Dutch disease in a new era: a tale of renewable resource dependence and tourism in Bhutan

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Introduction

The impact of the planned expansion of hydropower in Bhutan between 2019 and 2030 is examined in this study. Four scenarios are considered: (1) no additional growth in hydropower after 2020, (2) a reference scenario with the planned expansion of four additional hydropower plants, (3) the planned expansion with revenues diverted towards human and physical capital accumulation, and (4) the planned expansion with fiscal transfers where revenues are used to fund a Basic Income Grant to households. A comparison of the first and second scenarios yields insights into the impact of the planned expansion, particularly in terms of Dutch Disease style effects, while a comparison of scenarios 3 and 4 with the reference scenario highlights the implications of diverting additional hydro revenues to support specific policies.

The study employs a recursive dynamic Computable General Equilibrium (CGE) model calibrated to a 2019 Social Accounting Matrix (SAM) for Bhutan. Key features of the Bhutanese economy including delayed capital installation and cessation of large foreign investment flows during the period are included in the representation of the economy.

Modelling hydro power investments

The starting point for the analysis is to identify the process through which the planned additional hydro power investment between 2020 and 2025 is likely to filter through the economy. Four large scale hydro power projects are currently under construction in Bhutan. Two plants, Punatsangchhu II (Puna II) and Nikachhu are due to be commissioned in 2023 and a further two plants, Punatsangchhu I (Puna I) and Kholongchhu in 2025. The four projects together are set to increase the installed hydroelectric capacity of Bhutan from 2326MW in 2019 to 5264MW in 2025. Average annual energy production is set to increase from 10,724GWh in 2019 to 23,574GWh from 2025 onwards.

Large scale construction projects such as hydro power stations, typically have two phases of impact: the construction phase and the revenue phase. The first four steps in Figure

1 show the construction phase and the last four steps, the revenue phase. During the construction phase, the additional investment boosts the construction sector and associated demand for inputs including construction workers. Where the investment comes from abroad, large investment flows may also impact the real exchange rate. The culmination of the construction phase is the formation of the finished capital stock, here, hydro power plants. In Bhutan, the construction phase runs from 2020 to 2025 across the four plants.

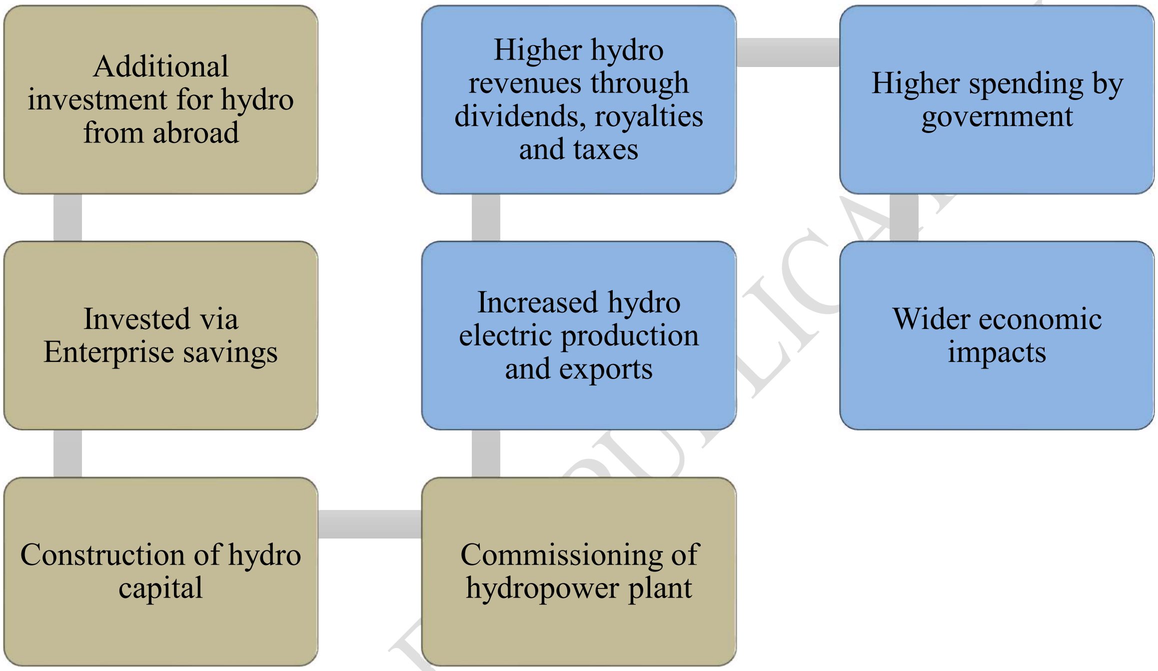


Figure 1 The process of hydropower expansion

The revenues phase begins when the plant is commissioned and revenues, in the form of dividends, royalties, and Corporate Income Tax, are received. In Bhutan, the revenues phase for the planned projects, i.e., revenues over those received for previous hydropower projects, begin in 2023 and continue throughout the project period to 2030. There are therefore two years, 2023 and 2024, in which the construction and revenues phases overlap.

The wider economic impact of the revenues depends upon how they are spent (or saved) within the economy. Where revenues are derived, in large part, from export sales, as is typical in resource dependent economies, the real exchange rate will be impacted and may lead to 'Dutch disease' style effects in which the inflow of foreign currency appreciates the real exchange rate and adversely affecting lagging export sectors.

Method

This study employs an economy-wide Computable General Equilibrium Model calibrated to a 2019 Social Accounting Matrix for Bhutan. The model is set up to capture the process of hydropower expansion in Figure 1.

A Social Accounting Matrix for Bhutan in 2019

A Social Accounting Matrix (SAM) is a detailed snapshot of an economy's circular flow and depending on data availability can provide a high level of detail about an economy's structure. It is a *social* accounting matrix, because contrary to other economic statistical frameworks (e.g., national accounts, input-output and supply and use tables) it also captures transactions of households and other institutions within the economy. SAMs provide essential information about the structure of an economy. They allow for multiplier analysis to be conducted and are used as databases for economy-wide models such as computable general equilibrium (CGE) models.

To date, Bhutan SAMs have been developed with base years of 2007 and 2012 with different level of disaggregation (Feuerbacher, 2014; Feuerbacher *et al*., 2017). This study uses a 2019 Social Accounting Matrix (SAM) for Bhutan (Feuerbacher *et al*., 2022) which was developed to produce a SAM with a more recent base year and to provide a detailed representation of the hydropower sector. 2019 was selected as a base year, as it is the last year before the global COVID-19 pandemic, which had a profound impact on the Bhutanese economy.

The development of the SAM is *inter alia* based on national accounts data from 2019 and structural data from a 2012 Supply-Use-Table. Given the increasing importance of hydropower generation within Bhutan's economy, the SAM has a detailed disaggregation of the electricity sector. The electricity and utilities sector has been disaggregated into hydropower generation and remaining utilities (water). There are two electricity activities (generation; transmission and distribution) producing four electricity commodities (electricity generated at the wholesale level, electricity transmission services, low-voltage, medium-voltage, and high-voltage electricity). The disaggregation was achieved utilizing audited annual company reports from the main Bhutanese hydropower companies and sectoral hydropower data provided by the Ministry of Finance of Bhutan. A Bayesian, cross-entropy estimation approach is employed to obtain the final comprehensive and consistent micro-SAM, reconciling data discrepancies between the different data sources.

The 2019 SAM consists of a total of 114 accounts, including 38 commodities (of which 33 are produced within Bhutan), 29 activities, 15 factors, and 12 household accounts (see Table 4 in the annex for a full description of the SAM accounts). Of the 15 factors represented, there are 5 labour, 6 capital and 3 land factors. Households are disaggregated "strategically" into a total of 12 representative groups by source of income, area (urban versus rural), and in the case of agricultural households, poor and non-poor. In addition, there are 2 enterprise accounts differentiated by private or public ownership. The remaining 18 accounts consist of two margin accounts (trade and transportation), the government and six tax accounts, the capital account (savings and investments) and six capital-type specific investment accounts, stock changes and the rest of the world (RoW) account. The disaggregation of household accounts, natural resource activities and the return to different labour types relied on survey data from the Bhutan Living Standard Survey 2017, the Agricultural Census 2018, and the Labour Force Survey 2018. The resulting macro-SAM for 2019 as used in this study is shown in Table 1.

Table 1 2019 Macro SAM for Bhutan in Million Nu.

	Commodity	Margin	Activity	Value added	Household	Enterprise	Government	Investment	Rest of the world	Total
Commodity		29959	105951		103430		32603	69147	61936	403026
Margin	29959.2									29959
Activity	277058									277058
Value added			167597							167597
Household				86322	2666	29812	4735		197	123732
Enterprise				73711			14779		14423	102912
Government	9826		3510		1924	19757			16757	51774
Saving				2086	15713	40564			11128	69147
Rest of the world	86183			5478		12780				104441
Total	403026	29959	277058	167597	123732	102912	51774	69147	104441	

Source: Authors' compilation

<u>A Computable General Equilibrium model for Bhutan</u>

The model

A recursive dynamic variant of the STAGE single-country CGE model (McDonald, 2022) is used in this study. The model is a member of the class of single country CGE models that are descendants of the approach to CGE modelling described by Dervis *et al*., (1982). More specifically, the implementation of this model, using the GAMS (General Algebraic Modelling System) software, is a direct descendant and development of models devised in the late 1980s and early 1990s, particularly those models reported by Robinson *et al*., (1990), Kilkenny (1991) and Devarajan *et al*., (1994). The model is a SAM based CGE model, wherein the SAM serves to identify the agents in the economy and provides the transactions database with which the model is calibrated.

The model is characterised by several distinctive features. First, the model allows for products that are both domestically produced and imported/exported or only domestically produced or only imported/exported. Second, the model allows for firms who produce more than one product under various assumptions; by-products that are a fixed share of production, varying output mixes by firms in response to changes in the (basic) prices of commodities, and domestically produced products that are differentiated by firm or are homogeneous, i.e., undifferentiated by firm. Hence the numbers of products and number of firms are not necessarily the same. Third, the (value added) production technologies can be specified as generalised nested Constant Elasticity of Substitution (CES) functions[1] allowing for the structure of production to differ by sector. Fourth, trade and transport margins between factory and dock gate and the consumer are levied on domestic consumption. Fifth, consumption expenditure by each representative household group is represented by nested CES and Stone-Geary (linear expenditure system – LES) utility functions which allows for subsistence levels of consumption. Sixth, the distribution of income is determined according to the ownership (domestic and foreign) of factors used within the economy. And seventh, the model is calibrated using two matrices detailing the factor use by activity and the factor ownership by institution.

In addition to the transactional data contained in the SAM, the CGE model requires further data to enable its application and to link the data with the behavioural relationships represented in the mathematical representation of the economy, i.e., the model: parameter values and elasticities. The starting parameter values, e.g., for trade shares, are calculated from the initial database. In the absence of empirical elasticity estimates for Bhutan, a set of assumptions are used (see Table 5 in the annex).

