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How Much Has Nepal Lost in the Last Decade Due to Load Shedding?

An Economic Assessment Using a CGE Model

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Abstract

Nepal suffered with severe shortage of electricity supply or load shedding in the last decade. Electricity load shedding is considered one of the major barriers to the country's economic development. This study uses a computable general equilibrium model to estimate the economic costs of electricity load shedding the country faced during 2008–16. The study shows that if there had been no load shedding, annual gross domestic product, on average, would have been almost 7 percent higher than it was during 2008–16. The worst effects of load shedding were on the investment environment. If there had been no load shedding, investment would have been 48 percent higher than it was. Although electricity load shedding has been reduced recently in the residential sector through better electricity load management and increased electricity production and imports, the industrial sector, one of the main sources of economic growth in the country, still faces load shedding. Unless the electricity load shedding is eliminated, Nepal will continue to suffer a heavy economic loss.

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How Much Has Nepal Lost in the Last Decade Due to Load Shedding? An Economic Assessment Using a CGE Model[1]

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How Much Has Nepal Lost in the Last Decade Due to Load Shedding? An Economic Assessment Using a CGE Model

1. Introduction

Nepal, a small country on the lap of the Himalayas, is one of the poorest countries in the world in terms of infrastructure and economic development. In 2013, per capita electricity consumption in Nepal, for example, was 427 times lower than that in Iceland, the country with the highest per capita electricity consumption in the world; 182 times lower than that in Norway, a country with hydropower as the primary source for electricity supply, like Nepal; 101 times lower than that in the United States; 81 times lower than that in the Republic of Korea; 30 times lower than that in China; and 6 times lower than that in neighboring India.[3] As of January 31, 2018, Nepal has about 1,000 MW of power generation capacity for its almost 30 million population. Of this total installed capacity, which is mostly run-of-river type, 70% is not available during the dry season (March-April). The lack of electricity generation capacity and further unavailability of the existing capacity due to very low river discharge in the dry season, the country has suffered from huge load shedding over the decade starting in 2008. In the dry season in 2015 and 2016, the country faced up to 14 hours of load shedding in a typical day.[4]

More recently, starting from 2017, the situation has improved and regular electricity supply to households in major urban areas, including the capital city, Kathmandu, has been resumed. Several factors, including an innovative load management system adopted by the state electricity utility- Nepal Electricity Authority, increased domestic supply due to commissioning of a few new power plants and increased imports of electricity from India facilitated by the completion of a 400 KV, 1,000 MW cross-border transmission line. Yet, many parts of the country still face load shedding and demand for industrial customers is yet unmet. In a personal communication, representatives from the Federation of Nepalese Chambers of Commerce and Industry (FNCCI) of Nepal claim that the current industrial sector load alone exceeds 3,000 MW, whereas the country

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[3] Calculated based on data from the World Bank's online database available at http://databank.worldbank.org/data/home.aspx.

[4] The Himalayan Times, January 03, 2016. https://thehimalayantimes.com/kathmandu/.

has less than 1,000 MW of total installed capacity. Lack of grid electricity supply has increased the production costs of bigger industrial firms and perhaps impacted their competitiveness as they are forced to rely on expensive diesel-based captive generation (or self-generation) for their electricity supply. For small and medium enterprises, lack of quality electricity supply is a critical problem for their business because they cannot afford captive power generation. Thus, lack of adequate electricity supply capacity and load shedding are one of the major barriers to Nepal's economic development and its goal to alleviate poverty.

In the short-run, chronic electricity outage or load shedding would impact the economy in several ways. First, factories, especially those small and medium size which cannot afford expensive back-up systems, are forced to lose their production thereby culminating in significant loss of industrial outputs. Second, chronic load shedding is one of the key barriers to new investment, especially foreign direct investment, in the productive sector. Third, load shedding causes huge discomfort to households, for example, children cannot finish their homework, people miss recreation and relaxing watching TV, and people lose telephone and internet connections. Households, in aggregate, spend millions of dollars on backup technologies, such as batteries and inverters, all imported. However, quantitative assessments combining all these losses have not been made yet. Some studies, for example, Jyoti et al. (2006), Shrestha (2010), attempted to estimate the economic costs of load shedding, however, their estimates are very narrow as they focus only on the loss of power sales from the utility. They do not even capture direct economic losses from the disruption of production in the manufacturing and service sectors. Therefore, this study aims to contribute in filling this research gap.

Beyond the context of Nepal, the study is also expected to contribute to the existing body of literature assessing economic costs of unreliable electricity supply. Many studies have estimated the cost of power system unreliability both in developed and developing economies. Key studies include Abdullah and Mariel (2010), Braimah and Amponsah (2012), Kaseke and Hosking (2012), Oseni and Pollitt (2013), Allcott et al (2016). However, most of these studies deal with unplanned electricity outages and use a methodology where potential consumers are surveyed asking their willingness to pay to have reliable supply of electricity. For example, Abdullah and Mariel (2010) use a choice experiment method to determine the willingness to pay for improved electricity services, surveying 200 households in Kisumu District, Kenya. Braimah and Amponsah (2012) surveyed 320 micro and small industries from three industrial clusters within the Kumasi metropolis in Ghana to explore the relationship between frequent and unscheduled electricity outages to micro and small-scale industries. Bose et al. (2006) use a two-stage random sampling survey of 500 manufacturing firms and 900 farmers to assess willingness to pay for reliable supply of electricity in Karnataka in India. However, these studies are different from the current study in two respects. First, they deal with unplanned electricity outages and do not necessarily deal with the planned outages or load shedding the current study is investigating. Second, these studies estimate only direct economic costs of not getting a reliable supply of electricity. Their methodology is not useful for assessing the overall economic costs of either unreliable supply or shortage of electricity supply.

Some existing literature, such as Kaseke and Hosking (2012), Oseni and Pollitt (2013) and Allcott et al (2016), assesses the impacts of planned electricity outages or load shedding. Kaseke and Hosking (2012) estimate the economic costs of load shedding in the mining sector in Zimbabwe. Oseni and Pollitt (2013) use cross-sectional data on electricity outages collected by the 2007 World Bank Enterprise Survey of 6,854 firms in 12 African countries. Allcott (2016) analyzes the impacts of weekly "power holidays" or load shedding in the manufacturing industry in India. The methodologies in these studies captures only the direct costs of load shedding and they do not include the economic costs due to interlinkages of industries and economic agents. These indirect impacts are important because, depending upon the structure of an economy, the size of indirect impacts could be higher than the size of direct impacts.

We used a computable general equilibrium (CGE) model for assessing the economic costs of load shedding. The CGE model we used in this study has a capacity to capture load shedding's economywide impacts caused directly and indirectly. For example, load shedding causes either short-supply of electricity to an industry or increased electricity input cost of that industry. The result would be either cut- or increased price- of outputs from that industry. This would further cause increase in prices of outputs of other industries where this industry supplies an input. The chain continues, and overall output of the economy will be curtailed and prices of most goods and services of domestic industries will rise. Households not only suffer with discomfort due to irregular supply of electricity, but also face higher prices of goods and services. Moreover, domestic production would be more expensive as compared to their international counterparts and thus domestic industries lose competitiveness. The CGE model used here accounts all these impacts of load shedding.

Nepal could not meet, on average, 20% of its total electricity demand in each year during the 2008-2016 period. This shortage of electricity supply or load shedding would have reduced Nepal's GDP by more than 6% during that period. Total investment demand during the period was estimated to drop by 33%. Total sectoral output dropped by about 7%. Due to the drop in domestic production activities, both imports and exports also dropped.[5]

This paper is organized as follows. Section 2 briefly presents the CGE model used as an analytical tool for the study, followed by a brief description of data in Section 3. Section 4 describes the load shedding scenario simulated. This is followed by presentation and discussion of key results in section 5. Finally, section 6 concludes the study and draws some policy remarks.

2. Analytical Approach

The study uses a single country static general equilibrium model of Nepal. This is a standard CGE model with representation of factor market, product market and household welfare. It follows the rich literature on single country CGE modeling, such as Shoven and Whalley (1984, 1992) Decaluwé et al. (2005) and Coady and Harris (2001). The structure of the model is briefly described below. The detailed description of the model is presented in the Appendix.

