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ブータンのマクロ経済シミュレーション分析:

世代間重複モデルの適用

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2022 Doctor's Thesis

BHUTAN'S MACROECONOMIC SIMULATION ANALYSIS:

An application of an Overlapping Generations Model

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List of Abbreviations

BTN	Bhutanese Ngultrum
CES	Constant Elasticity of Substitution
COVID	Coronavirus Disease
DPA	Department of Public Accounts
DPR	Detailed Project Report
ECCD	Early Childhood Care and Development
EROI	Energy Return on Energy Invested
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GNI	Gross National Income
GW	Gigawatts
HP	Hydropower project
IG	Inter-Government
IMF	International Monetary Fund
JV	Joint Venture
kW	Kilo Watts
LDC	Least Developed Countries
LLDCs	Low-Income Landlocked Developing Countries
MDG	Millennium Development Goals
MFCC	Macroeconomic Framework Coordinating Committee
MIC	Middle Income Country
MoF	Ministry of Finance, Bhutan
MW	Megawatts
NER	North East Region of India
NSB	National Statistics Bureau
Nu.	Ngultrum
OLG	Overlapping Generations
SDG	Sustainable Development Goals
SFP	School Feeding Program
Sl.No	Particulars
TCC	Teacher Training Center
TFP	Total Factor Productivity
TFR	Total Fertility Rate
UN	United Nations
US	The United States of America
WFP	World Food Program

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Chapter 1: Introduction

1.1. Background

Economic growth has enabled societies and regions to raise their living standards, due to which global authorities pursue it as one of their core policies. Especially for developing countries, economic growth provides the necessary causes and conditions to elevate people out of poverty. Despite the topical issues on the inequality of income and wealth caused by economic growth, it is established and widely agreed upon that economic growth positively affects the living standards of the nation.

While economic growth positively affects socioeconomic circumstances, it requires significant amount of investments in public and private sectors, including any policy initiatives. In case of developing and underdeveloped economies, majority of such investments are initiated by the government. The most common sources of financing development activities by government are either debts or taxes. Other forms of funding, such as foreign aid and grants, public-private partnership, etc., but such sources are limited to a specific period or a particular project. The trade-off between debt and tax financing and its implication on the economy have been argued for a long time. Nevertheless, economies must balance the type of policy they implement with the kind of financing policy they choose for sustainable long-run economic growth.

1.2. Bhutan: Overview

Bhutan is one of the low-income countries whose development agenda is driven by a development paradigm of Gross National Happiness rather than solely focusing on Gross Domestic Product or economic growth. Nevertheless, economic growth is an essential domain among the nine domains of Gross National Happiness. The other eight domains are: psychological wellbeing, health, education, time use, cultural diversity and resilience, good governance, community vitality and ecological diversity and resilience. Further, as Bhutan is one of the 17 low-income landlocked developing countries (LLDCs) listed with the United Nations (UN), the Millennium Development Goals (MDG) in the past and Sustainable Development Goals (SDGs) currently also guide the developmental visions of the country. After joining the UN in 1971, Bhutan is scheduled to graduate from Least Developed Country (LDC) to Middle Income Country (MIC) in 2023, having qualified for two out of three graduation criteria as per the 2018 triennial review (United Nations, 2020). The two fulfilled criteria are GNI per capita (Bhutan: US$2,401, Threshold: US$1,230) and Human assets index (Bhutan: 72.9, Threshold: 66.0). The Economic Vulnerability Index (also referred to as the Economic and Environmental Vulnerability Index) of 36.3 remains above the graduation threshold of 32.0 (should be below 32.0 to qualify) as Bhutan struggles to diversify its economy away from hydropower-driven growth.