The sectoral elasticity values, together with the structure of production (see Table 5 in the annex), govern the way in which intermediate inputs and the factors of production combine to produce the final good of each sector. While the Electricity generation sector follows the same production structure as other similar industries, the substitution possibilities between inputs is restricted through lower elasticity values to ensure that any expansion in

[1] The nesting system for production is flexible and is configured by the user by set definitions that encompass both primary and intermediate inputs, i.e., there is no requirement to change the behavioural relationships or calibration code.

hydroelectric production uses a similar input mix. Specifying the production of hydropower in this way ensures that the electricity generation sector does not expand hydropower production after the end of the investment period by substituting labour/energy inputs for capital, i.e., the specification locks down the relationship between hydro capital installation and hydropower production which is desirable for this study.

Market clearing and model closure

From an economic perspective, the model closure defines the functioning of the economy and the way in which markets clear. The model closure for Bhutan regarding interactions with the rest of the world assumes the exchange rate is fixed (to reflect the peg with the Indian Rupee) with a varying external balance, Bhutan is assumed to be a price taker on world markets and, as such, world prices are fixed. The economy is assumed to be investment driven with household savings adjusting to meet the exogenous investment level. Enterprise savings do not adjust to maintain the link between foreign hydropower investment and hydro capital formation through the public enterprise account.

The crux of scenarios 3 and 4 in this study is the impact of diverting additional government hydropower revenue away from general government spending towards investments in productivity improvements (scenario 3) or fiscal transfers (scenario 4). The government account closure is therefore specified such that government borrowing and transfers are fixed at the 2019 level and tax rates do not change. All additional revenue is therefore channelled into government expenditure in the reference scenario.

All factors are assumed to be fully employed, recognising the role of labour in providing non-market services including home and caring duties which are not captured in the standard definition of the labour force. Land is mobile between the sectors that use it in 2019: Agriculture and Livestock. It is assumed that all installed capital is immobile, while new capital seeks out the sectors with the highest returns. This factor market specification results in economy-wide returns for labour (except for agricultural labour that is only used in a few sectors), sector-wide returns for land, and sector specific returns for capital.

The specification of fixed technology at all production levels (once the growth in total factor productivity consistent with GDP projections has been established), fixed (private) enterprise transfers to households, a fixed volume of enterprise demand and the Consumer Price Index (CPI) as the numéraire against which changes in prices are benchmarked, round out the specification of the functioning of the economy through the closure rules of the model.

Modelling the path of the economy through time

The long-term growth of the Bhutan economy is the focus of this study. Therefore, a recursive dynamic application of the model is used. It operates as series of comparative static simulations where the 'dynamic' updates are implemented between each comparative static simulation. These updates incorporate exogenously specified growth in key economic variables including Total Factor Productivity of value added (calibrated to target GDP projections), real investment, the quantity and quality of factors (labour, capital and land) and population.

In addition to the standard projection variables, the growth path for Bhutan is augmented with several features specific to the Bhutanese economy: international investment in hydropower with delayed installation, hydropower export prices, and international donor payments. To capture the process of hydropower expansion shown in Figure 1, the dynamic update incorporates projections of international investments in hydropower alongside a time lag. This introduces a delay between the formation of hydro capital and the commissioning of the plants as seen in multi-year hydro projects. The dynamic update also redirects capital investments from hydro capital to other forms of capital at the end of the hydro investment period in the proportions determined by relative returns to non-hydro capital.

Together these standard and specific projections define the growth path of Bhutanese economy in the model over time. The assumed values of the projections depend upon the scenario narratives and quantification as discussed in the next section.

Scenarios

Four scenarios are used to explore alternative long-term growth trajectories for Bhutan. The scenarios each span an 11-year period from 2019 (the base year of the SAM) to 2030. A 'reference scenario' approach is taken whereby a specific scenario, scenario 2 Hydro-led, is used as the comparison point for the other scenarios.

Scenario 1: No additional hydro (S1_NoAdd_Hydro) The continuation of past trends and current policies in place is assumed in this scenario. Investment in hydropower ends in 2020 with no further investment in, installation or commissioning of, hydropower plants. A comparison of this scenario with the reference scenario shows the impact of the planned hydropower projects, particularly on structural change via impacts on hydropower revenues and the real exchange rate (Dutch Disease).

Scenario 2: Hydro-led (S2_HydroLed) This scenario includes the continuation of past trends and current policies in place plus the construction and commissioning 4 planned hydropower projects: Punatsangchhu I, Punatsangchhu II, Nikachhu and Kholongchhu. The additional planned investment results in an expansion in hydro capacity and production after 2023/2025. No additional projects are planned after 2025. This scenario serves as a reference scenario for Scenarios 1, 3 and 4.

Scenario 3: Hydro-led with economic diversification (S3_HydroLed_Div) As scenario 2, but with public policy to diversify the economy by investing additional hydro revenues from the 4 hydropower plants in human capital accumulation (training) and physical capital accumulation. A comparison of this scenario with the reference scenario shows the impact of spending additional hydropower revenues on a diversification policy.

Scenario 4: Hydro-led with fiscal transfers (S4_HydroLed_BIG) As scenario 2, but with public policy to make hydro-led growth inclusive through fiscal arrangements, by distributing additional hydropower revenues from the 4 hydropower plants through a Basic Income Grant. The grant is assumed to be untargeted and unweighted such that all adults and children receive an equal per capita payment. A comparison of this scenario with the reference scenario shows the impact on the economy of targeting additional hydropower revenues on fiscal transfers.

The quantification of the four scenario narratives is shown in Table 2.

Table 2 Scenario quantification

	S1 No additional hydro	*S2 Hydro-led*	*S3 Hydro-led with diversification*	*S4 Hydro led with fiscal transfers*
TFP in line with GDP target (average)	0.3% per year			
Capital accumulation	Endogenous based on investment plus 2% per year (non-hydro capital)			
Hydro investment after 2020 (real)	None	Investment in planned projects: 57401 (Nu, millions)		
Non-hydro investment (real)	35% of S2 real GDP projections		35% of S2 real GDP projections plus invested hydro revenues	35% of S2 real GDP projections
Hydro installed capacity	In line with 2326MW	In line with 2326MW (2019), 3464MW (2023), 5264MW (2025)		
Hydroelectricity production	In line with 10724GWh	In line with 10724GWh (2019), 15460GWh (2023), 23574GWh (2025)		
Hydroelectricity export price increase (*cf* 2019, deflated, 2020-30 average shown)	40%	49%		
Hydro interest payments	Calibrated to yield hydro revenue projections in line with the World Bank macro model.			
Employed workers (annual compound growth)	0.46%			
Human capital accumulation (annual compound growth)	2.2%		2.8%	2.2%
Population (annual compound growth)	1.2%			
Agricultural land area (annual compound growth)	0.9% per year			
Yields	Stable at 2019 levels			
Donor inflows	-1% per year			

TFP Total factor productivity[2] is calibrated for the reference scenario using annual GDP projections from the World Bank macroeconomic model. TFP growth is assumed to be the same in all scenarios. TFP growth is dampened by 90% in the electricity generation sector to prevent productivity induced expansion of hydropower beyond projected output levels.

Capital accumulation Endogenous capital accumulation based on investment plus exogenous productivity improvement for non-hydro capital.

Hydro investment Annual international investment in Punatsangchhu I and II, Kholongchhu and Nikachhu deflated using the GDP deflator from the World Bank macroeconomic model (World Bank, 2022a).

Non-hydro investment Non-hydro investment is assumed to be 35% of projected GDP based on the average share of investment in GDP between 2009 and 2019 (World Bank, 2022b). Non-hydro capital is assumed to depreciate at 4% based on insights from the World Bank growth accounting exercise, and a rate of interest of 5% is assumed. A partial adjustment mechanism governs the reallocation of capital between type at a rate of 0.05 for non-hydro capital. In scenario 3, invested hydropower revenues raise the level of investment.

Hydro installed capacity The hydro capital stock in the 2019 SAM is consistent with installed hydro capacity of 2326MW. The commissioning of Punatsangchhu II and Nikachhu in 2023 increases installed capacity to 3464MW and Punatsangchhu I and Kholongchhu to 5264MW. The interest rate is selected to achieve an increase in the hydro capital in line with the installation of the plants, given investments in hydropower between 2020 and 2025. A 0.3% depreciation rate is assumed, to capture minimal depreciation in the years after commissioning.

Hydroelectricity production The output of the hydroelectricity sector in the 2019 SAM is consistent with the average annual energy production of 10724GWh. The commissioning of Punatsangchhu II and Nikachhu in 2023 increases production to 15460GWh and the commissioning of Punatsangchhu I and Kholongchhu increases hydro production to the maximum of 23574GWh per year. Hydro production in the model follows the path of these increases.

[2] Operational on value-added in the model.

Hydroelectricity export price increase The increase in the price of hydroelectricity exports accounts for higher expected export prices accruing to hydro exports. Export price growth is computed from the Bhutan FSA Baseline as total export revenue divided by total exports with and without exports from Punatsangchhu I, Punatsangchhu II, Nikachhu and Kholongchhu and deflated using the GDP deflator.

Hydro interest payments The interest payments on the debt are provided in the World Bank macro model, however, due to different expense accounting in the macro and CGE models, the interest payments adjusted to ensure that hydro power revenue projections are similar in both cases.

Employed workers Continuation of the 2009-2019 trend in employed workers which accounts for population, labour force participation rates, and unemployment trends (World Bank (2022b).

Human capital accumulation Growth in labour productivity guided by World Bank growth accounting (World Bank, 2022b). In the diversification scenario (scenario 3), labour productivity is assumed to be higher due to increased government spending on education.

Population Continuation of the 2009-2019 trend in population growth (World Bank, 2022b)).

Agricultural land area Continuation of the increase in operational land between 2008 and 2018 as reported in the RNR Census.

Yields Assumed to be stable at 2019 levels given differences between reported yields and those calculated from raw Census data.

Donor inflows Anticipated reduction in international donor inflows arising from Bhutan no longer having UN Least Developed Country (LDC) Status.

Scenario results

The evolution of a key economic variables is shown in Table 2. The value of each variable is shown for the reference scenario in 2019 and 2030, alongside the values under each of the three alternative scenarios in 2030. The shading shows the percentage change under the alternative scenarios compared to the reference scenario, providing a heat map of impacts. A more detailed presentation of results including sectoral impacts is included in Table 6 in the Annex.