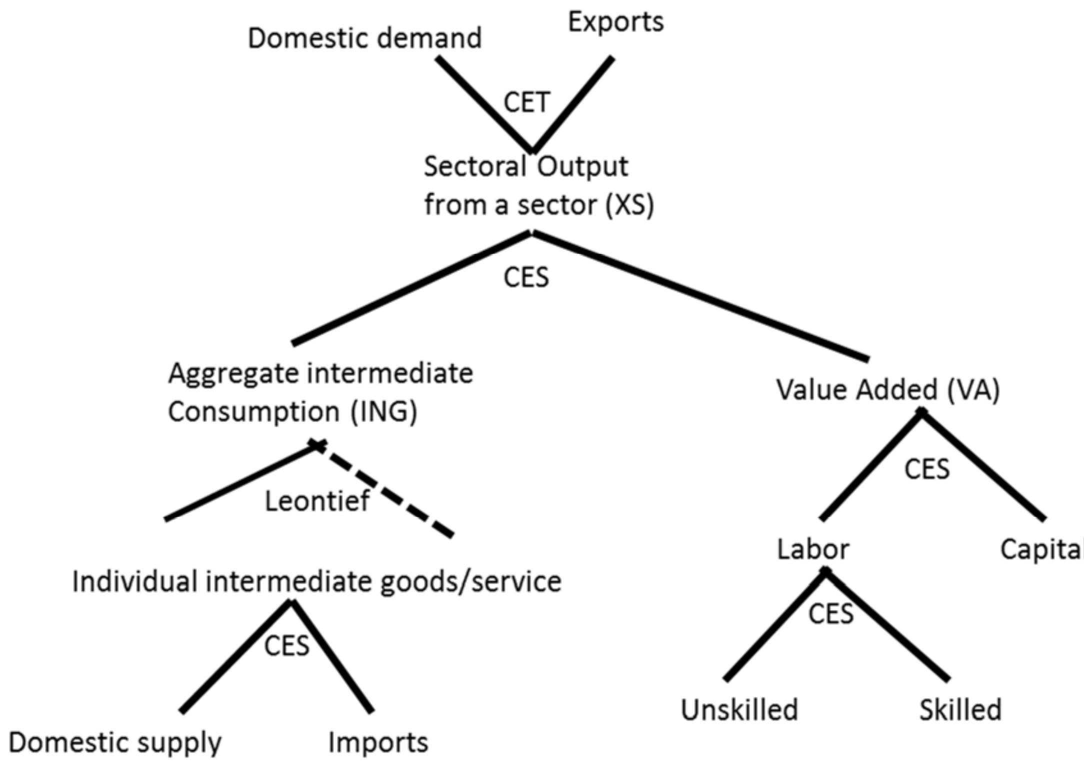
Sectoral production: The number of sectors and commodities can be changed as needed. For this analysis, we considered 15 sectors.[6] The production structure of agriculture and non-agriculture are differentiated because while land is the main input in the agriculture sector, it is not in the other sectors. Figure 1 illustrates the basic structure of modeling the production sector. At the highest nesting level of the production structure, sectoral output is a constant elasticity of substitution (CES) combination of sectoral value added and total intermediate inputs. While a sectoral value

[5] The falling oil prices after 2014 might have lowered the cost of load shedding for two years out of 10 years considered in the analysis. There might be some small influences (slight decrease) on the 10-year average impacts of load shedding due to the decreased oil price in the last two years of the study horizon. However, capturing this influence is quite complicated, therefore we have ignored it.

[6] For the sake of clarity, we further aggregated the sectors when results are presented and discussed. For example, five agriculture (crop sectors) and a forestry sector are lumped into single 'agriculture and forestry' sector.

added is CES combination of labor and capital inputs, total intermediate input is a Leontief aggregate of individual intermediate inputs.[7] The capital in the agriculture sector is derived from Cobb-Douglas function combining agricultural capital and land. The composite labor is a CES aggregate of skilled and unskilled labors in each sector. This hierarchical nested specification allows different scale of substitution among primary factors (Despotakis, 1980).

Figure 1: Simplified structure of modeling production sectors



Foreign trade: Imports are divided into competitive and non-competitive categories. The competitive imports are modeled with Armington assumptions (Armington, 1969) and non-competitive imports are modeled with the Leontief fixed coefficient technology. For a competitive or tradable good, import demand is derived from a CES combination of a domestically produced

[7] Leontief specification does not allow substitution between intermediate consumption in a production sector. Since this specification does not allow structural adjustment through input substitutions, the reported impacts are likely overestimated. More flexible forms, such as CES, resolve this issue. However, key parameters of the CES specification, particularly the elasticity of substitution, are not available.

component and an imported component. A CET function is used to allocate total domestic production or domestic output of a good or service to domestic consumption and exports. The standard small-country assumption implying no good or service produced in Nepal can influence the international price of that good or service.

Households and government: The Stone-Geary linear expenditure function[8] is used to model household consumption. Hicksian equivalent variation (Hicks, 1943) is estimated to measure household welfare effects of counterfactual simulation, here load shedding scenario. Household savings are derived based on exogenously specified marginal propensity to consume. Government collects taxes, makes public expenditure and saves, receives and provides transfers.

Macro closure: The model we developed for this analysis is a static model, where investment is assumed to be at its steady state rate. Total investment is financed through domestic savings (household savings, government savings, firm's savings) and foreign savings (or borrowing from foreign countries or institutions). The supplies of primary factors (i.e., labor, capital and land) are fixed for a given year. For labor, in fact, the working-age population for a given year is exogenous and fixed. However, the model allows labor to move across the sectors. The agricultural capital is mobile (can be moved from one crop to another based on their profitability) while industrial capital is sector specific. The model closes keeping foreign saving (current account balance) as exogenous. The exchange rate is fixed and the real exchange rate acts as the price numeraire.

3. Data

We used the social accounting matrix (SAM) of year 2007. The social accounting matrixes of later years (e.g., 2012) are also constructed by some studies.[9] We used the 2007 SAM by design,

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[8] The Stone-Geary function is used to model household demand when households are assumed to have a subsistence level of consumption irrespective of the prices of goods for subsistence consumption and household income. Households then make a choice for further consumption. It uses the linear expenditure system (LES) for estimating consumer demand. The LES functional form was first introduced by British economist Sir John Richard Nicholas Stone (Stone, 1954) and explained by Ragner Frisch (Frisch, 1954), the Norwegian economist and the co-recipient of the first Nobel Memorial Prize in Economic Sciences in 1969.

[9] Macroeconomics & Fiscal Management Global Practice, South Asia Region, Economic Impacts of Hydropower Investments, World Bank, April 2017, unpublished document.

because in that year there was no load shedding. This means all sectors and households got the full amount of electricity as they demanded. After 2007, when load shedding started, a SAM might misrepresent electricity input because the technical or input-output coefficient either overestimates the marginal product of electricity input in a sector or a portion of the technical coefficient for electricity (i.e., ratio of output from sector to its electricity input) might have diverted to oil if the sector used captive power running its own diesel fired backup generators. The SAM of any year after 2007 needs an adjustment if used for this type of analysis. The SAM of 2007 serves as a benchmark for the analysis of the economic impact of load shedding. All share parameters and other parameters are calibrated based on the 2007 SAM. The values of the elasticity of substitution in the CES and CET nests are from the existing literature.

4. Load Shedding Scenario Design

Table 1 presents electricity supply and demand balance for years during the 2007-2016 period. In 2007, supply met the demand. Since then supply is always lower than demand for electricity thereby causing load shedding. For 2015 and 2016, we could not get electricity requirement data. For year 2008, the electricity deficit was 9% of the demand. For years, during 2009 to 2014, the supply deficit was around 20% of the demand. It was much higher in 2015 and 2016 when the country faced most serious load shedding. Since 2008 the deficit has been less than 10% and in 2015 and 2016 deficits might be much higher than 20% of corresponding demand. We assumed that, on average, 20% of the annual demand for electricity was not met by the supply. Therefore, we simulated the economic impacts of 20% cuts in electricity supply in each year.

Table 1. Electricity supply and demand balance in Nepal during 2007-2016 (GWh)

Year	NEA Supply	IPP Supply	Domestic Supply	Import	Total supply	Deamnd	Deficit	% deficit
2007	1,761	329	2,090	962	3,052	3,000		
2008	1,802	425	2,228	958	3,186	3,490	-304	-9%
2009	1,849	356	2,205	926	3,131	3,859	-728	-19%
2010	2,122	639	2,760	591	3,352	4,367	-1,015	-23%
2011	2,125	694	2,820	1,039	3,858	4,833	-975	-20%
2012	2,359	746	3,105	1,074	4,179	5,195	-1,016	-20%
2013	2,292	790	3,082	1,176	4,258	5,446	-1,188	-22%
2014	2,298	1,319	3,617	1,070	4,687	5,909	-1,222	-21%
2015	2,367	1,370	3,737	1,269	5,006	n.a.	n.a.	n.a.

2016	2,168	1,173	3,342	1,758	5,100	n.a.	n.a.	n.a.

Source: Nepal Electricity Authority (NEA). Annual Reports for the period between 2007 and 2017.

One of the limitations of shocking the load shedding in this analysis is that the model does not capture captive power generation to back up electricity supply during the load shedding. While not all industries can afford backup power generation, large industries invest in backup power supply. In such a case, large industries would not cut their production during the load shedding, instead they pay a higher price for electricity supplied through the backup system. However, lack of data does not allow us to model it. The problem lies in the data collection and reporting system adopted by the statistical organization that produces the input-output table, the primary source of data for CGE modeling. For example, when oil (diesel or fuel oil) is purchased by an industry, it can be used for multiple purposes. If it is diesel it can be used in heavy trucks, electricity generation and other processes. If it is fuel oil, it can be used in boilers, process heating and electricity generation. Industries do not keep records of how much oil is used for one purpose vs. others. Surveys for data collection from industries would be needed. Even if the surveys are carried out and the necessary data are collected, a major restructuring of the input-output (I-O) tables is further needed. I-O tables are periodically published by the National Statistical Offices, they report how much a commodity is used in an industry. It does not differentiate consumption of commodity (e.g., oil) in a production sector (say manufacturing) by type of end-use (freight transportation, power generation, heating, etc.). Therefore, representing captive power (e.g., backup electricity) in industry is not possible from the existing data reporting system. Similarly, the study has not captured the effect of investments households have made in their backup systems, such as storage devices (e.g., inverters, storage device powered lighting devices).

