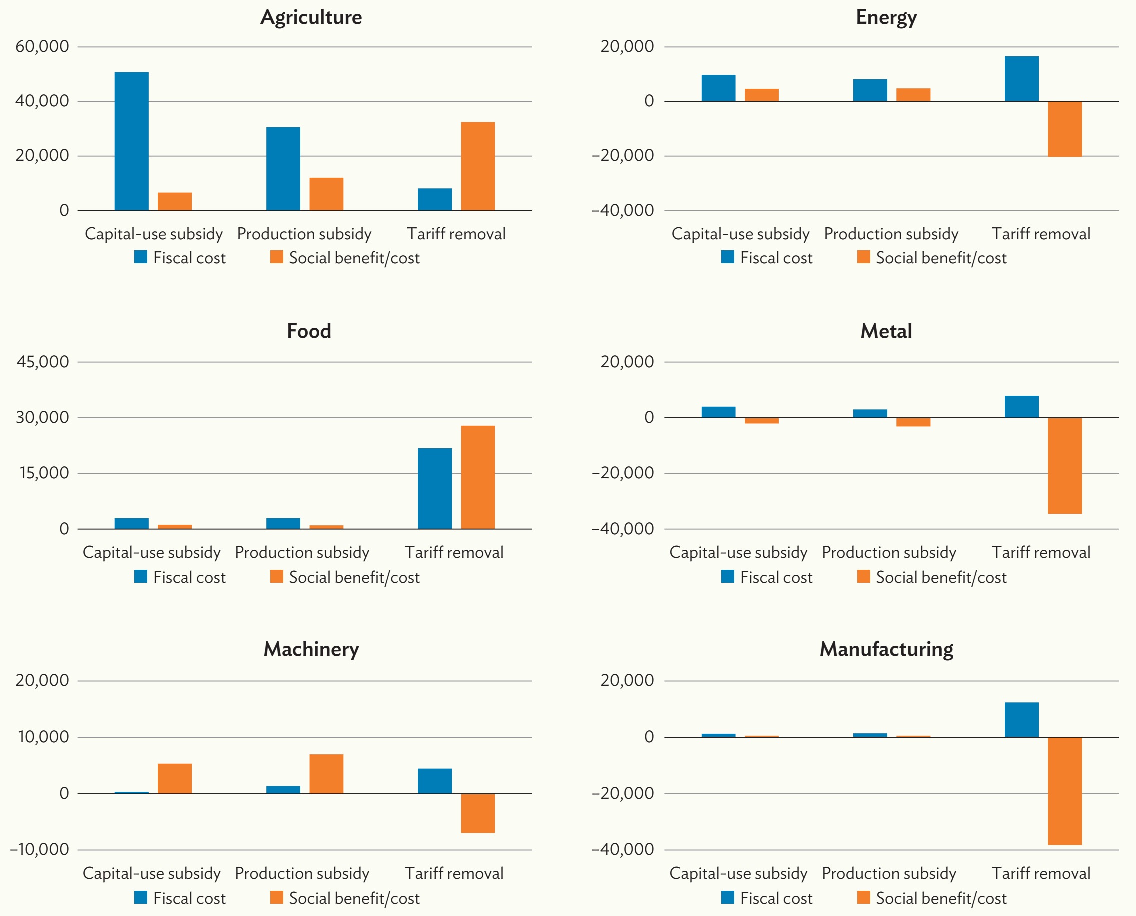


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Figure 10.3 *continued*

NRs = Nepalese rupees.

On the basis of the same objective of recovery of output to the pre-disaster level in the 11th year, the fiscal costs of the production subsidy are significantly smaller than those of the capital-use subsidy, especially in the agriculture, trade, tourism, transportation, and service sectors. The production subsidy policy could also generate more social benefits than the capital-use subsidy in the agriculture, machinery, and tourism sectors.

All of the recovery policies actually worsened social benefits in the metal, trade, and service sectors, implying that such interventions might negatively distort the market. In contrast, the simulation results show that tariff removal could also make households substantially better off in the agriculture and food sectors, suggesting that trade liberalization in these two sectors could improve resource allocation in the aftermath and recovery process for Nepal. Most interestingly, for the energy, metal, and manufacturing sectors, the removal of the customs tax for import goods could neither contribute to their output recovery nor generate social benefits, indicating the high vulnerability of these sectors toward international competition.

10.3.3 Cost-Effectiveness of Policies

Next, we derived the ratio of social benefits/costs to fiscal costs to acquire indicators of the cost-effectiveness of the policies. The indicators could provide a quick reference and identification of sectoral resilience and help the government to decide on the highest ratio (Table 10.3). Based on the cost–benefit ratio, we could infer that for the agriculture, energy, recreation, and transportation sectors, providing production subsidies would be more cost-effective for the recovery, while capital-use subsidies may work better in the food, machinery, and manufacturing sectors despite their higher fiscal costs. Policymakers should also be aware that the provisional subsidy policies for the metal, trade, and service sectors may negatively distort the market and thus require additional consideration.