Figure 2 Scenario results

	All scenarios	*S2_HydroLed Reference Scenario*		*S1_NoAddHydro*	*S3_HydroLed_Div*	*S4_HydroLed_BIG*
	2019	2019-2030	2030	Values in 2030. Shading shows percentage change compared to S2_Hydroled in 2030		
GDP	180.93		280.58	260.79	293.28	277.11
Domestic absorption	205.18		271.28	292.81	292.75	264.05
Savings	69.15		98.21	98.21	107.77	98.21
Hydro production (real)	20.16		44.67	23.46	45.56	45.07
Non-hydro production (real)	256.90		331.26	354.64	350.26	334.35
Economic concentration (index)	621.03		725.55	685.76	722.18	719.52
Government consumption	32.60		56.12	47.70	49.99	34.73
Household consumption per capita (real, '000s Nu)	129.78		147.27	184.49	169.77	165.28

Units: Billion Nu unless otherwise indicated

Key: -

<15%	-5% to -15%	Up to -5%	Up to 5%	5% to 15%	>10%

Percentage change relative to S2_HydroLed reference scenario in 2030

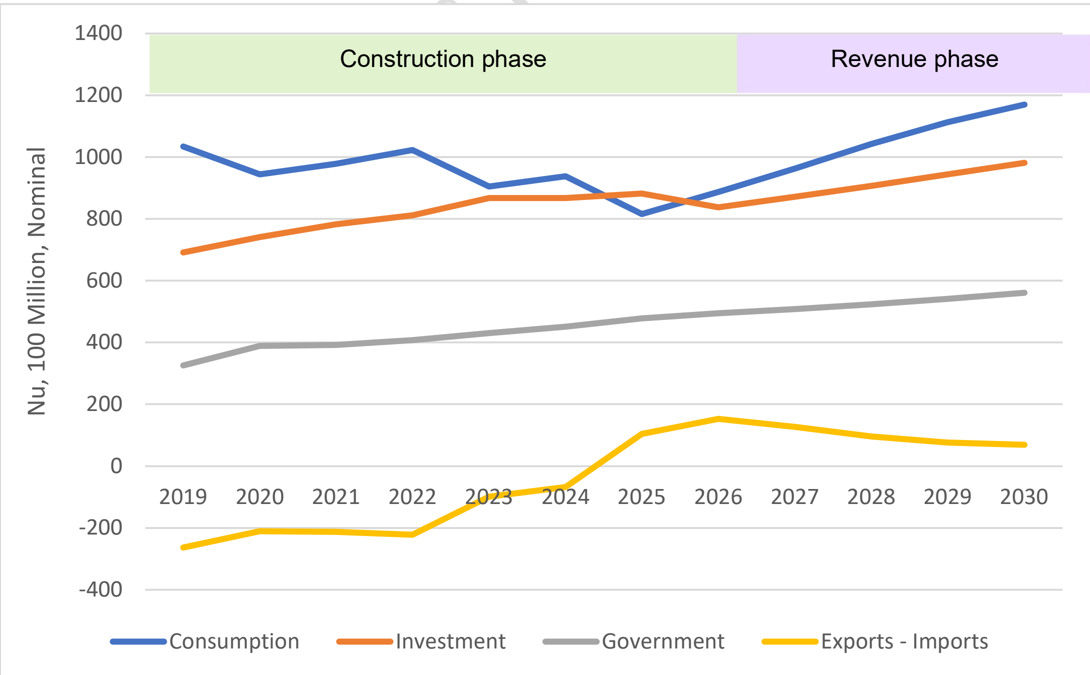
Table 3 Sector groupings

Sector grouping	*Group members*
Agriculture	Agriculture, Livestock, Forestry
Natural resources	Mining
Food and beverages	Food, beverages & tobacco
Industry	Textiles, Wood production, Chemicals, Cement, Rubber, Basic metals, Fabricated metals, Manu not elsewhere classified
Utilities	Electricity generation, Electricity distribution, Utilities
Construction	Hydro construction, Non-hydro construction
Services	Trade, Hotels & restaurant, Land transport, Air transport, Travel agency, Telecommunication, Finance, Public admin, Education, Health, Other Services

S2 Hydro-led: the reference scenario

The reference scenario clearly shows the impact of hydro-led growth in Bhutan between 2019 and 2030. GDP growth is strong, with domestic absorption slightly lower, highlighting the contribution of increasing hydroelectric exports. As shown in the sparkline in Figure 2, growth in domestic absorption is slow during the construction phase but picks up during the revenue phase. The growth path of the components of GDP in the reference scenario are shown in Figure 3.

Figure 3 Macroeconomic growth in the reference scenario



Investment rises strongly in line with hydropower investments during the construction phase; investment during the revenues phase (after 2025) is set at 35% of GDP by assumption. Consumption fluctuates during the construction phase as household savings adjust to meet investment levels. In contrast, government consumption rises strongly in line with the expansion in hydropower export revenues which is evident in the improvement in the trade balance.

There is significant structural change during the period as shown in Table 6. The expansion in hydropower shown in Figure 2 is much stronger than growth in all other sectors. Construction keeps pace with GDP thanks to the spill over demand from the formation of hydro capital (hydropower plants), but all other sectors experience slower growth. Unlike other resource dependent economies, the service sector does not appear to benefit from a higher real exchange rate that accompanies large resource-based investments and exports. This is because many of Bhutan's service sectors are export focused through tourism. The ramifications of this characteristic are examined in more detail in the next section on Dutch Disease. The resulting economy is one that is specialised in hydro-power production and reliant on hydropower exports for a large share of its government revenue.

An index of economic concentration, akin to the Herfindahl-Hirschman index used to measure market concentration, is included in Figure 2,

$$Economic\ concentration_{s,t} = \sum_a \left[\left(\frac{QX_{a,s,t}}{\sum_a QX_{a,s,t}}\right) * 100\right]^2.$$

The index of economic concentration is equal to the squared share of each activity's output, QX_a, in total output expressed as an integer, summed across all activities. The index is computed for each scenario and year. For the 29 activities considered, the limits of the index are 344 if all activities contribute equally to production, and 10,000 if only one activity produces all output. Production becomes more concentrated, i.e., less diversified, in the reference scenario as the economy expands hydro-power production.

The hydro-led structural change is reflected in the change in factor demands and returns across the period. The increase demand for labour in electricity production and distribution (albeit from a small base) is met by the projected growth in labour and by drawing it in from elsewhere in the economy. The formation and installation of hydro capital during the period can be seen in the sparklines, with the commissioning of the plants in 2023 and 2025. There is a shedding of capital in agriculture which is compensated for by more labour-intensive production. Wage rates for all types of labour except for agricultural labour grow moderately across the period, as do returns to capital. Land prices remain stable as the increase in land available for agricultural and related activities is in line with the expansion of production in these sectors.

Through investments in hydro capital, the production of electricity increases by 122% between 2019 and 2030 in line with projections. Much of the extra supply goes to meet export demand which increases by 137%. Domestic demand for electricity also increases but by less than export demand, 54%. As expected, government revenue in the form of dividends, royalties and Corporate Income Tax, increases strongly across the period, funding the strong rise in government consumption.

Moderate growth in factor returns translates into moderate increases in household incomes and consumption. Real household consumption per capita, a measure of welfare, increases by 13% between 2019 and 2030. In line with the relatively lower growth in agriculture and agricultural factor returns, agricultural households experience the lowest growth in consumption in the reference scenario. The exception to this is Urban households who experience income growth over the period but increase their savings which keeps their consumption levels at close to 2019 levels. Urban households account for more than 80% of private savings in 2019 and are therefore the primary source for raising private investment funds as total non-hydro investment increases.

<u>The impact of additional hydropower investments</u>

A comparison of scenario 1 'No additional hydro' with the reference scenario isolates the impact of the four large scale hydropower projects planned between 2020 and 2025.

Without the additional hydropower projects, the economy is smaller with a lower share of trade and a more diversified economic base. This contrasts with high levels of export-led growth which has enabled Bhutan to graduate from UN Least Developed Country (LDC) status. As expected, growth in the Utilities sectors is much slower. The primary sectors are larger without the additional hydro and the economy operates from a wider economic base.

Capital growth is lower without the additional hydro investment and capital is allocated more evenly across the economy. Labour and land supply remains at the same level by exogenous assumption. The change in demand for labour from the broader structure of the economy results in growth in wages that are more similar. Higher capital returns favour urban households, boosting their consumption growth. All household have higher consumption levels in scenario 1 without the additional hydropower expansion.

As expected, electricity production and exports are much lower without the additional hydropower plants which, in turn, leads to lower hydropower revenues both during the projection period and beyond, and lower government consumption growth. Lower government consumption growth leads to lower education and health spending which reduces the rate of human capital accumulation into the future.

Dutch Disease effects

Resource dependent economies are known to experience structural change due to the appreciation of the real exchange rate arising from large inflows of foreign currency. First termed Dutch Disease by the Economist magazine in an analysis of the impact of the discovery of the gas fields on Dutch manufacturing in the 1960s, this effect has historically been observed in countries endowed with fossil reserves. However, the expansion of hydropower production in Bhutan shares characteristics with the discovery of fossil reserves: a large share is destined for export, generating large foreign currency inflows. In Bhutan there is a large inflow of international investment funds in addition to the export revenues. As such, we consider the possibility of Dutch Disease style effects in an economy dependent on renewables.

The starting point for examining Dutch Disease effects is the induced change in the real exchange rate. The real exchange rate, rer, is defined as the nominal exchange rate, ER, multiplied by the ratio of the index of non-domestic prices, pw_ind, to the index of domestic prices, pd_ind,

$$rer = ER * \left[\frac{pw\_ind}{pd\_ind}\right].$$

A fall in the real exchange rate index is an appreciation in the real exchange rate. Notably, all price indices and therefore the real exchange rate index exclude hydropower prices. This is to avoid the index being skewed by the large increase in hydropower export prices over the period.

The pathway through which large inflows affect the real exchange rate depends on whether the country's currency is fixed or flexible (Ebrahimzadeh, 2020). Under a flexible exchange rate, the appreciation of the nominal exchange rate (defined as domestic currency units per unit of foreign currency) leads to an appreciation of the real exchange rate. Under a fixed exchange rate, the large inflow of money increases domestic demand pushing up domestic prices relative to non-domestic prices and appreciating the real exchange rate. Bhutan falls into the latter category due to the peg to the Indian Rupee.

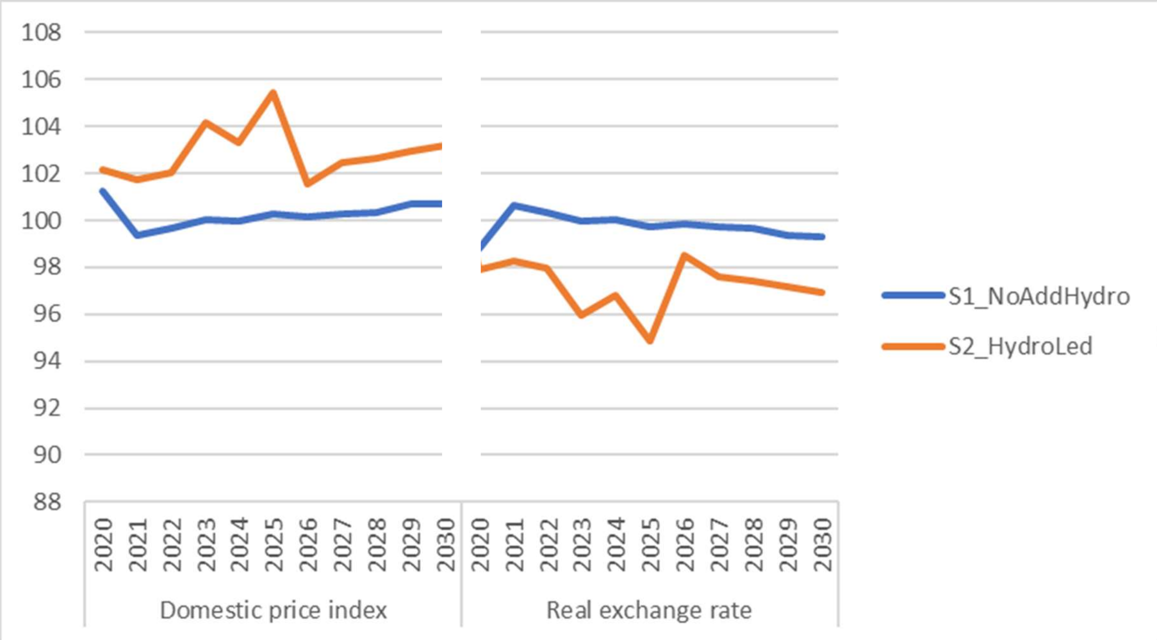
The impact of the planned hydropower expansion on domestic prices and the real exchange rate is shown in Figure 4. The planned investment in, and commissioning of, the additional hydropower leads to higher domestic prices compared to a ‘no additional hydro’ situation. The higher levels of foreign investment plus additional export revenues raise domestic incomes and spending and push up domestic prices. There is a drop in prices as the economy adjusts to the post-investment period but then prices begin to rise as export revenues increase.