The implication of this limitation is that estimated impacts presented in the current analysis are higher than that would be when impacts of backup power supply systems in both production sectors and households are accounted for.

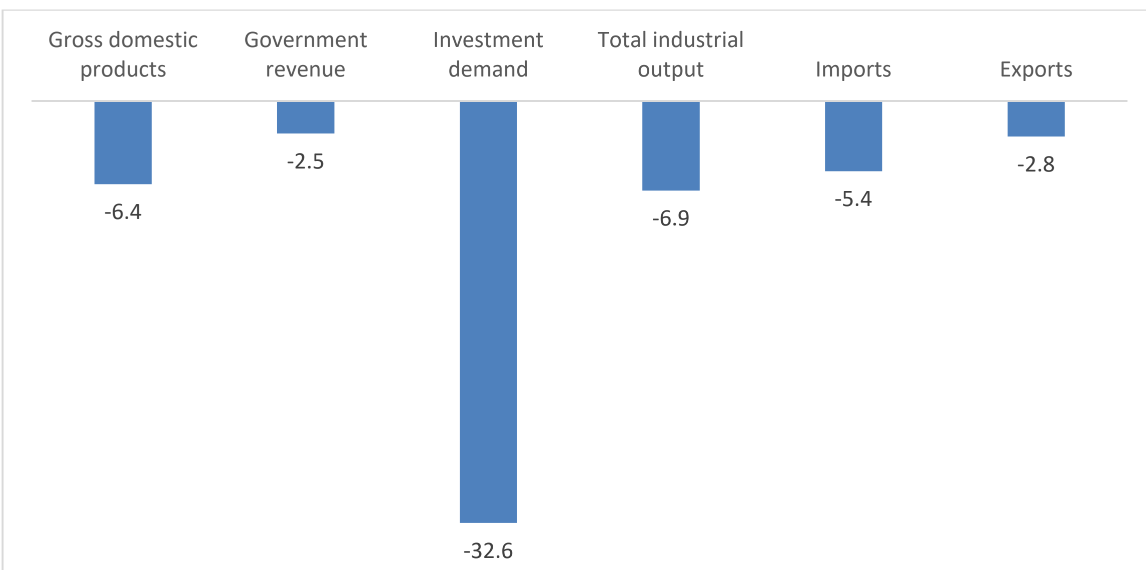
5. Results from Model Simulations

5.1 Impacts on key macroeconomic variables

Figure 2 presents the impacts of load shedding on key macroeconomic variables. These are the average annual deviation as compared to a hypothetical situation where load shedding would not have occurred. The results reveal that load shedding caused a reduction of 6.4% of annual GDP, on average, during the 2008-2016 period. This means if there were no load-shedding annual GDP would have been almost 7 percent higher, on average, as compared to what it was during the 2008-2016 period.[10] The worst impacts can be observed on the investment side. The load shedding caused almost 33 percent loss of investment demand as compared to the baseline. In other words, if there were no load shedding, the average annual investment would be more than 48% higher as compared to the level during 2008-2015. Due to the lower investment and production loss caused by the load shedding, total industrial outputs decreased by almost 7%. As production activities decrease, international trade would also decrease; due to the load shedding, annual exports and imports were estimated to be decreased by, on average, 2.8% and 5.4%, respectively during the 2008-2016 period.

Figure 2: Impacts on key macroeconomic variables

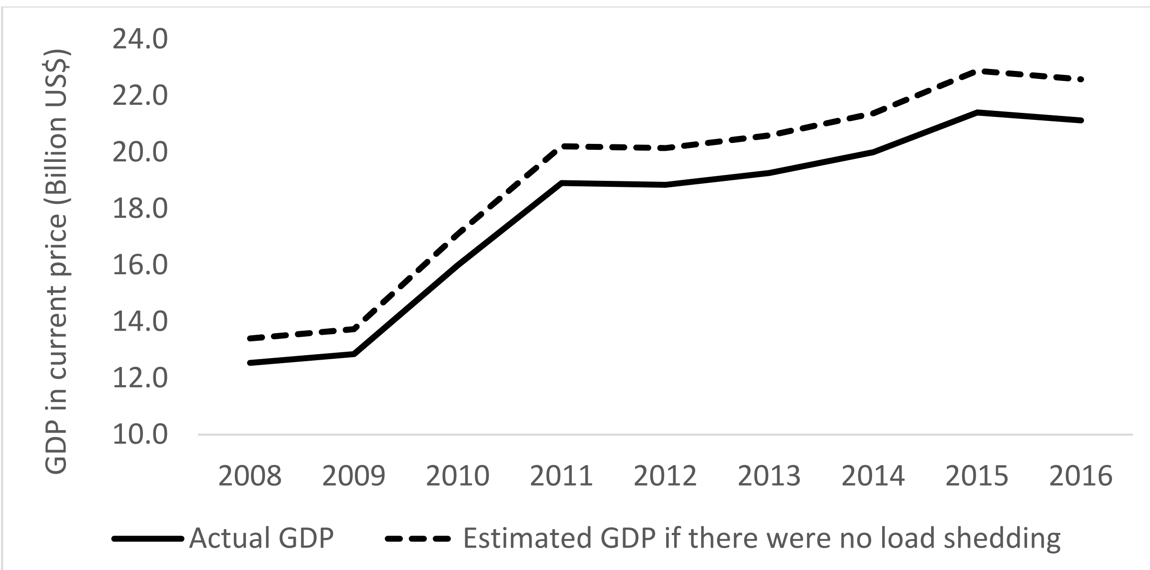
Annual average deviation from the baseline (%) during the 2008-2015 period



[10] This means the actual GDP (with load shedding) is 6.4% smaller as compared to the baseline (without load-shedding). If we consider the actual GDP, with the load shedding, as the base, the hypothetical GDP would be [{100/(100-6.4)}-1]*100 = 6.9%.

We also estimated the total or cumulative economic loss Nepal might have experienced due to the load shedding during the 2008-2016 period. Figure 3 presents actual GDP (measured in current price) and GDP the country would have realized if there were no load shedding. Our model estimates that Nepal has lost a total of US$11 billion value of GDP in nine years during the 2008-2016 period due to the electricity load shedding. This amount is almost equal to Nepal's GDP in year 2008. If the annual GDP loss is expressed in 2016 price using the corresponding GDP deflator values, the total GDP loss over the 2008-2016 period amounts to US$14.5 billion.

Figure 3: Actual GDP and estimated GDP if there were no load shedding (Billion US$ current price)



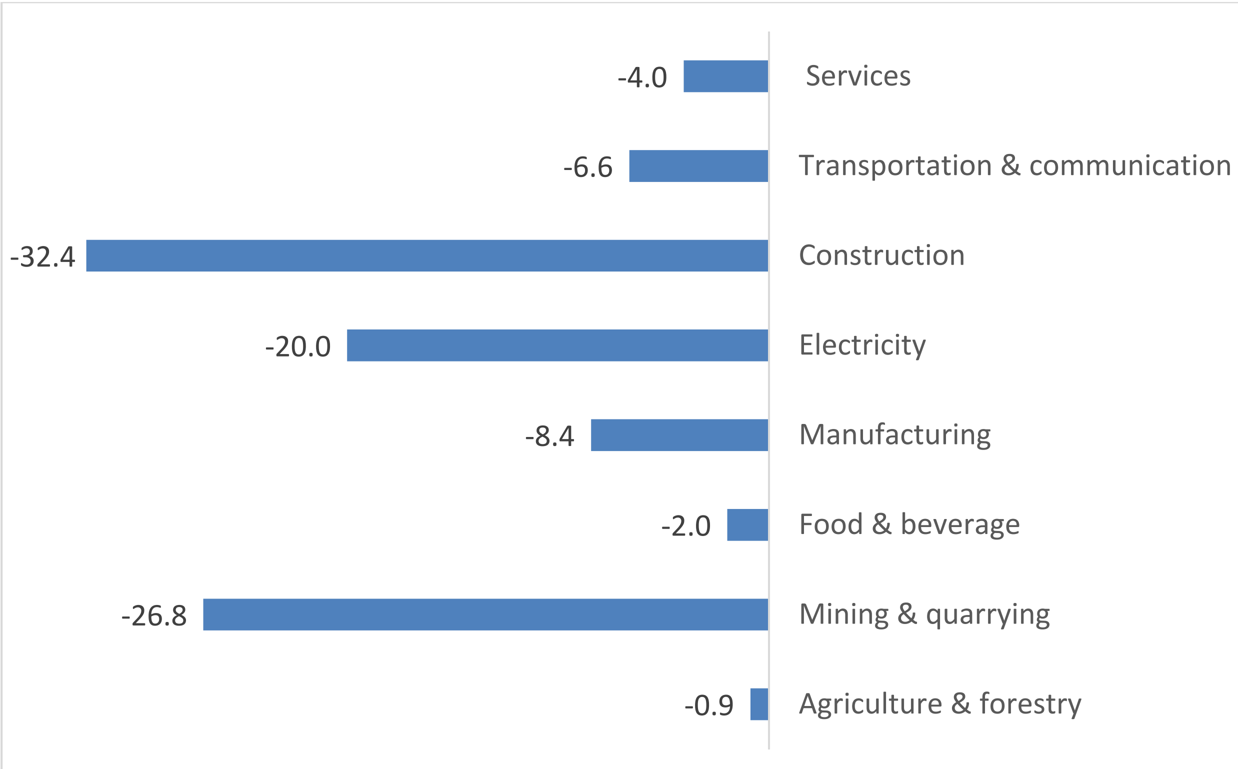
Since the estimated impacts are based on a modeling exercise rather than an actual accounting exercise, the numbers should be interpreted as indicative. Note that the impacts of load shedding estimated here are relevant only in the context of not meeting electricity demand to the customers already connected to the national electricity grid. The country has been also suffering due to lack of electricity access in areas not served by the national grid or off-grid/distributed generation systems. Meaning that there was lack of access to electricity in the baseline as well. This analysis does not include economic loss of not providing electricity in those areas. Moreover, some large-scale electricity intensive industries, such as fertilizer factories, chemical industries, might not have installed in Nepal due to unavailability of the large quantity of electricity they need. This study also does not capture economic loss of not having such large-scale industries, when insufficient supply of electricity is the only reason for not getting them installed.