On the other hand, the tariff removal policy showed a substantially higher ratio in the agriculture and food sectors, indicating that such a policy could be applied as a supplementary instrument to improve the social benefit.

Table 10.3: Ratio of Fiscal Costs to Social Benefits

	Capital-Use Subsidy	Production Subsidy	Tariff Removal
Agriculture	0.13	0.39	3.97*
Energy	0.48	0.59	−1.23
Food	0.39	0.34	1.28*
Metal	−0.51	−1.05	−4.36
Machinery	15.37	5.12	−1.56
Manufacturing	0.46	0.42	−3.07
Trade	−0.07	−0.22	−0.75
Recreation	0.32	0.67	−0.63
Transportation	0.12	0.19	−0.55
Service	−0.28	−0.73	−2.65

Note: *Output level does not recover in the policy.

10.3.4 Toward Building Forward Better in the Energy Sector

The demonstration of production and capital-use subsidies plus tariff removal showed the build-back-better path of the recovery. The energy sector, including electricity, petroleum, and natural gas, remains vulnerable in Nepal; thus, innovative reinforcement for the sector's recovery would be necessary. Being a landlocked nation, Nepal has limited access to fossil fuel from the international market, which is why people in Nepal use less commercial energy than in any other South Asian countries. The scant commercial energy sources leave Nepal to rely heavily on traditional energy resources. Despite the rapidly falling cost of solar photovoltaics, Nepal's share of modern renewable energy is less than 3%. As a result, energy poverty remains exceptionally high. On this basis, earthquake recovery projects could take advantage of the opportunity to designate favorable and aggressive policies to support the improvement of the energy system from renewable sources, such as the utilization of solar or hydropower in Nepal.

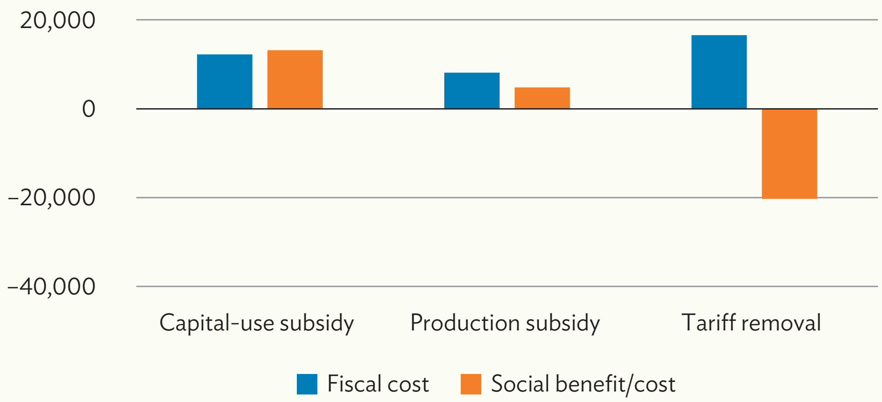
These reinforcements would be equipped with solar power generation with battery storage and balanced with storage such as off-river pumped hydropower technology. This implementation is expected to generate spillover effects to other systems of service sectors such as tourism, trade, transportation, and service. Therefore, we examined the build-forward-better approach based on the method developed by Huang and Kim (2021) and Nakano and Washizu (2013) of utilizing renewable energy in Japan (Table 10.4; Figure 10.4).

Table 10.4: Indicators for Build-Forward-Better Policy in the Energy Sector (NRs million)

	Capital-Use Subsidy	Production Subsidy	Tariff Removal	BFB
Fiscal cost	9,719	8,141	16,550	12,229
Social benefit	4,676	4,809	−20,290	13,145
Cost−benefit (%)	0.48	0.59	−1.23	1.07

BFB = build forward better, NRs = Nepalese rupees.

Figure 10.4: Energy Sector in Build-Forward-Better Policy



Based on the technology parameters projected by Huang and Kuroda (2021), we calibrated the 2015–2020 estimate of a technology improvement of 5.9% in the energy sector with a 10% efficiency rise as a spillover effect to occur from the fifth year of the policy implementation in the trade, transportation, tourism, and service sectors. It is notable that although the fiscal burden of this build-forward-better policy would be higher than for capital-use and production subsidies, the performance in social benefits and the cost–benefit ratio makes it a more favorable policy.

10.4 Conclusion

10.4.1 Discussion and Policy Implications

While the focus of the world has been on the reconstruction of Nepal, this chapter has examined recovery policy recommendations for sectoral output recovery and welfare analysis as a build-back-better approach. The study demonstrates a comprehensive analysis of the direct impact of physical damage and the indirect impact of production disruption as economic losses. The evidence-based simulation results could help visualize possible reconstruction costs and policy effectiveness by identifying the fiscal and social benefits/costs.