The impact of the appreciation of the real exchange rate on the structure of the Bhutanese economy can be evaluated as per Corden & Neary (1982) by dividing the sectors of the economy into 3 groups: the booming resource sector, lagging export sectors and non-tradeable sectors[3].

Dutch Disease leads to structural change through the appreciation of the exchange rate which reduces the competitiveness of tradable goods on global markets. It typically shifts an economy in the direction of non-tradable services and reduces the size of the lagging export sectors. Structural change arises via two effects: the spending effect and the resource movement effect. The spending effect is the impact on production of the additional revenue generated by the booming export sector, while the resource movement effect is the change in

[3] Firstly, sectors are split into tradables and non-tradables according to the 2019 share of exports in total supply: sectors producing commodities with less than 5% exported are identified as non-tradables. Secondly, tradables are divided into the booming resource sector and lagging export sectors according to the spending and resource movement effects of the additional hydropower investments. Note that these effects are of the same sign for all sectors except Food, beverage and tobacco and Agriculture as discussed in the text.

Figure 4 The impact of planned hydropower expansion on domestic prices and the real exchange rate

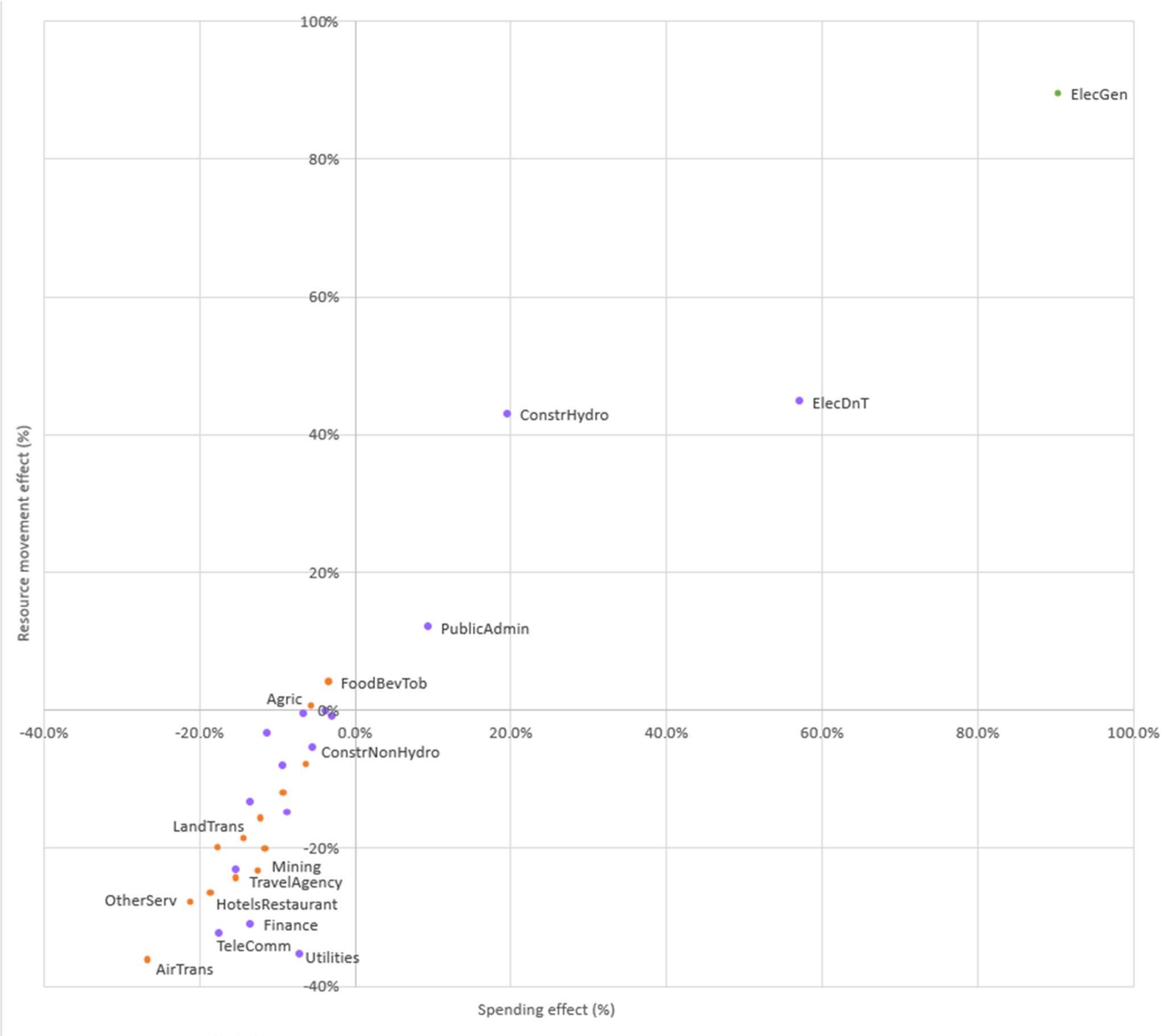


the share of labour (as the mobile factor) demanded by sectors as the expansion of the booming sector changes the pattern of labour demand.

The spending and resource movement effects of the additional hydropower expansion in Bhutan are shown in Figure 5. The results are derived by comparing the supply and labour demand by sector in the S2 HydroLed reference scenario with those in the alternative S1 NoAddHydro scenario. The effects are evaluated in 2030 when the maximum period for structural change has passed.

The impact of the planned expansion in hydropower on the electricity generation sector is clear with very strong spending and resource movement effects. The spending effect leads to a 90% higher level of supply in 2030 (44,668 Mn Nu compared to 23,464 Mn Nu). The resource movement effect is also 90% but from a small starting share of labour (4.6% in S2 compared to 2.4% in S1 in 2030). The change in the pattern of labour demand is shown by broad sectoral category in Figure 6. The remaining 3 sectors to benefit from the expansion in hydropower are all non-tradables connected to the hydropower sector: electricity distribution, hydropower construction and public administration. The movement of labour into public administration following hydropower investment as shown in Figure 6 is in line with the findings of Norbu (2017).

Figure 5 Dutch disease effects: spending and resource movement



Key: green – booming resource sector, orange – lagging export sector, purple – non-tradable sector. Selected sectors shown (see

Table 6 Detailed scenario results

		S2_HydroLed Reference Scenario		S1_NoAddHydro	S3_HydroLed_Div	S4_HydroLed_BIG
		Annual compound growth 2019-2030	Values 2019-2030	Annual compound growth 2019-2030. Shading shows percentage change compared to S2_Hydroled		
Macro	GDP	4.1%		3.4%	4.5%	4.0%
	Domestic absorption	2.6%		3.3%	3.3%	2.3%
Value added	Agriculture	1.1%		1.9%	1.7%	1.9%
	Natural resources	1.4%		2.5%	2.4%	2.3%
	Food and beverages	0.8%		1.4%	1.3%	1.4%
	Industry	2.7%		4.1%	3.6%	3.6%
	Utilities	11.0%		5.0%	11.3%	11.1%
	Construction	3.8%		3.8%	4.6%	3.7%
	Services	3.0%		3.6%	3.2%	2.1%
Labour demand	Agriculture	2.5%		2.6%	3.2%	2.6%
	Natural resources	-0.8%		1.3%	1.1%	1.6%
	Food and beverages	2.3%		1.9%	2.8%	2.0%
	Industry	0.8%		2.5%	2.5%	2.5%
	Utilities	7.6%		2.6%	8.3%	8.4%
	Construction	2.4%		2.9%	4.0%	3.6%
	Services	2.0%		2.3%	2.1%	1.0%
Capital demand	Agriculture	-1.8%		-1.6%	-1.6%	-1.7%
	Natural resources	1.5%		1.7%	2.2%	1.6%
	Food and beverages	1.2%		1.4%	1.9%	1.3%
	Industry	1.8%		2.1%	2.5%	1.9%
	Utilities	7.8%		1.7%	8.0%	7.9%
	Construction	1.3%		1.5%	2.0%	1.4%
	Services	1.8%		2.1%	2.4%	1.9%
	Hydro	7.8%		1.7%	8.0%	7.9%
	Non-hydro	1.4%		1.7%	2.1%	1.5%

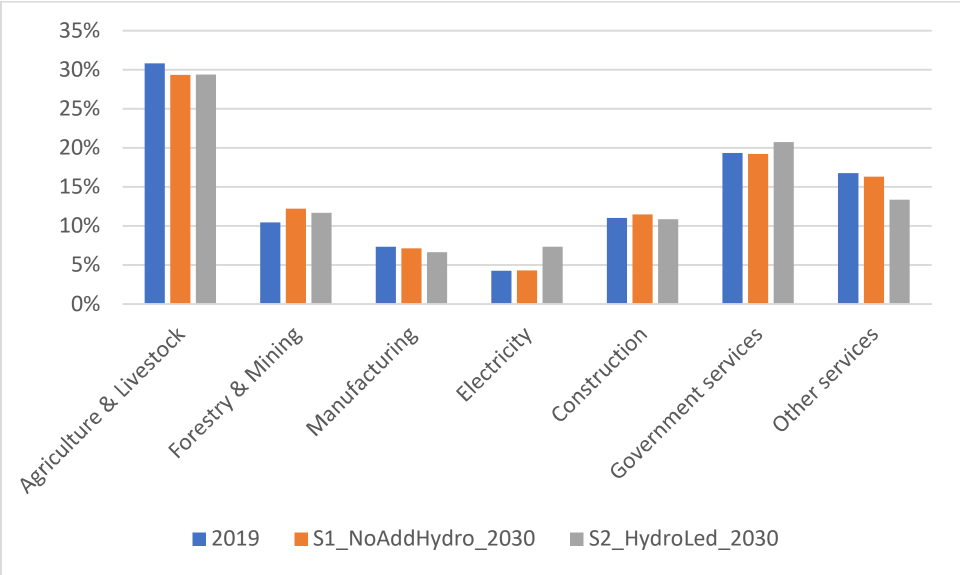
Example: Annual compound growth in GDP is 0.4 percentage points higher in S3 than the reference scenario (4.5% vs. 4.1%). The annual compound growth rate is between 10% and 50% higher in S3 than the reference scenario as indicated by the shading.