5.2 Impacts on Sectoral Outputs

Electricity load shedding would impact all sectors negatively (see Figure 4). Sectors which are electricity intensive would suffer the most. For example, when 20% of electricity supply is unavailable due the load shedding, the construction sector suffers with more than 30% of output loss. This is consistent with the large drop of investment demand presented earlier. Other sectors, such as mining and quarrying and manufacturing sectors also suffer relatively higher output losses. The agriculture & forestry sector and food & beverage sectors, which are relatively less electricity intensive in Nepal, would suffer less due to the load shedding. Note, however, that due to lack of electricity, many food and beverage industries, such as cold storage, fruit processing, are very few in numbers in Nepal. If electricity supply is increased, expansion of these and many other industries would have occurred. However, this study has not accounted for the output losses from the industries which would not have installed due to lack of electricity access.

Figure 4: Impacts on sectoral outputs

Annual average deviation from the baseline (%) during the 2008-2015 period



5.3 Impacts on International Trade

5.3.1 Exports

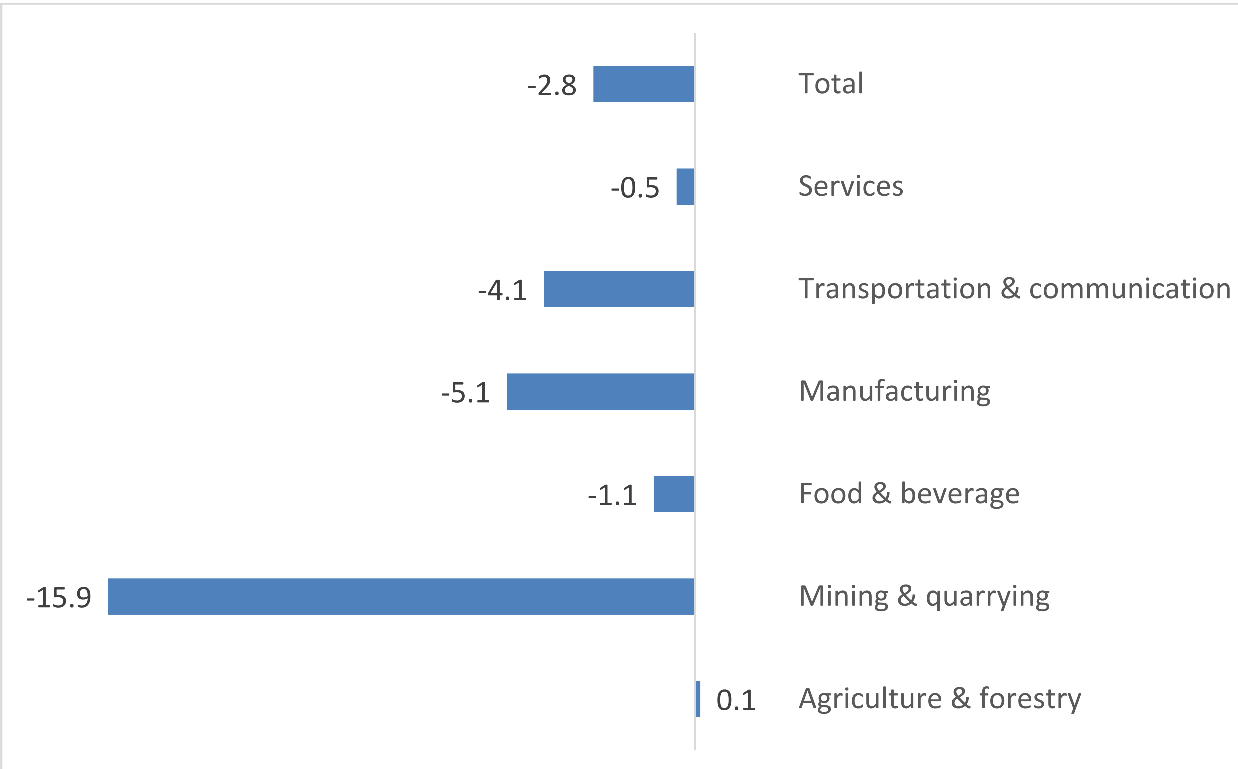
Since load shedding causes firms to cut their output and household consumption does not change much,[11] exports of goods and services would decrease. As shown in Figure 5, total annual exports during the study period (2008-2015) drops by about 3%, on average. Consistent with the highest percentage production loss, the mining and quarrying goods also suffer with the highest loss in their exports, 16%. Exports of manufacturing goods also decrease significantly, more than 5%, on average, each year during the 2008-2015 period. The change in exports can also be explained through changes in relative prices of domestically produced goods as compared to their

[11] Load shedding would cause a 0.34% drop in household consumption, on average, annually during the 2008-2015 period.

world prices. Load shedding causes domestic production of goods and services to be more expensive, therefore domestic prices of almost all commodities would be higher than corresponding world prices. This would cause exports to decrease.

Figure 5: Impacts on exports

Annual average deviation from the baseline (%) during the 2008-2015 period

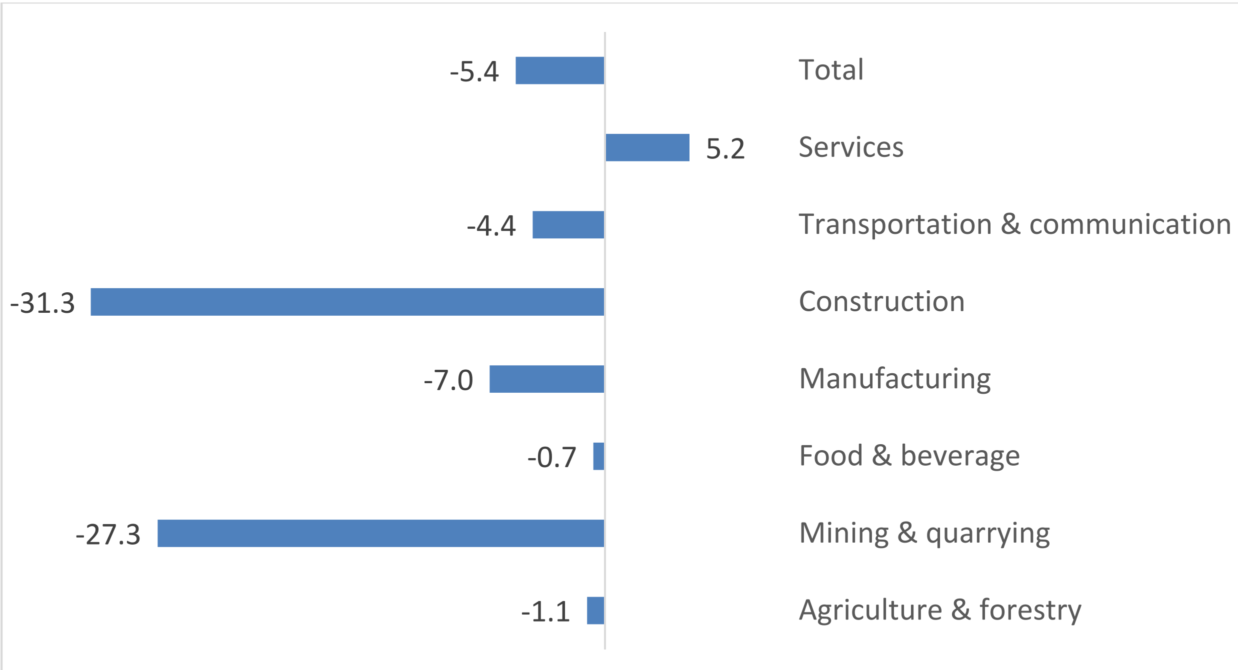


5.3.2 Imports

Since load shedding causes production activities to decline, inputs needed for production would also decline. Annually, the country has suffered 5% drop of imports, on average, during the 2008-2015 period. Imports of construction goods would face the highest decline as the construction sector faces the highest decline in its output. The service sector is an exception (see Figure 6). This is because some energy commodities such as cooking gas, LPG, are included in the service sector. Import of LPG has increased for cooking.