Based on the simulation results, the capital-use subsidy is more costly than the production subsidy in all sectors for the recovery target designated in the 11th year after the disaster. Nevertheless, the food, machinery, and manufacturing sectors may recover with higher cost-effectiveness when referring to the cost–benefit ratio. If the target is to improve social welfare regardless of output recovery, the tariff removal policy could substantially improve the social benefit in the agriculture and food sectors. Additionally, we calibrated the energy technology parameter to evaluate its spillover effects of efficiency improvement on other service-related sectors. While such a recovery policy may require more resource input with international collaboration for technology transfer, as a build-forward-better approach, it could generate greater social benefit than a mere return to the pre-disaster output level.

These quantitative results enable decision makers to consider the policy options in advance so that after a disaster, resources could be allocated more efficiently. Such indicators also serve as useful measures of sectoral vulnerability as well as resilience. The research results also provide policymakers with an empirical and scientific framework for developing policy options to foresee the possible consequences and budget needed for the recovery.

10.4.2 Limitations and Future Prospective

Despite this chapter's comprehensive coverage of the recovery process following the Nepal earthquake of 2015 for all industries, and despite the in-depth policy implications we are able to offer, the approach we used remains limited in scope for evaluating the well-being of disaster-affected people in a scenario in which residential buildings have been substantially damaged. Additionally, the calibration of technology parameters might be too simplified. The technology transfer platform should be illustrated with more supporting evidence.

In future research, an input–output analysis would be indispensable to interpret further the transition and overall impact of the policy intervention. Updates and more specific sectors, such as carbon dioxide emission compilation, would be desirable to connect the decarbonization approach, which is highly expected to provide essential evidence and incentive for the build-forward-better scope. In addition to a single-country model, the research hopes to utilize firsthand data collection for constructing a world trade model with the Global Trade Analysis Project (GTAP) to examine the impact of foreign direct investment based on the approaches by Hosoe (2014) and Ko (2014), especially for the sectors related to renewable energy goods and construction. This extension is expected to allow research to interpret the recovery impact with a broader scope including Nepal and foreign direct investment outflow countries such as Japan, the European Union, and the United States, with further implications for international cooperation.

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Appendix 10

Table A10.1: The 2010 Social Accounting Matrix of Nepal (million Nepalese rupees)

	Agriculture	Energy	Food	Metal	Machinery	Manufacturing	Trade	Tourism	Transportation	Service	Labor	Capital	Tax	Tariff	Household	Government	Investment	Import	Total
Agriculture	121,445	7	61,793	0	0	13,582	0	2,850	0	7,945					492,537	0	19,189	7,444	726,793
Energy	4,714	3,400	770	95	437	1,758	916	741	1,329	35,320					61,075	0	40,344	24,983	175,883
Food	37,576	0	5,322	0	0	218	0	21	0	20,480					60,513	0	7,641	24,875	156,645
Metal	0	504	0	14,903	964	537	0	0	0	9,010					4,052	0	41,059	201	71,233
Machinery	4,436	1,393	0	59	657	24	0	0	1,063	134					13,227	0	10,596	11,104	42,694
Manufacturing	0	127	219	0	0	14,205	56	5,727	10,804	32,461					12,370	0	40,198	17,769	133,935
Trade	12,187	4,324	2,518	2,755	347	23,801	983	2,274	8,717	7,752					83,022	0	34,642	23,700	207,021
Tourism	318	370	0	0	0	0	855	1,464	791	22,183					37,648	0	0	0	63,628
Transportation	17,057	824	1,245	932	141	2,708	622	16,568	10,859	45,391					97,938	0	22,927	7,153	224,366
Service	5,258	4,428	107	78	91	2,311	10,051	7,599	25,658	75,895					223,349	138,429	255,058	10,155	758,467
Labor	246,038	4,677	2,577	3,757	236	2,403	81,787	9,865	31,059	122,628									505,027
Capital	253,180	22,650	12,578	12,167	932	6,719	110,618	9,257	65,721	254,691									748,514
Tax	2,533	10,402	13,061	1,820	17,643	14,591	200	6,542	14,057	40,561									121,412
Tariff	9,058	18,319	24,106	8,771	4,943	13,778	121	93	7,006	9,938									96,133
Household											505,027	748,514							1,253,541
Government													121,412	96,133	129,850				347,395
Investment															37,959	208,966		224,729	471,654
Export	12,991	104,457	32,348	25,897	16,303	37,299	814	627	47,302	74,076									352,113
Total	726,793	175,883	156,645	71,233	42,694	133,935	207,021	63,628	224,366	758,467	505,027	748,514	121,412	96,133	1,253,541	347,395	471,654	352,113	