		S2_HydroLed Reference Scenario		S1_NoAddHydro	S3_HydroLed_Div	S4_HydroLed_BIG
		Annual compound growth 2019-2030	Values 2019-2030	Annual compound growth 2019-2030. Shading shows percentage change compared to S2_Hydroled		
Factor supply	Agriculture	2.6%		2.6%	3.3%	2.6%
	Unskilled & low-skilled	2.3%		2.3%	2.9%	2.3%
	Semi-skilled	2.5%		2.5%	3.2%	2.5%
	Highly-skilled	2.6%		2.6%	3.2%	2.6%
	Capital	3.1%		1.7%	3.6%	3.2%
	Land	0.9%		0.9%	0.9%	0.9%
Factor returns	Agriculture	-1.0%		-0.3%	-1.1%	-0.4%
	Unskilled & low-skilled	1.1%		1.0%	0.6%	0.3%
	Semi-skilled	0.9%		1.0%	0.2%	-0.2%
	Highly-skilled	1.3%		1.1%	0.4%	0.1%
	Capital	1.8%		1.9%	1.9%	2.0%
	Land	0.0%		0.6%	0.3%	0.4%
Household consumption	Urban	0.1%		4.0%	2.5%	0.1%
	Rural	2.5%		3.5%	3.2%	2.9%
	Unskilled & low-skilled	2.6%		3.2%	3.1%	3.2%
	Semi-skilled	2.5%		3.9%	3.3%	2.5%
	Highly-skilled	2.2%		4.5%	3.5%	1.8%
	Poor agricultural	1.5%		2.0%	1.9%	6.7%
	Non-poor agricultural	1.6%		2.4%	2.2%	3.4%
Electricity	Electricity output	7.5%		1.4%	7.7%	7.6%
	Electricity price	4.7%		3.9%	4.7%	4.6%
	Electricity exports	8.2%		1.7%	8.3%	8.3%
	Electricity domestic sales	4.0%		-0.2%	4.2%	4.0%
Govt	Hydro revenue	6.6%		3.9%	7.1%	6.8%
	Government consumption	5.1%		3.5%	4.0%	0.6%

Table 7 in the Annex for the full results).

Spending effect: percentage change in the supply by each sector in S2 HydroLed compared to S1 NoAddHydro in 2030. Resource movement effect: percentage change in the share of labour employed in each sector in S2 HydroLed compared to S1 NoAddHydro in 2030.

Figure 6 Share of labour by broad sector



All but two of the remaining sectors experience both a negative spending and resource movement effect due to the higher real exchange rate. The analysis indicates that the economy moves strongly towards the booming sector and closely related sectors, at the expense of almost all other sectors which is in line with the analysis of the reference scenario above. The magnitude of the expansion is such that non-tradable sectors do not experience the typical growth seen in standard Dutch Disease analysis, although they are generally less badly hit than the lagging export sectors. Exceptions to this are the Finance, Telecommunications, and Utilities non-tradable sectors. These non-tradable sectors experience negative spending and resource movement effects because they largely derive their demand from other sectors and the contraction in related sectors leads to a contraction in these service sectors.

The lagging export sectors related to tourism are particularly badly hit with large spending and resource movement effects seen in the air transport, hotels and restaurants, and travel agency sectors. The contraction in tourism sectors is led by a strong reduction in export demand, compounded by falling intermediate demand from interlinked contracting sectors.

The finding of Dutch Disease effects in export-led service sectors differs from standard Dutch Disease analysis that finds impacts in the manufacturing sector. This is in line with the findings of Benjamin et al. (1989), who show that it is the exportable sector that suffers, whether that be manufacturing in developed countries, agriculture in developing countries, or, for Bhutan, tourism services.

Two sectors, Agriculture and Food, beverages, and tobacco, deviate from the above trends with the spending and resource movement effects operating in different directions. Specifically, both sectors experience a negative spending effect which leads to a lower level of production but a positive resource movement effect indicating more labour is employed in the sector. This effect is due to the substitution of labour for capital in the two sectors. Production is lower but is more labour intensive which shows up here as a resource movement effect because the metric is based on labour as a mobile factor.

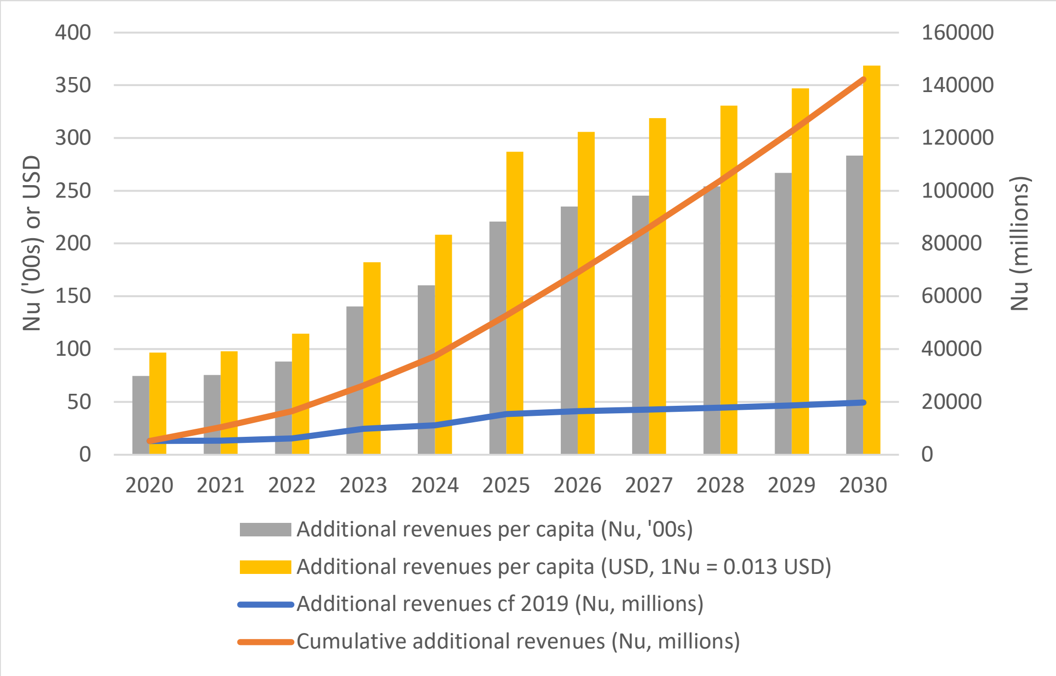
Options to manage the impact of Dutch Disease on a resource dependent economy include the use of revenues to improve the allocation of inputs in lagging sectors and offset the loss of competitiveness due to the real exchange rate appreciation. As seen in the analysis above, tourism related sectors are likely to be particularly badly hit. Using hydropower revenues to increase human and physical capital accumulation is considered in Scenario 3. Alternatively, efforts can be made to directly mitigate the impacts on households through fiscal transfers as examined in scenario 4.

Policies funded by additional hydropower revenues

The planned expansion in hydropower will generate large flows of government income via dividends, Corporate Income Tax and royalties. In this section, the impact of channelling additional funds, generated after 2019, towards alternative policies is examined. Two policies are considered: firstly, investments in human and physical capital to promote the diversification of the economy (S3_HydroLed_Div), and secondly, fiscal transfers to households in the form of a Basic Income Grant (S4_HydroLed_BIG). A comparison of the outcomes of these two policy scenarios against those of the reference scenario provides insights into the implications of implementing these policies.

The additional revenues from the planned expansion in hydropower are shown for the reference scenario (S2_HydroLed) in Figure 7. Under the reference scenario, the additional funds are spent on increasing education, health and public administration according to the usual pattern of government spending (see Figure 9).

Figure 7 Additional hydro revenues after 2019 in the reference scenario



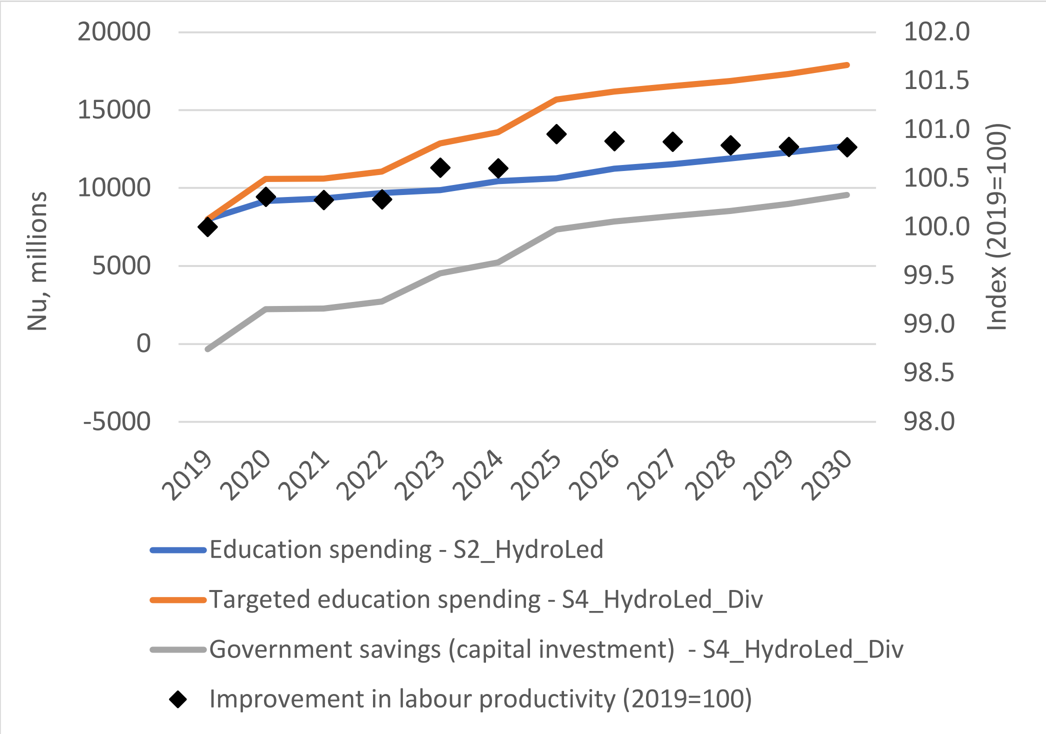
There is a step change in additional revenues in 2023 and 2025 with the commissioning of the new hydropower plants. This leads to cumulative additional revenues of 142315 million Nu across the entire period and average annual additional revenues of 17926 million Nu during the revenue phase, 2026 to 2030. To give a sense of the magnitude of these revenues, government spending on education and health was 12367 million Nu in 2019. These additional hydropower revenues therefore represent a significant source of funds for the implementation of large-scale policies.

Accounting for projected population growth, the additional revenue per capita ranges from an average of 12652 Nu (164 USD), during the construction phase to an average of 25702 Nu (334 USD) during the revenue phase.

Scenario 3: Hydro led with diversification (S3_HydroLed_Div)

The impact of redirecting additional hydropower revenues from general government spending towards investments in human and physical capital is explored in this scenario. A stylized approach is taken in which additional revenues are split equally between spending on training by the government via the Education category resulting in labour productivity improvements, and spending on capital investments via government savings. The projected growth path for both categories is shown in Figure 8 alongside the projected growth path for labour productivity. In the absence of empirical estimates, labour productivity is assumed to increase by 0.02% for every 1% increase in education expenditure above the reference scenario level.