Figure 6: Impacts on imports

Annual average deviation from the baseline (%) during the 2008-2015 period



6 Conclusions and Further Remarks

Over the last 10 years, electricity load shedding created severe discomfort to households and posed a major barrier to economic development in Nepal. The problem started in 2008 and peaked in 2016 when the country faced up to 14 hours of power cuts in the dry (winter and spring) season. Recently, the situation has improved for residential consumers. However, industrial consumers are yet facing load shedding that causes either production cuts or increased production costs due to adoption of expensive self-generation systems. In the absence of a comprehensive assessment of the economic loss caused by electricity load shedding in Nepal, this study analyzes the impacts of load shedding during the 2008-2016 period.

The study estimates that Nepal has lost a total of US$11 billion value of GDP in nine years during the 2008-2016 period due to electricity load shedding. This amount is almost equal to Nepal's GDP in 2008. If the annual GDP loss is expressed in 2016 price using the corresponding GDP deflator values, the total GDP loss over the 2008-2016 period amounts to US$14.5 billion. On average, the country lost more than 6% of its GDP annually during that period. All sectors experienced cuts in their outputs, which was caused either by lack of electricity supply (small and medium sized industries which cannot afford back-up power) or increased electricity costs (e.g., large industries which can afford expensive back-up generation). The most notable impact is found on investment, which was highly depressed due to the lack of reliable electricity supply. For example, if there were no load shedding, annual investment, on average, would have increased by 48% during the 2008-2016 period. Due to the lower investment and production loss caused by load shedding, total industrial outputs decreased by 6.9%. Load shedding would have also affected Nepal's international trade during the 2008-2016 period causing 2.8% reduction of exports and 5.4% reduction of imports.

Since the estimated impacts are based on a modeling exercise rather than an actual accounting exercise, the numbers should be interpreted with caution. The results are indicative because the estimates change, though not significantly, if some model parameters, such as the elasticity of substitution, are altered. The adverse impacts reported here might be overestimated because the model has not accounted for some of the offsetting measures provided through the provision of back-up power supply during load shedding. The impacts of load shedding estimated here are relevant only in the context of not meeting electricity demand to the customers already connected to the national electricity grid. The country also has been suffering due to lack of electricity access in areas not served by the national grid or off-grid/distributed generation systems. This analysis does not fully include economic loss of not providing electricity in those areas. Moreover, some large-scale electricity intensive industries, such as fertilizer factories, chemical industries, might not have been installed in Nepal due to unavailability of the large quantity of electricity they need. This study also does not capture economic loss of not having such large-scale industries, when insufficient supply of electricity is the only reason for not getting them installed. However, further investigation would be needed to confirm if such a situation exists and to what extent.

Although the recent reduction of load shedding in the residential sector has certainly helped reduce the discomfort faced by households and has also reduced household expenditure on back-up devices (e.g., batteries, inverters) thereby increasing household real income, the range of economic loss estimated in this study (or slightly lower value) would still persist because industries are continuously facing load shedding or higher electricity expenditure due to expensive back-up supply provisions. Therefore, the elimination of load shedding, particularly from the industrial sector, is crucial to avoid billions of dollars of economic loss in years to come. Moreover, elimination of load shedding is also critical to improve the business environment for potential investors, which is absolutely needed to boost Nepal's economic growth.

References

Abdullah, Sabah and Petr Mariel (2010). Choice experiment study on the willingness to pay to improve electricity services, Energy Policy, Vol.38, pp. 4570–4581.

Allcott, H. et al (2016). How do electricity shortages affect productivity? Evidence from India. American Economic Review, 106(3): 587–624.

Armington, P. (1969). A Theory of Demand for Products Distinguished by Place of Production. IMF Economic Review, Vol. 16, No. 1, pp. 159-178.

Bose R.K., Shukla M. Srivasta L and Yaron G. (2006). Cost of unserved Power in Karnataka, India. Energy Policy, 34 (12), 1434-1447.

Braimah, I. and O. Amponsah (2012). Causes and effects of frequent and unannounced electricity blackouts on the operations of micro and small-scale industries in kumasi. Journal of Sustainable Development, 5(2), 17-36.

Coady, D., and R. Harris (2001). A Regional General Equilibrium Analysis of the Welfare Impact of Cash Transfers: An Analysis of Progresa in Mexico. Trade and Macroeconomics Division, Discussion Paper No. 76. International Food Policy Research Institute, Washington, DC.

Decaluwé, B., L. Savard and E. Thorbecke (2005). General Equilibrium Approach for Analysis with an Application to Cameroon. African Development Review, 17, pp. 213-243.

Despotakis, K.A. (1980). Economic performance of flexible functional forms: Implications for equilibrium modeling. European Economic Review, Vol. 30, pp. 1107-1143.

Frisch, R. (1954). Linear Expenditure Functions: An Expository Article. Econometrica, Vol. 22, No. 4, pp. 505-510.

Jyoti, R., Ozbafli, A., and G. Jenkins (2006). The Opportunity Cost of Electricity Outages and Privatization of Substations in Nepal. Queen's Economics Department Working Paper No. 1066, Queen's University, Canada.

Kaseke, N. and S. Hosking (2012). Cost of electricity load shedding to Mines in Zimbabwe: Direct Assessment Approach. International Journal of Physical and Social Sciences, *2*(6), 207-237.

Nepal Electricity Authority (NEA). Annual Reports for the period between 2007 and 2017.

Oseni, M. and M. Pollitt (2013). The Economic Costs of Unsupplied Electricity: Evidence from Backup Generation among African Firms, Department of Economics Working Paper #1351. University of Cambridge.

Shoven, J.B. and J. Whalley (1984). Applied General Equilibrium Models of Taxation and International Trade: An Introduction and Survey. Journal of Economic Literature XXII, pp. 1007-1051.

Shoven, J.B. and J. Whalley (1992). Applying General Equilibrium. Cambridge University Press.

Shrestha, R. S. (2010). Electricity Crisis (Load Shedding) in Nepal, Its Manifestations and Ramifications, Hydro Nepal, Issue 6, pp. 7-17.

Stone, R. (1954). Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand. The Economic Journal, Vol. 64, No. 255, pp. 511-527.

Appendix 1. Details of the CGE Model[12]

A1. Production and Employment

Total sectoral production XST_i is a CES aggregate of regional production ($XST_{i, reg}$):

$$XST_i = \beta\_xs_i * (\Sigma_{reg}, \delta\_xs_{i,reg} * XS_{i,reg}^{-\rho\_xs(i)})^{(-1/\rho\_xs(i))} \ldots\ldots \quad (1)$$

Urban and Terai production are derived from the above expressions:

$$XS_{i,"URB"} = (\delta\_xs_{(i,"HMT")}/\delta\_xs_{(i,"URB")})^{\sigma\_xs(i)} (P_{(i,"URB")}/P_{i,"HMT")})^{\sigma\_xs(i)} XS_{i,"HMT"} \ldots\ldots (2)$$

$$XS_{i,"TER"} = (\delta\_xs_{(i,"HMT")}/\delta\_xs_{(i,"TER")})^{\sigma\_xs(i)} (P_{(i,"TER")}/P_{(i,"HMT")})^{\sigma\_xs(i)} XS_{(i,"HMT")} \ldots\ldots \quad (3)$$

where, XST_i is sectoral production of the ith branch, $XS_{i,reg}$ is sectoral production in region reg.

Production in the branches follows fixed coefficient Leontief technology. Total output (XS_i) is equal to min (IC_i / io_i , VA_i / v_i), where VA_i is the value added of the ith branch and IC_i is the intermediate consumption of the ith sector. The io_i and v_i are the Leontief technical coefficients of domestic intermediate inputs and value added, respectively, and are defined as $v_i = VA_i/XS_i$ and $io_i = IC_i / XS_i$. Regional production follows a Leontief technology at the first level:

$$XS_{i,reg} = VA_{i,reg} / v_{i,reg} \ldots\ldots \quad (4)$$

Intermediate Demand: Intermediate consumption demand is a derived Leontief technology. Intermediate consumption is derived from sectoral production levels and input-output coefficients. $IC_i = LF^*(X_i^s) = io_i \cdot VA_i / v_i$. since, $VA_i / v_i = XS_i$, we can simply write regional intermediate consumption as:

$$IC_{i,reg} = io_{i,reg} * XS_{i,reg} \ldots\ldots \quad (5)$$

Inter-industry transactions (ICJ_{ij}) are given by $ICJ_{ij} = a_{ij} IC_j \Rightarrow a_{ij} = ICJ_{ij} / IC_j$; where, a_{ij} are the familiar Leontief input-output coefficients. Following this, regional inter-industry transactions are defined similarly as:

[12] The model was originally set for regional-level disaggregation, therefore the model description presented here also reflects regions. However, we ran the model at the national level as the regional disaggregation used earlier is not relevant for now because Nepal has adopted a new federal structure with seven regions that are completely different from the three regions considered in the earlier version of this model. The model cannot be implemented in the new regional setup, as the necessary data are not available. However, keeping the regional disaggregation of the model in its description could be helpful to readers who might be interested to develop a regional CGE model for Nepal with the new federal structure in future.

$ICJ_{i,j,reg} = aij_{i,j,reg} * IC_{j,reg}$................. (6)

The demand for intermediate imports is treated as non-competitive imports given the absence of domestic production of the bulk of capital equipment and industrial raw materials. The non-competitive import demand ($ICNCI_i$) is similarly defined as demand for domestic intermediate demand: $ICNCI_i = noi_i . VA_i/v_i$, where noi_i is the Leontief coefficient for non-competitive imports.

Thus, regional intermediate transactions are similarly defined as:

$ICNCI_{i,reg} = noi_{i,reg} * XS$.............................(7)

We have grouped the production sectors and factor demand in the major three categories: agricultural sectors, non-agricultural sectors, and government sectors. This is important because there are obvious differences in production and cost structure in these industries.

Agricultural activities: The value added in agriculture is a CES between composite agricultural capital and labor.

$VA_{ag,reg} = \beta\_ag_{ag,reg} [(\delta\_ag_{ag,reg} KT_{ag,reg}^{-\rho\_ag(ag)} + (1-\delta\_ag_{ag,reg}) LD_{ag,reg}^{-\rho\_ag(ag)}]^{-1/\rho\_ag(ag)}$...(8)

where KT is the composite agricultural capital.

The total labor demand is a derived CES function. It is derived from equation (8).

$LD_{ag,reg} = ((1-\delta\_ag_{ag,reg})/ \delta\_ag_{ag,reg})^{\sigma\_ag(ag)} * (R_{ag,reg} / W_{ag,reg})^{\sigma\_ag(ag)} * KT_{ag,reg}$ .... (9)

The composite agricultural capital is a Cobb-Douglas aggregate of capital demand in agriculture and land.

$KT_{ag,reg} = \alpha\_ag_{ag,reg} * KD_{ag,reg}^{\alpha\_Kag,reg} * LAND_{ag,reg}^{\alpha\_ldag,reg}$ …….. (10)

where A and α are the Cobb-Douglas scale and elasticity parameters.

The capital demand in agriculture is a derived Cobb-Douglas. It is derived from equation (10).

$KD_{ag,reg} = (\alpha\_k_{ag,reg} * R_{ag,reg} * KT_{ag,reg} / RA_{reg}$ .... (11)

where ra is the rate of return on agricultural capital.

Labor aggregation in agriculture

The total labor demand is a CES agregate of unskilled and skilled labor.

$LD_{ag,reg} = \beta\_lb_{ag,reg} * (\delta\_lb_{ag,reg} * LDNQ_{ag,reg}^{(-\rho\_lb(ag))} + (1-\delta\_lb_{ag,reg}) * LDQ_{ag,reg}^{-\rho lb(ag)})^{-1/\rho\_lb(ag)}$..(12)

The skilled labor demand in agriculture is a derived CES technology. The skilled labor demand depends on the distributional share of wage between unskilled and skilled labor together with the elasticity of substitution of labor in the production process and level of unskilled labor demand in the agriculture sector. The skilled labor demand in agriculture is derived from (12).

$$LDQ_{ag,reg} = (1-\delta\_lb_{ag,reg} / \delta\_lb_{ag,reg}))^{\sigma\_lb(ag)} * (WNQ_{reg} / WQ_{reg})^{\sigma\_lb(ag)} * LDNQ_{ag,reg} \ldots\ldots \quad (13)$$

Non-agricultural activities: The value added in non-agriculture is a CES between capital and labor in the sector concerned.

$$VA_{in,reg} = \beta\_in_{in,reg} *(\delta\_in_{in,reg} *KT_{in,reg}^{-\rho\_in(in)} + (1-\delta\_in_{i,reg})*LD_{i,reg}^{(-\rho\_in(in)} \ldots\ldots\ldots\ldots \quad (14)$$

where $VA_{in,reg}$ is the value added in industry, KT and LD are capital and labor demand in industry, respectively.

The total labor demand in non-agriculture sectors is a derived CES function. The first-order condition of profit maximization of (14) provides (15).

$$LD_{in,reg} = (1-\delta\_in_{in,reg})/ \delta\_in_{in,reg}))^{\sigma\_in(in)} * (R_{in,reg} / W_{in,reg})^{\sigma\_in(in)} * KT_{in,reg} \ldots\ldots\ldots\ldots \quad (15)$$

Labor aggregation in non-agriculture: The total labor in non-agriculture is a CES aggregate of unskilled and skilled labor.

$$LD_{in,reg} = \beta\_wk_{in,reg} [\delta\_wk_{in,reg} LDNQ_{in,reg}^{-\rho\_wk(in)} + (1-\delta\_wk_{in,reg})LDQ_{in,reg}^{-\rho\_wk(in)}]^{(-1/\rho\_wk(in)} \ldots (16)$$

The skilled labor demand in non-agriculture is a derived CES technology. The skilled labor demand depends on the distributional share of wages between unskilled and skilled labor together with the elasticity of substitution of those in the production process and level of unskilled labor demand in the industry. The demand for skilled labor is derived from (16).

$$LDQ_{in,reg} = (1-\delta\_wk_{in,reg})/ \delta\_wk_{in,reg}))^{\sigma\_wk(in)} *(WNQ_{reg})/WQ_{reg})^{**\ \sigma\_wk(in)} * LDNQ_{in,reg} \ldots (17)$$

where, wq and wnq are the wage rates of skilled and unskilled labor, respectively.

Government sector

Value added of the government sector is simply the wage bill. For simplicity, we have assumed that all the government employment consists of skilled labor.

$$VA_{ad,reg} = LDQ_{ad,reg} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

The demand in the government sector is determined by the ratio of value added at the government sector to the wage rate.

$$LDQ_{ad,reg} = P_{ad,reg}*XS_{ad,reg} - \Sigma_j ICJ_{j,ad,reg}*PC_j - ICNCI_{ad,reg}*PCN_{ad,reg})/WQ_{reg}*(1+tv) \quad (19)$$

The total labor demand is provided with equation (20).

$$LD_{ad,reg} = LDQ_{ad,reg} \quad (20)$$

Income and savings

The household income consists of wage income, rental income, dividends, and transfers.

$$YH_{hh} = \Sigma_{reg}\ \gamma\_nq_{hh,reg} *WNQ_{reg} * \Sigma_n LDNQ_{n,reg}$$
$$+\gamma\_q_{hh,reg} *WQ_{reg} *\Sigma_i LDQ_{i,reg})$$
$$+\gamma\_kd_{hh,reg}*(\Sigma_{in} R_{in,reg} *KT_{in,reg} +RA_{reg} * \Sigma_{ag} KD_{ag,reg})$$
$$+\gamma\_lnd_{hh,reg} *\Sigma_{ag} RT_{ag,reg}*LAND_{ag,reg}$$
$$+DIV_{hh} +E*TRH_{hh} +PINDEX*TGH_{hh} \quad (21)$$

where, YH_{hh} is total household income by hh households, wnq and wq are the wages of unskilled and skilled labor, respectively. The DIV_{hh} is the dividend distributed to household hh, TGF is government transfer payments to firms (volume measure), TRH_{hh} is foreign transfer payments to various household groups hh, TFR is firms' transfer payments to the rest of the world, ER is the exchange rate (NRs per US dollar). The γ_h^{nq}, γ_h^{q}, γ_{hh}^{kd}, γ^{lnd}, r_{in} ra, rt_{ag} are the parameters. Similarly, γ_h^{nq} and γ_h^{q} are the shares of non-qualified and qualified income. The γ_{hh}^{kd} and γ_{hh}^{lnd} are the shares of rental income of other capital and land; r_{in} and ra are the rate of return on capital in industry and agriculture and rt_{ag} is the rental on land.

The firms' capital income is defined as the share of non-household rental income.

$$YK = \Sigma_{reg} [\{(1-\Sigma_{hh}\ \gamma\_kd_{hh,reg}) *(\Sigma_{in} R_{in,reg} *KT_{in,reg} +RA_{reg} * \Sigma_{ag} KD_{ag,reg})\}$$
$$+\{(1-\Sigma_{hh}\ \gamma\_lnd_{hh,reg})* \Sigma_{ag} RT_{ag,reg} *LAND_{ag,reg}\}] \quad (22)$$

where, KT_{in} and KD_{ag} are capital demand in industry and agriculture, respectively.