Figure 8 Targeting hydropower revenues on training and capital accumulation



N.B. Government savings are kept at the 2019 level in the reference scenario.

Both education spending and capital investments increase strongly compared to the reference scenario and together exhaust total annual additional hydro revenues in each year. Education spending increases in proportion to the pattern of government spending in the reference scenario and increases more quickly in the diversification scenario due to the diversion of funds away from Public Administration and Health. Capital investments by the government are fixed at the 2019 level in the reference scenario and therefore increase very strongly in the diversification scenario. Total investment is increased in line with the increase in savings to avoid crowding out effects as the additional government savings are made with the purpose of generating new capital rather swapping the ownership from households to government.

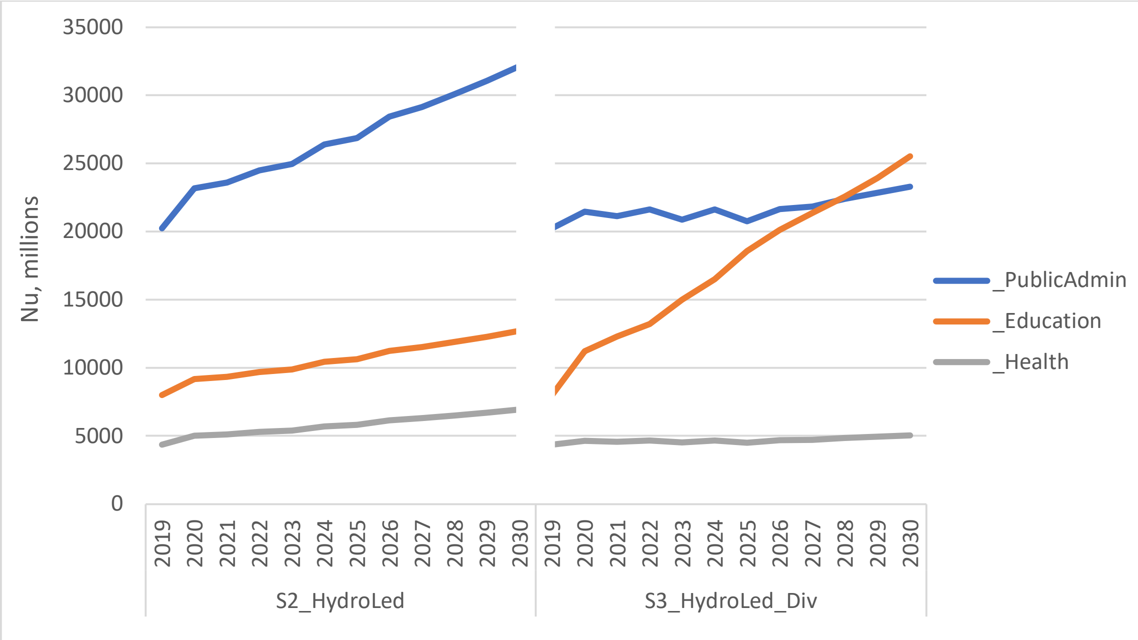
The change in government spending and saving results in higher growth in the supply of labour services (through the productivity increase) and the supply of capital to the economy as shown in Table 6. Households benefit from the investments, with higher growth in consumption across all household types compared to the reference scenario. The productivity improvements in labour supply result in higher household incomes and outweigh the lower wage growth seen for some labour types.

The increased supply of labour and capital leads to changes in the structure of the economy compared to the reference scenario. The economy has a more diversified economic base as indicated by the lower concentration index compared to the reference value. The labour intensive industrial and construction sectors benefit most, but there is also higher growth in all sectors through the direct factor effect and indirect spending effect via higher household consumption (as evident in the higher growth of domestic absorption). The output of agriculture and related sectors increases in response to higher demand from all sources. This expansion increases land and agricultural capital returns, providing a further boost to agricultural household incomes. The service sector receives some boost from this policy but not enough to outweigh the impact of the hydropower expansion through the real exchange rate effects (growth in services is higher in Scenario 1). Notably, the diversification policy is the only scenario in which growth is higher in Food, beverages and tobacco than in the reference scenario through the lower growth in labour costs and higher growth in consumption demand.

GDP growth in this scenario is strong and outstrips GDP growth in the reference scenario. However, this result is sensitive to the assumption of the rate of improvement in labour productivity arising from increased education spending. Other caveats in this stylized scenario include the speed with which training investments result in productivity improvements. There is likely to be a lag between education investments and productivity improvements which is not captured here. The scenario also assumes that labour productivity improvements do not affect the level of TFP growth. Finally, government investments in physical capital are assumed to increase total investment, whereas it is likely that there may be some crowding out from these large-scale investments.

There are also considerations to be made of the impact of the policy on other categories of government spending. The diversion of additional hydropower revenues away from general government spending and towards education spending and savings leads to a stagnation in spending on public administration and health as shown in Figure 9. This may be of concern, particularly against a backdrop of a larger population with increasing health needs.

Figure 9 Government spending by category

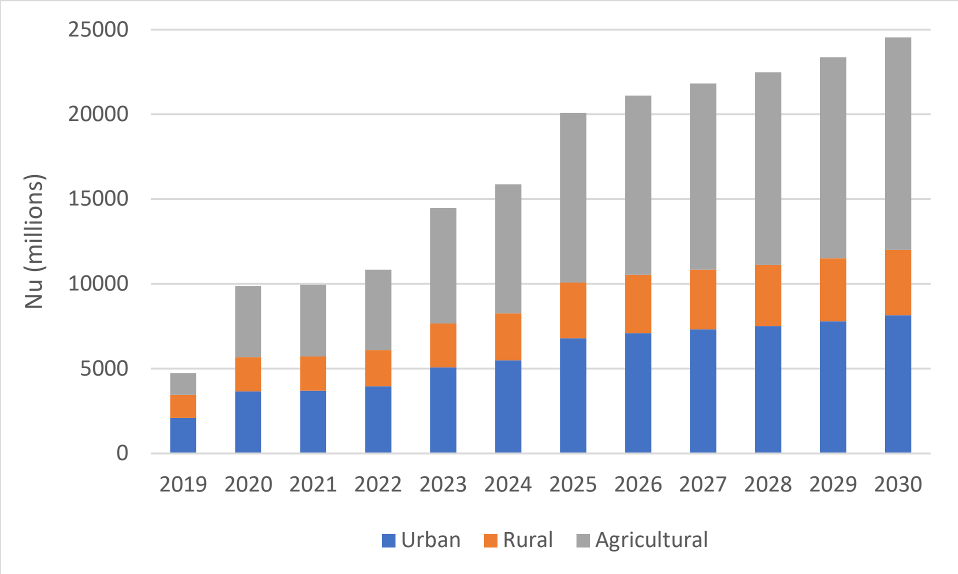


Scenario 4: Hydro led with fiscal transfers (S4_HydroLed_BIG)

Revenues from hydropower dividends, royalties and Corporate Income Tax above the 2019 level are allocated to households in the form of a Basic Income Grant (BIG) in this scenario. The BIG is assumed to be untargeted and unweighted, such that all people receive the same per capita transfer. A comparison of the results of this scenario with the reference scenario shows the impact of diverting these funds away from general government spending towards households. The implementation of the BIG does not account for administration costs as these are unknown. As such the results should be viewed as an outer bound on the likely impacts of the policy.

The Basic Income Grant changes both the size and distribution of government transfers to households compared to 2019 levels as shown in Figure 10 (see Table 8 in the annex for a full breakdown by household). Total household transfers increase from 4735 million Nu in 2019 to 24542 million Nu in 2030. The composition of transfer shifts from a 44% urban, 29% rural and 27% agricultural household split in 2019 to 33% urban, 16% rural and 51% agricultural households in 2030, reflecting the large transfers to agricultural households under the BIG due to their share in the population.

Figure 10 Value and composition of government transfers to households including BIG



The impact of the BIG on key economic indicators is shown in Figure 2. The redistribution of hydro revenues from government spending to households is evident. Growth in government consumption falls from 5% per year to 0.6% per year, while urban and rural household consumption growth increases by 12% and 17% respectively compared to the reference scenario.

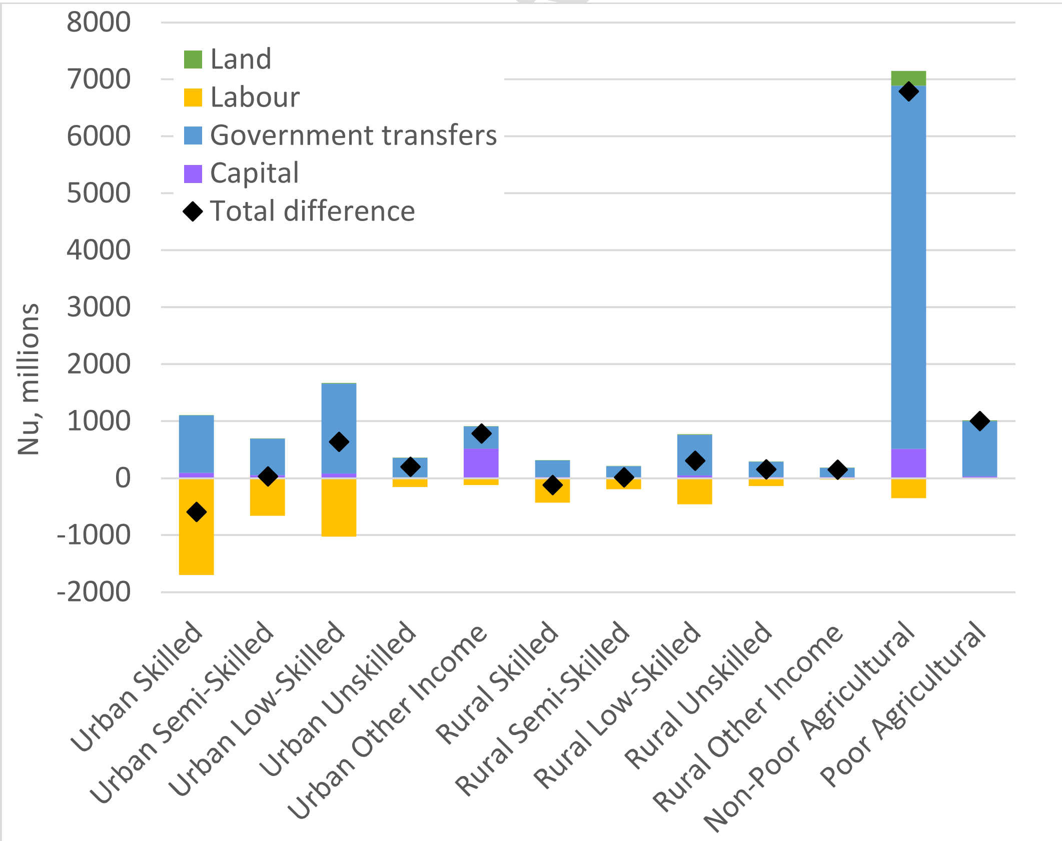
The different pattern of spending and savings by households compared to the government leads to structural change in the economy, albeit on a slightly slower growth path. Many of the sectors that stagnate under the hydro-led reference scenario, receive a boost due to the BIG. Agriculture, natural resources, food and beverages and industry all exhibit higher growth due to the pattern of household consumption. Construction experiences a slight contraction alongside declining growth in the service sector due to the contraction in government service spending. Export-led services however increase, compared to the reference scenario, albeit to a smaller extent than under the diversification scenario. Interestingly, excluding the impact on construction and government services, the sectoral impact of the BIG is stronger than in the stylized diversification scenario. These sectoral effects result in an economic base that is more diversified than in the reference scenario as shown by the lower concentration index. Indeed, the diversification effect of the BIG is similar in size to that of the diversification policy.

The restructuring of production filters through to factor demands, with higher demand for capital in all sectors except agriculture and slightly less capital shedding in agriculture due to the additional consumption demand. The higher demand for capital is reflected in the growth in capital returns which increases from 1.8% per year in the reference scenario to 2% per year in the BIG scenario. Higher agricultural demand also increases the returns to land. The contributions to household incomes for those that supply these factors can be seen in Figure 11, with the Urban Other Income household group benefitting from higher capital returns and the Non-Poor Agricultural household benefitting from higher capital and land returns in addition to the large government transfer through the BIG.

Labour demand growth is higher in all sectors except food and beverages and the services sector. The change in the sectoral demand for labour is reflected in wage rate growth with an improvement in the returns to agricultural labour but lower growth in Unskilled & low-skilled labour, Semi-skilled labour and Highly-skilled labour.

Indeed, the lower growth of non-agricultural wages is such that household consumption among households that receive a large share of their income from labour is lower, even with the BIG transfer as seen in Figure 11. For these households, the BIG transfer does not compensate for the reduction in income from lower wages and demand for their labour arising from BIG-induced structural change.

Figure 11 Impact of the BIG on household income by source



The graph shows the difference in average household income by source between 2020 and 2030 (S4_HydroLed_BIG minus the reference scenario).

In contrast, consumption by agricultural households, particularly poor agricultural households, grows strongly in this scenario due to the direct BIG transfer. The breakdown of the impact of the BIG on incomes by source in Figure 11 shows that Poor Agricultural households benefit from the direct transfer but experience little impact from the wider changes in the economy. This reflects their characteristics as subsistence farmers with low capital holdings and labour which is mobile only across a limited number of sectors. In contrast, Non-Poor Agricultural households receive a boost to agricultural incomes via higher land and capital returns in additional to the large BIG transfers. Given that non-poor agricultural households comprise approximately half the population of Bhutan, this impact, alongside the induced diversification of the economy, makes the BIG an attractive policy to consider, if the impact on the service sector can be addressed.

Conclusions

A major expansion in hydropower capacity and production is planned for the coming period in Bhutan, with four large scale hydro power projects currently under construction. Together, these hydropower plants are set to significantly increase hydroelectric capacity and average annual energy production in Bhutan.

The impact of the planned expansion of hydropower between 2019 and 2030 is examined in this study using a recursive dynamic Computable General Equilibrium (CGE) model, calibrated to a 2019 Social Accounting Matrix for Bhutan. Key features of the Bhutanese economy including delayed capital installation, and cessation of large foreign investment flows during the period, are included in the representation of the economy.

Four scenarios are implemented to show the impacts of Dutch Disease and alternative spending plans for hydropower revenues; firstly, with revenues diverted towards human and physical capital accumulation to boost economic diversification, and secondly, with revenues channelled into fiscal transfers in the form of a Basic Income Grant to households.

The study used a reference scenario approach which defines the growth path of Bhutanese economy up to 2030. GDP growth is strong in the reference scenario, with domestic absorption slightly lower, highlighting the contribution of increasing hydroelectric exports. Investment rises strongly in line with hydropower investments and government consumption rises strongly in line with the expansion in hydropower export revenues.

The expansion in hydropower is the driver of growth in the reference scenario and, while the construction sector experiences some spillover growth, growth in all other sectors is slower. This orientates the economy further towards hydropower, which is reflected in an increase in the index of economic concentration, indicating a less diversified economy by 2030.

As a (renewable) resource-dependent economy, Dutch Disease effects arise from the expansion in hydropower via the appreciation of the real exchange rate. The expansion of hydropower moves the economy strongly toward the booming electricity generation and allied industries: electricity distribution, hydropower construction and public administration. The services sector does not increase as in standard Dutch Disease analysis due to the importance of export-led tourism services in the economy. The rise in the real exchange rate resulting from the expansion in hydropower, leads to a contraction in tourism related sectors. Bhutan’s strategy of high value, low volume tourism is sensible in light of this effect, as it focuses on tourists that are likely to be less sensitive to price changes.

The Dutch Disease effect compounds the movement in the economy towards a less diversified economic base as the appreciation of the real exchange rate depresses non-hydropower related sectors. The use of hydropower revenues to improve the allocation of inputs in lagging sectors and offset the loss of competitiveness and redistributing additional hydropower revenues directly to households in the form of a Basic Income Grant are considered as alternative policies.

Redirecting additional hydropower revenues from general government spending towards investments in human and physical capital leads to an economy with a more diversified economic base. Labour intensive industrial and construction sectors benefit most, but there is higher growth in all sectors due to higher household consumption. GDP growth is strong and outstrips GDP growth in the reference scenario. However, diverting hydropower revenues away from general government spending leads to a stagnation in spending on public administration and health which may be of concern, particularly against a backdrop of a larger population with increasing health needs.

It should be noted that, as a stylized scenario, the results are sensitive to assumptions regarding the rate of improvement in labour productivity from increased education spending, the speed with which training investments result in productivity improvements, and whether large-scale government-funded investments in physical capital crowd out private investment.

Allocating additional hydropower revenues to households in the form of a Basic Income Grant moves the focus of revenue spending from government to households. Under the BIG scenario, many of the sectors that stagnate under the hydro-led reference scenario, receive a boost which results in an economic base that is more diversified than in the reference scenario. Indeed, the diversification effect of the BIG is similar in size to that of the diversification policy.

Consumption by agricultural households, particularly poor agricultural households, grows strongly due to the direct BIG transfer. Given that non-poor agricultural households comprise approximately half the population of Bhutan, this impact, alongside the increased diversification of the economy, makes the BIG an attractive policy to consider, if the slight contraction of the service sector due to reduced government service spending can be addressed.

The findings of this study would be augmented by an exploration of a targeted Basic Income Grant and the inclusion of administration costs for both the diversification and fiscal transfers scenarios.

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Annex: Data and model description

SAM accounts

Table 4 SAM accounts

SAM Account Name	Description
C19_Agric	Crops
C19_Lvstock	Livestock goods
C19_Forestry	Forest products
C19_Mining	Mining commodities
C19_FoodBevTob	Processed food, beverages and tobacco
C19_Textiles	Textile products
C19_WoodProd	Wood-based products
C19_CokeFuels	Coke
C19_Fuels	Other fossil fuels
C19_Charcoal	Charcoal
C19_Chemicals	Chemicals
C19_Cement	Cement
C19_Rubber	Rubber products
C19_Fert	Chemical fertilizer
C19_Pest	Chemical pesticide
C19_BasicMetals	Basic metals
C19_FabMetals	Fabricated metals
C19_MachineryEquip	Machinery and equipment
C19_ManuNec	Manufactured goods not elsewhere considered
C19_HydroPow	Electricity (hydropower) generation -
C19_ElecTrans	Electricity transmission and distribution services
C19_LVelec	Low voltage electricity (230/415 V)
C19_MVelec	Medium voltage electricity (6.6 - 33 kV)
C19_HVelec	High voltage electricity (>=66 kV)
C19_Utilities	Utility services like waste management, water, gas
C19_Construction-NonHydro	Construction services (infrastructure such as roads, irrigation; building.)
C19_Construction-Hydro	Hydropower related construction services (e.g., transmission lines, power plants, substations, etc.)
C19_Trade	Trade services incl. wholesale, retail, and storage
C19_Hotels-Restaurant	Hotel and restaurant services
C19_LandTrans	Land transportation services for persons and freight
C19_AirTrans	Air transportation services for persons and freight
C19_TravelAgency	Auxilliary travel services incl. Tour guide services
C19_TeleComm	Telecommunications, postal services
C19_Finance	Finance, insurance, business services & real estate
C19_PublicAdmin	Public administration
C19_Education	Education services
C19_Health	Health services

C19_OtherServ	Other services
A19_Agric	Crops
A19_Lvstock	Livestock goods
A19_Forestry	Forest products
A19_Mining	Mining commodities
A19_FoodBevTob	Processed food, beverages and tobacco
A19_Textiles	Textile products
A19_WoodProd	Wood-based products
A19_Chemicals	Chemicals
A19_Cement	Cement
A19_Rubber	Rubber products
A19_BasicMetals	Basic metals
A19_FabMetals	Fabricated metals
A19_ManuNec	Manufactured goods not elsewhere considered
A19_ElecGen	Electricity (hydropower) generation
A19_ElecDnT	Electricity transmission and distribution services
A19_Utilities	Utility services like waste management, water, gas
A19_ConstrNonHydro	Construction services (infrastructure such as roads, irrigation, buildings etc.)
A19_ConstrHydro	Hydropower related construction services (infrastructure such as transmission lines, power plants, substations, etc.)
A19_Trade	Trade services including wholesale, retail, and storage
A19_HotelsRestaurant	Hotel and restaurant services
A19_LandTrans	Land transportation services for persons and freight
A19_AirTrans	Air transportation services for persons and freight
A19_TravelAgency	Auxiliary travel services incl. Tour guide services
A19_TeleComm	Telecommunications, postal services
A19_Finance	Finance (banking), insurance, business services, real estate, and R&D
A19_PublicAdmin	Public administration
A19_Education	Education services
A19_Health	Health services
A19_OtherServ	Other services (recreation, hairdressers, regional ceremonies, housekeeping, nurseries, etc.)
F19_HighSkilledLab	Highly-skilled labour (has tertiary education or employed in a high-skilled occupation)
F19_SemiSkilledLab	Semi-skilled labour (at least completion of grade 10 and can read and write)
F19_LowSkilledLab	Low-skilled labour, can read and write but has not passed grade 10,
F19_UnskilledLab	Unskilled labour (cannot read and write)
F19_AgriLab	Agricultural labour (reports "farmer" as main occupation)
F19_PrivCapital	Incorporated capital owned by private institutions
F19_PubCapital	Incorporated capital owned by state-owned enterprises
F19_HydroCapital	Incorporated capital owned by state-owned enterprises and employed in hydropower
F19_AgriCapital	Informal capital employed in agricultural activities
F19_Cattle	Cattle
F19_OthAnim	Other animals (poultry, pigs, sheep, goats, horses, fish)
F19_Wetland	Irrigated land
F19_Dryland	Rainfed land