The dividend is assumed as a fixed rate of the firms' capital income

$$DIV_{hh} = dvr_{hh} *(1+cdv)*YK \quad (23)$$

where, dvr_{hh} is the dividend rate of household category hh and CDV is the factor of proportionality.

The household saving is defined as a fixed percent of the disposable income of the household.

$SH_{hh} = mps_{hh}\ YDH_{hh}$ …………………….   (24)

where, SH_{hh} is household savings, mps_{hh} is the marginal propensity to save parameter by household groups, and YDH is household disposable income.

The disposable income is derived as household income net of income taxes.

$YDH_{hh} = (1- ty_{hh})*(1+cty))*YH_{hh}$ …………………   (25)

where ty_{hh} is the household income tax rate by category of household hh.

Firm's income and saving: The firm's income consists of firm's capital income, government transfers to firms evaluated at producer prices and rest of the world transfer to firms at local currency.

$YF = YK + PINDEX * TGF + ER * TRF$ ………………..   (26)

where, YF is firm total income, PINDEX is producer price index and ER is the exchange rate.

The firm saving is derived through deducting the capital taxes, dividends and transfers to the rest of the world from the firm's total income.

$SF = YF - tk\ YK - DIV - TFR$ …………………   (27)

where, SF is firm saving and tk is the capital income tax rate.

Government's income and saving: The government income comprises of taxes from households, capital tax of the firms, production taxes, transfers from the rest of the world to government, import tariff and export duty.

$$YG = \Sigma_{hh} TXY_{hh} + tk*YK + E*TRG + \Sigma_i TVA_i$$

$$+\Sigma_{reg} \Sigma_i\ TXS_{i,reg} + \Sigma_m TXM_m + \Sigma_x TXE_x$$

$$+\Sigma_{hh}\ ctc*\Sigma_i\ PC_i *CH_{hh,i} + \Sigma_{reg} \Sigma_i\ TMNI_{i,reg} \quad (28)$$

where, YG is government revenue, TXS_i is indirect taxes, TXM_n is revenue from import duties, TXE_n is revenue from export tariffs and SG is government saving. The government saving is equal to government income less government transfers less total government consumption.

$SG = YG - PINDEX\ TGF - CTG - TGR - \sum_{hh} TGH_{hh}$ ……………….   (29)

Taxes

Value Added Tax

$TVA_n = TV * PVA_n * VA_n$ ……………………… (30)

$TVA_{ad} = TV * WQ * LDQ_{ad}$ …………………… (31)

Production Tax and Sales

Indirect taxes are equal to the tax revenue generated from total output at producer prices.

$TXS_{i,reg} = tx_{i,reg} (1+ctx).P_{i,reg} .XS_{i,reg}$ .... (32)

where, tx_i is the indirect tax rate.

Tariff: The import duty at domestic prices is equal to the tariff rate levied on CIF import value multiplied by the nominal exchange rate to convert it into domestic prices.

$TXM_n = tm_n ER. PWM_n. M_n$ ……………… (33)

where, TXM_n is the total tariff collected from imports, tm_n is import duty rate, ER is the nominal exchange rate, PWM_n is the world price of imports, and M_n is the volume of imports.

The export duty is equal to the rate of export duty applied to the domestic value of export sales.

$TXE_n = te_n PE_n EX_n$ ……………………… (34)

where, TXEn is the total export duty collected, te_n is export duty rate, PE_n is the domestic price of exports and EX_n is the exchange rate.

$TXY_{hh} = ty_{hh} .(1+cty).YH_{hh}$ .... (35)

The tariff revenue from non-competitive imports is equal to the rate of non-competitive tariff applied to the value of CIF imports of non-competitive imports converted to the domestic currency by the nominal exchange rate.

$TMNI_{i,reg} = tmi_{i,reg} .PCNW_i .ICNCI_{i,reg} .E$................... (36)

where, $TMNI_i$ is the total tariff collected from non-competitive imports, tmi_i is the tariff rate on non-competive imports, $PCNW_i$ is the world price of non-competitive imports, ICNCIi is the volume of non-competitive imports.

The compensatory consumption tax revenue (TC) is equal to the endogenously determined uniform consumption tax (tc) multiplied by the total value of household consumption.

$TC = tc\Sigma_{hh} \Sigma_i PC_i \; CH_{hh,I}$ ………………………………………… (37)

Demand

Household consumption: The total household consumption is equal to disposable income of the households less saving of the households. The household consumption function is estimated following a Linear Expenditure System. Government consumption is defined as the volume of regular expenditure that the government sector incurs. Total consumption of good i is a volume measure comprising of household and government consumption.

Total household consumption is equal to disposable income of the households less saving of the households.

$CTH_{hh} = YDH_{hh} - SH_{hh}$ ………………………….   (38)

where, CTH_{hh} is total household consumption, YDH_{hh} is disposable income, SH_{hh} is household saving.

The household consumption behavior is modeled using a Linear Expenditure System (LES). It has two components. One is the minimum subsistence consumption of the household, and other one is the supernumerary consumption above the household minimum.

$CH_{hh,i} = MINI_{hh,i} + \beta_{hh,i}^{C} (CTH_{hh} - \sum_j PC_j \; MINI_{hh,j})/PC_i$ …………..   (39)

where $CH_{hh,i}$ is household consumption of good i by hh households, Mini is subsistence level of consumption, $\beta_{hh,i}^{C}$ is the marginal share of good i in household consumption by household group hh, CTH_{hh} is the total household consumption , PC_j is the composite price of good j and $MINI_{hh,j}$ is the minimum subsistence requirement of commodity j by household group hh.

Government consumption: Government consumption is defined as the volume of consumption that the government sector consumes.

$CG_i = \beta_i^{G} CTG/PC_i$ ………………………….   (40)

where, CG_i is public consumption of good i, where, β_i^{G} is the share of good i in public consumption, CTG is the total value of government consumption and PC is the composite price.

Total consumption: Total consumption of good i is a volume measure comprising of household and government consumption.

$C_i = \sum_{hh} CH_{hh,i} + CG_i$ ……………………………….   (41)

where, C_i is consumption of good i, $CH_{hh,i}$ is the household consumption of good i by hh household groups and CG_i is the public consumption of good i.

Intermediate demand: Intermediate demand of good i is derived from the input-output relations and intermediate consumption of good i.

$INTD_i = \sum_j a_{ij} IC_j$ ………………………………….. (42)

where, $INTD_i$ is intermediate demand of good i (volume), a_{ij} are the Leontief coefficients and IC_i is total intermediate consumption by branch i.

Investment Demand

Investment is also a volume measure determined by the share of good i in the total volume of investment, normalized through the composite price index.

$INV_i = \beta_i^I IT/PC_i$ ………………………………… (43)

where, INV_i is consumption of good i for investment uses (volume), β_i^I is the share of good i in investment, IT is total investment (value), and PC_i is the price of the composite commodity.

Foreign Trade

The standard small-country assumption in a simple commodity trade model is that the world price is fixed (i.e. that the country modeled is a price-taker) and that the domestic good is a perfect substitute for the internationally traded commodity, so that the law of one price holds. Given the high level of aggregation in an economywide model, the assumption of perfect substitutability between domestic goods and international traded goods is not reasonable for most sectors. Thus, for imports, an alternative formulation, first proposed by Armington (1969), is used. Nepal's demand for imports is assumed to be too small to affect world prices, so the world price of imports expressed in foreign currency (PWM) is fixed exogenously. The domestic price of imports is determined by $PM_n = (1+tm_n). ER. PWM_n.$ Likewise, the domestic FOB price of exports (PE_n) is equal to the exogenous world FOB price in US$ (PWE) converted to domestic currency, less export taxes: $PE_n = ER.PWE_n/(1+te)$. Analogous to import goods, export goods and goods produced and consumed domestically may not be perfect substitutes because of the relatively high level of aggregation in the model.

The import demand function is derived from the cost minimization of the CES.

Export supply: Following Condon, Dahl and Devarajan (1987), total output in the exportable sectors is defined as a constant elasticity of transformation (CET) function between the domestic and export markets.

$XST_x = b_x^T[\ (\delta_{nx}^T EX_x{}^{\rho_x^T} + (1-\delta_x^T)\ D_x{}^{\rho_x^T}\ ]^{1/\rho_x^T}$ …… (44)

where, D_x is local demand for domestically produced goods (volume), b_x^T is CET scale parameter, δ_x^T is CET distributive share parameter, ρ_x^T is CET transformation parameter, σ_x^T is CET elasticity of transformation,

Export supply is derived from the profit maximization subject to the above CET function. It is determined by the relative price of export to domestic price index, domestic output level and degree of transformation between domestic and export markets.

$EX_x = D_x [PE_x (1-\delta_x^T) / PD_x \delta_x^T)]^{\sigma_x^T}$ ……………… (45)

Where ${}^{\sigma}{}_x{}^T = 1/(1+\rho_x^T)$ is the CET elasticity.

In the non-exportable sectors (nx), composite output is sold solely on the domestic market.

$XST_{nx} = D_{nx}$ ………………… (46)

In the importable branch, the composite commodity Q_m is a CES function of domestic and imported commodities:

$Q_m = b_m^s (\delta_m^s M_m^{-\rho_m^s} + (1- \delta_m^s) D_m^{-\rho_m^s})^{-1/\rho_m^s}$ …………………… (47)

where, b_m^s is the CES scale parameter, δ_m^s is the CES distributive share parameter, ρ_m^s is the CES substitution parameter, σ_m^s is the CES elasticity of substitution parameter.

Import demand function: The import demand function is derived from the cost minimization and the CES.

$M_m = D_m [PD_m \delta_m^s / PM_m (1- \delta_m^s)]^{\sigma_m^s}$ …………… (48)

where $\sigma_m = 1/(1+\rho_m^S)$ is the Armington elasticity.

Equation (45) expresses the ratio of imported goods to domestically produced goods as a function of the relative prices of imported and domestically produced goods, The larger the value for σ_m , the greater the sensitivity of the share of imports in total supply to price changes. In the limit, with σ_m equal to infinity (i.e. imports and domestic goods are perfect substitutes), PD must equal PM if imports and domestic production are both non-zero.

In the non-importable branch, only domestic goods are consumed.

$Q_{nm} = D_{nm}$ …………………………………… (49)

Government demand of the composite commodity is simply the government services or output.

$Q_{ad} = X_{ad}$ ………………………………………. .(50)

Current account balance: The exogenous current account balance (CAB) is equal to the trade balance plus exogenous transfer payments from the rest of world (TGR) less exogenous transfers from the rest of the world to households (TRHhh), firms (TRF), and government (TRG). The current account deficit is encountered if there is excess demand of goods and services.

$$CAB = (1/e)TGR + \sum_n PWM_n M_n + \sum_i PNCW_i . ICNCI_i$$

$$- \sum_{hh} TRH_{hh} - TRF - TRG - \sum_n PWE_n EX_n \quad \ldots\ldots\ldots \quad (51)$$

Prices

In the general equilibrium framework, agents face relative prices. The relative price changes affect consumers and producers' decisions. The price equations are provided for producer prices, value added price, domestic price of imports, domestic price of exports, composite prices, non-competitive import prices, prices of government services and producers price index. In the small open economy setting, the external shocks are transmitted through the price mechanism. Therefore, world prices of exports and imports are exogenously determined in the world market.

Factor prices: The rental rate of composite agricultural capital ($R_{ag,reg}$) is defined as the operating surplus per unit of composite agricultural capital.

$$R_{ag,reg} = (PVA_{ag,reg} * VA_{ag,reg} - W_{ag,reg} * LD_{ag,reg}) / KT_{ag,reg} \ldots. \quad (52)$$

The rental rate of land in agriculture is the ratio of differential rental income between composite agricultural capital and other capital demand in agriculture to that of land.

$$RT_{ag,reg} = (R_{ag,reg} * KT_{ag,reg} - RA_{reg} * KD_{ag,reg}) / LAND_{ag,reg} \ldots.. \quad (53)$$

$$RT_{ag,reg} = RTF_{reg} \ldots\ldots\ldots\ldots\ldots \quad (54)$$

where RTF_{reg} is return on land.

The wage rate in agriculture is defined as:

$$W_{ag,reg} = (WNQ_{reg} * LDNQ_{ag,reg} + WQ_{reg} * LDQ_{ag,reg}) / LD_{ag,reg} \ldots. \quad (55)$$

The rental rate ($R_{in,reg}$) in non-agriculture capital is the operating surplus per unit of composite capital in non-agriculture:

$$R_{in,reg} = (PVA_{in,reg} * VA_{in,reg} - W_{in,reg} * LD_{in,reg}) / KT_{in,reg} \ldots\ldots. \quad (56)$$

$$R_{in,reg} = RF_{reg} \ldots\ldots\ldots\ldots\ldots \quad (57)$$

where RF_{reg} is return on non-agricultural capital.

The wage rate of non-agricultural sectors is the average wages of skilled and non-skilled labor per unit of demand.

$W_{in,reg} = (WQ_{reg} *LDQ_{in,reg} +WNQ_{reg} *LDNQ_{in,reg})/ LD_{in,reg}$ ...... (58)

Domestic price of imports: The domestic price of imports is equal to world prices of imports evaluated at the nominal exchange rate inclusive of import tariffs.

$PM_m =(1+tm_m) ER.PWM_m$ …………………. (59)

Domestic price of exports: The domestic price of exports is equal to the world price of exports evaluated at the nominal exchange rate and adjusted for export taxes.

$PE_x =ER. PWE_x/(1+te_x)$ ………………………… (60)

The after-tax consumer price (PCF) is equal to the pre-tax consumer price (PC) multiplied by one plus the uniform compensatory consumption tax rate (tc):

$PCF_i = PC_i *(1+tc)$........................... (61)

Composite price: Composite price PC_n is defined as the weighted average price of domestic and import prices, the weights being the shares of domestic and imported output in the composite commodity.

$PC_m =(D_m/Q_m)PD_m +(M_m/Q_m)PM_m$ ……………... (62)

In the non-importable sector, this price is simply equal to the price of domestic goods:

$PC_{nm} = PD_{nm}$ …………………………………………………………. (63)

Domestic price of non-competitive imports: The domestic price of non-competitive imports is equal to world prices of non-competitive imports evaluated at the nominal exchange rate with the inclusion of tariffs imposed on non-competitive imports.

$PCN_{i,reg}= (1+tmi_{i,reg})PCNW_i \cdot ER$ ………………….. (64)

Price of government services: The price of the government services is the domestic prices of government services.
$PC_{ad} =P_{ad}$ ……………………………….. (65)

Value-added price: The price of value added is the ratio of total output less intermediate consumption to the value added in the sector.

$PVA_{n,reg} =(P_{n,reg} *XS_{n,reg} -\Sigma_j PC(J) *ICJ_{j,n,reg} -PCN_{n,reg} *ICNCI_{n,reg})/ (1+tv)VA_{n,reg}$……….(66)

Producer price: The aggregate composite producer price (PT) is equal to the weighted sum of the regional producer prices (P) multiplied by the production tax rate (tx):

$PT_i = \Sigma_{reg} (XS_{i,reg}/XST_i) P_{i,reg} (1+tx_{i,reg}) (1+ctx)$…………………… (67)

Price of exportable products: The aggregate composite producer price (PT) in exportable sectors is a weighted average of the producer prices on domestic and export sales, with the volume weights equal to the respective weights of these sales in total production:

$PT_x = (PD_x *D_x +PE_x *EX_x)/ XS_x *(1+tx_x)*(1+ctx_x)$………… (68)

In non-exportable sectors this price is simply equal to the price of domestic goods.

$PT_{nx}= PD_{nx}$ …………………………………………….. (69)

Producers price index

The producer price index is the weighted average of domestic prices, the weights being the shares of goods in the total domestic production.

$PINDEX =\Sigma_{reg}\Sigma_i \beta_i^X P_{i,reg}$ …… …………………… (70)

The investment price index (PINV) is the weighted average of prices, the weights being the shares of goods in total domestic production.

$PINV = \Pi PC_i / \beta\_i_i^{\beta\_i(i)}$………………………………………...... .(71)

Market Equilibrium

The composite commodity Q_{zz} is equal to the total domestic absorption of consumption demand, intermediate demand and investment demand.

$Q_{zz} =C_{zz}+INTD_{zz} + INV_{zz}$ ……………… (72)

Factor market equilibrium

The sum over sectors of the demand for unskilled labor in each region ($LDNQ_{reg}$) is equal to the exogenously fixed regional unskilled labor supply ($LSNQ_{reg}$) and, similarly, the sum of sectoral demands for skilled labor by region (LDQ_{reg}) is equal to the exogenously fixed regional supply (LSQ_{reg}).

$LSNQ_{reg} = \Sigma_n LDNQ_{n,reg}$ …………………… (73)

$LSQ_{reg} = \Sigma_I LDQ_{i,reg}$ ……………………… (74)

The sum of sectoral demands for agricultural and non-agricultural capital by region ($KD_{ag,reg}$

$KT_{in,reg}$) is equal to their respective exogenous regional supplies (KSD_{reg} and KST_{reg})

$KST_{reg} = \Sigma_{in} ,KT_{in,reg}$ ……………………… (75)

$KSD_{reg} = \Sigma_{ag} KD_{ag,reg}$ ……………………… (76)

Total land supply (LANDS) is also fixed by region to the sum of sectoral demands for agricultural sectors ($LAND_{ag,reg}$).

$LANDS_{reg} = \Sigma_{ag} LAND_{ag,reg}$ …………………… (77)

Investment-Saving balance

The total investment is equal to total household saving by hh households plus firms' saving, government saving and foreign saving (as represented by the current account balance converted at the nominal exchange rate ER.

$IT = \sum_{hh} SH_{hh} + SF + SG + ER.\ CAB$ ………….. (78)

Walras

Leon = Q("wrt") –C("wrt")-INTD("wrt")-inv("wrt") ……………… (79)