F19_Orchards	Permanent crop land
F19_Forest	Forest and pastureland used by livestock
M19_Trade	Trade
M19_Transport	Transport
E19_eprivate	Private enterprise
E19_epub	Public enterprise
H19_UrbanSkilled	Urban households with majority of workers in highly-skilled category
H19_UrbanSemi-Skilled	Urban households with majority of workers in semi-skilled category
H19_UrbanLow-Skilled	Urban households with majority of workers in low-skilled category
H19_UrbanUnskilled	Urban households with majority of workers in unskilled category
H19_UrbanCapIncome	Urban households relying on non-labor income
H19_RuralSkilled	Rural households with majority of workers in highly-skilled category
H19_RuralSemi-Skilled	Rural households with majority of workers in semi-skilled category
H19_RuralLow-Skilled	Rural households with majority of workers in low-skilled category
H19_RuralUnskilled	Rural households with majority of workers in unskilled category
H19_RuralOthIncome	Rural households relying on non-labor income
H19_NonPoorAgri	Agricultural households (defined if at least one household member works in agriculture)
H19_PoorAgri	Agricultural households below the national poverty line (defined if at least one household member works in agriculture)
govt	Government
imptax	Import duties
exptax	Export taxes
saltax	Sales taxes
ectax	Excise duty
indtax	Production taxes
dirtax	Direct income taxes
i_s	Investment/savings
I19_I-S_nonHydro_priv	Private investment in non-hydro capital
I19_I-S_nonHydro_pub	Public investment in non-hydro capital
I19_I-S_Hydro	Investment in hydro capital
I19_I-S_AgriCap_priv	Private investment in agricultural capital
I19_I-S_Cattle_priv	Private investment in cattle
I19_I-S_OtherAnim_priv	Private investment in other animals
dstoc	Changes in stocks
row	Rest of the world

Production Structure & Elasticities

Table 5 Production structure and elasticity values

Production structure	Intermediates/aggregate value added (Sigmax, Leontief for Electricity generation) Intermediate inputs (Leontief) Aggregate value added (Sigmava) Aggregate land and fertiliser (elastf: 4, Agriculture, Livestock and Forestry only) Aggregate land (elastf: 4) Wetland Dryland Orchards Forest Aggregate Fertiliser & pesticides (elastf: 4) Fertilizer Pesticides Aggregate labour (elastf: 4 except Electricity generation, 0.3) Highly-skilled labour Semi-skilled labour Low-skilled labour Unskilled labour Agricultural labour Aggregate capital and energy (elastf: 4 except Electricity generation, 0.3) Aggregate capital (elastf: 4 except Electricity generation, 0.3) Private capital (non-hydro) Public capital (non-hydro) Hydro capital Agricultural capital Cattle Other animals Aggregate energy (elastf: 4 except Electricity generation, 0.3) Aggregate electricity (elastf: 4 except Electricity generation, 0.3) Hydropower Low-voltage electricity Medium-voltage electricity High-voltage electricity Aggregate non-electricity (elastf: 4 except Electricity generation, 0.3) Coke fuels Fuels Charcoal
Activity elasticities	Sigmax: 0.9 except Livestock, Food beverages & tobacco, Textiles, Chemicals, Cement, Rubber (0.5), and Wood products and Fabricated metals (0.65) Sigmava: 1.6 except Livestock, Food beverages & tobacco, Textiles, Chemicals, Cement and Rubber (0.8), Fabricated metals (1.2), Wood products (1.25), Agriculture, Mining and Basic metals (1.5), and Electricity generation (0.1) Omegaout: 0
Commodity elasticities	Sigma: 1.75 Omega: 2 Exdem: 0 Sigmaxc: 4
Household elasticities	Frisch: -2.5 Incelast: agriculture, livestock, and processed food (0.4), forestry, mining, manufacturing (1.5), fuels and electricity (2.2), construction (1.2), utilities, trade, transport, communications, and services (2.2) Comelasth: 2

Table 6 Detailed scenario results

		S2_HydroLed Reference Scenario		S1_NoAddHydro	S3_HydroLed_Div	S4_HydroLed_BIG
		Annual compound growth 2019-2030	Values 2019-2030	Annual compound growth 2019-2030. Shading shows percentage change compared to S2_Hydroled		
Macro	GDP	4.1%		3.4%	4.5%	4.0%
	Domestic absorption	2.6%		3.3%	3.3%	2.3%
Value added	Agriculture	1.1%		1.9%	1.7%	1.9%
	Natural resources	1.4%		2.5%	2.4%	2.3%
	Food and beverages	0.8%		1.4%	1.3%	1.4%
	Industry	2.7%		4.1%	3.6%	3.6%
	Utilities	11.0%		5.0%	11.3%	11.1%
	Construction	3.8%		3.8%	4.6%	3.7%
	Services	3.0%		3.6%	3.2%	2.1%
Labour demand	Agriculture	2.5%		2.6%	3.2%	2.6%
	Natural resources	-0.8%		1.3%	1.1%	1.6%
	Food and beverages	2.3%		1.9%	2.8%	2.0%
	Industry	0.8%		2.5%	2.5%	2.5%
	Utilities	7.6%		2.6%	8.3%	8.4%
	Construction	2.4%		2.9%	4.0%	3.6%
	Services	2.0%		2.3%	2.1%	1.0%
Capital demand	Agriculture	-1.8%		-1.6%	-1.6%	-1.7%
	Natural resources	1.5%		1.7%	2.2%	1.6%
	Food and beverages	1.2%		1.4%	1.9%	1.3%
	Industry	1.8%		2.1%	2.5%	1.9%
	Utilities	7.8%		1.7%	8.0%	7.9%
	Construction	1.3%		1.5%	2.0%	1.4%
	Services	1.8%		2.1%	2.4%	1.9%
	Hydro	7.8%		1.7%	8.0%	7.9%
	Non-hydro	1.4%		1.7%	2.1%	1.5%

Key: -
>50%
10% to 50%
Up to 10%
0%
Up to -10%
-10% to -50%
< -50%

Example: Annual compound growth in GDP is 0.4 percentage points higher in S3 than the reference scenario (4.5% vs. 4.1%). The annual compound growth rate is between 10% and 50% higher in S3 than the reference scenario as indicated by the shading.

		S2_HydroLed Reference Scenario		S1_NoAddHydro	S3_HydroLed_Div	S4_HydroLed_BIG
		Annual compound growth 2019-2030	Values 2019-2030	Annual compound growth 2019-2030. Shading shows percentage change compared to S2_Hydroled		
Factor supply	Agriculture	2.6%		2.6%	3.3%	2.6%
	Unskilled & low-skilled	2.3%		2.3%	2.9%	2.3%
	Semi-skilled	2.5%		2.5%	3.2%	2.5%
	Highly-skilled	2.6%		2.6%	3.2%	2.6%
	Capital	3.1%		1.7%	3.6%	3.2%
	Land	0.9%		0.9%	0.9%	0.9%
Factor returns	Agriculture	-1.0%		-0.3%	-1.1%	-0.4%
	Unskilled & low-skilled	1.1%		1.0%	0.6%	0.3%
	Semi-skilled	0.9%		1.0%	0.2%	-0.2%
	Highly-skilled	1.3%		1.1%	0.4%	0.1%
	Capital	1.8%		1.9%	1.9%	2.0%
	Land	0.0%		0.6%	0.3%	0.4%
Household consumption	Urban	0.1%		4.0%	2.5%	0.1%
	Rural	2.5%		3.5%	3.2%	2.9%
	Unskilled & low-skilled	2.6%		3.2%	3.1%	3.2%
	Semi-skilled	2.5%		3.9%	3.3%	2.5%
	Highly-skilled	2.2%		4.5%	3.5%	1.8%
	Poor agricultural	1.5%		2.0%	1.9%	6.7%
	Non-poor agricultural	1.6%		2.4%	2.2%	3.4%
Electricity	Electricity output	7.5%		1.4%	7.7%	7.6%
	Electricity price	4.7%		3.9%	4.7%	4.6%
	Electricity exports	8.2%		1.7%	8.3%	8.3%
	Electricity domestic sales	4.0%		-0.2%	4.2%	4.0%
Govt	Hydro revenue	6.6%		3.9%	7.1%	6.8%
	Government consumption	5.1%		3.5%	4.0%	0.6%

Key: -

>50%
10% to 50%
Up to 10%
0%
Up to -10%
-10% to -50%
< -50%

Table 7 Dutch disease results: spending and resource movement effects

	Export share (2019)	Spending effect	Resource movement effect
ElecGen	79.1%	90.4%	89.5%
ElecDnT	0.0%	57.2%	44.8%
ConstrHydro	0.0%	19.6%	43.0%
PublicAdmin	0.8%	9.4%	12.0%
Health	0.0%	-2.9%	-0.8%
FoodBevTob	9.6%	-3.5%	4.1%
Education	0.0%	-3.7%	-0.2%
ConstrNonHydro	0.0%	-5.5%	-5.3%
Agric	11.2%	-5.7%	0.6%
Cement	39.6%	-6.3%	-7.8%
Lvstock	0.0%	-6.6%	-0.6%
Utilities	0.0%	-7.1%	-35.3%
FabMetals	4.0%	-8.8%	-14.8%
Rubber	10.1%	-9.2%	-12.1%
Trade	0.0%	-9.3%	-8.1%
Forestry	3.3%	-11.3%	-3.4%
Mining	61.3%	-11.7%	-20.1%
WoodProd	5.5%	-12.2%	-15.5%
TravelAgency	61.4%	-12.5%	-23.4%
Finance	2.9%	-13.4%	-31.0%
Textiles	0.1%	-13.5%	-13.4%
LandTrans	13.3%	-14.3%	-18.7%
BasicMetals	82.1%	-15.2%	-24.3%
ManuNec	1.5%	-15.3%	-23.1%
TeleComm	1.9%	-17.5%	-32.3%
Chemicals	11.9%	-17.6%	-20.0%
HotelsRestaurant	53.5%	-18.6%	-26.5%
OtherServ	22.2%	-21.1%	-27.8%
AirTrans	38.4%	-26.6%	-36.2%

Key: green - boosted sector, orange – lagging export sector, purple – non-tradable sector.

Spending effect: percentage change in the supply by each sector in S2 HydroLed compared to S1_NoAddHydro in 2030. Resource movement effect: percentage change in the share of labour employed in each sector in S2 HydroLed compared to S1_NoAddHydro in 2030.

Table 8 Basic Income Grant by household (Nu, millions)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
UrbanSkilled	401	407	476	759	868	1196	1276	1332	1382	1452	1544
UrbanSemi-Skilled	253	257	301	479	549	756	806	841	874	918	976
UrbanLow-Skilled	627	636	743	1185	1356	1869	1993	2081	2160	2270	2412
UrbanUnskilled	138	140	163	261	298	411	438	457	475	499	530
UrbanOthIncome	154	156	182	291	333	459	489	511	530	557	592
RuralSkilled	115	117	137	218	250	344	367	383	398	418	444
RuralSemi-Skilled	79	80	94	150	172	237	252	263	273	287	305
RuralLow-Skilled	283	287	336	535	613	844	900	940	976	1025	1089
RuralUnskilled	108	109	128	204	234	322	343	358	372	391	415
RuralOthIncome	65	66	77	122	140	193	206	215	223	234	249
NonPoorAgri	2534	2571	3006	4794	5486	7560	8062	8415	8735	9179	9756
PoorAgri	388	394	460	734	840	1158	1235	1289	1338	1406	1494
All households	5144	5219	6102	9733	11138	15349	16368	17084	17736	18635	19807