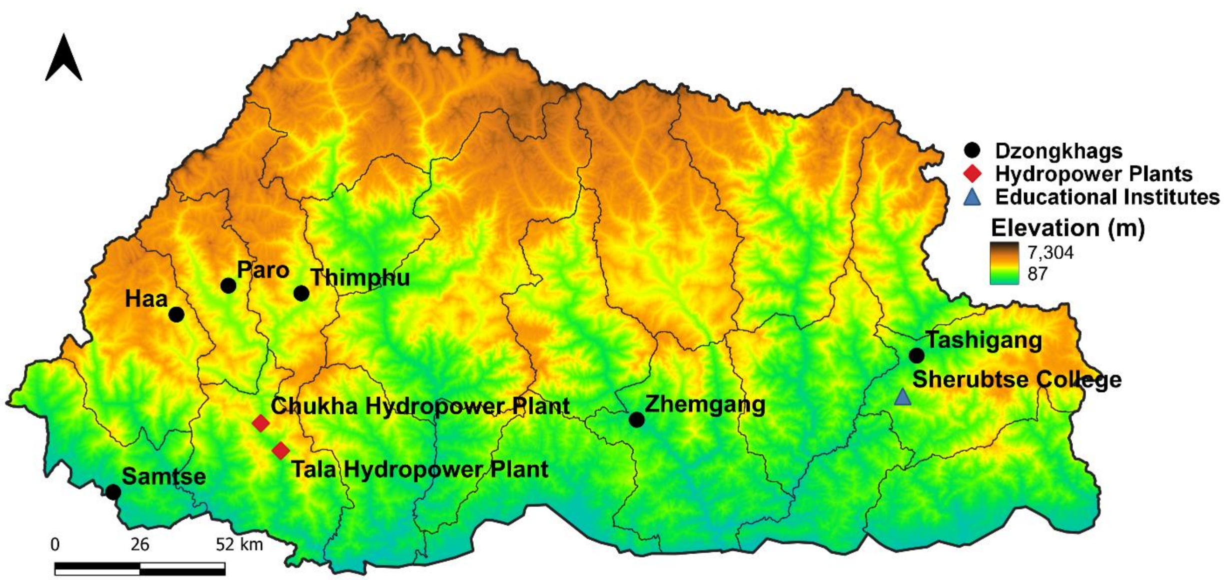

Figure 1.1: Bhutan map marking important locations of education and hydropower development.

Bhutan is a small landlocked mountainous country located in the Himalayas. The area of Bhutan is about 38,394 square kilometers, of which only 7 percent of the total land is arable. Bhutan's total population is about 756,129 (National Statistics Bureau, 2021), of which the working population is about 331,222 and about half of the working population is dependent on agriculture, forestry and fishing. Bhutan's topography and lack of natural resources endowment provide practical challenges for Bhutan to pursue modern economic growth. Despite the challenges, the fast-flowing rivers of rouged Himalayan mountains and growing energy demand in India while having a good diplomatic relationship with India provided Bhutan with the opportunity to pursue a hydropower development policy that has served Bhutan well for decades and continues to do so. Furthermore, human capital accumulation through education has also been considered an integral part of the country's development. The gradual investment in human capital development enabled by the economic growth brought in by the hydropower development has been notable as the country's adult literacy rate grew from 53 percent in 2005 to 67 percent in 2017.

1.3. Bhutan's economy and education

Since Bhutan opened up to the outside world and adopted modern education, it has progressed gradually. Conventionally, Bhutan only had a traditional Buddhist monastic education system, and after opening for modernization, it embraced modern education as well. By the 1950s, two schools were established in Ha and Bumthang within Bhutan, as one benchmark of human capital accumulation of the country Towards the late 1950s, 59 schools provided primary education to about 2,500 students. However, after primary education, those students needed to venture into India to continue their education (Savada, Harris and Library of Congress, 1993). The formal adoption of the five-year development plans starting in 1961 oversaw the operation of 108 schools, enrolling about 15,000 students in total and installing a system providing free universal primary education. By 1967, Bhutan produced its first batch of students that graduated from class X Bhutan (Ministry of Education, 2014).

Another benchmark of human capital accumulation through education in Bhutan was in 1968 with the establishment of the Teacher Training Institute in Samtse and Sherubtse Public School in Trashigang. In 1974, the government started the school feeding program with the World Food Program (WFP) assistance. An additional Teacher Training Center (TCC) was established at Paro in 1975. In 1983 the Teacher Training Institute, Samtse was upgraded to the National Institute of Education and Sherubtse Public School, Trashigang was upgraded to Degree College. These developments enabled Bhutan to develop its human capital domestically without depending on external support. Further, having two institutes training teachers helped Bhutan to expand school coverage and improve the enrollment rate and quality of education, bolstered by the school feeding program.

The continued effort of the government to improve human capital increased the adult literacy rate to 12 percent by 1981. Subsequently, the literacy rate increased to 52.81 percent in 2005, 55.32 percent in 2012 and 66.56 percent in 2017. From 2003 onwards, we can see that the number of people aged 3 years and above currently attending or previously attended school increased gradually, from 37 percent in 2003 to 47 percent in 2007, to 54 percent in 2012 and 55 percent in 2017. Predictably, the proportion of people who never attended has declined, as shown in Table 1.1. Bhutan's spending on education as a percent of Gross Domestic Product (GDP) from 2015 to 2019 was about 6.87 percent on average, while the Gross National Income (GNI) in 2019 was about US$ 3,150 per capita. During the same period, the World's average education expenditure was 4.21 percent of GDP with a GNI of US$ 11,577 per capita. Similarly, for Japan during the same period, the average education expenditure was 3.12 percent of GDP with a GNI of US$ 42,010 per capita. Figure 1.2 shows the education expenditure as a percent of GDP and the GNI for different countries across the World. Although Bhutan's GNI is amongst the lowest in the World, its education expenditure is relatively higher than most countries.

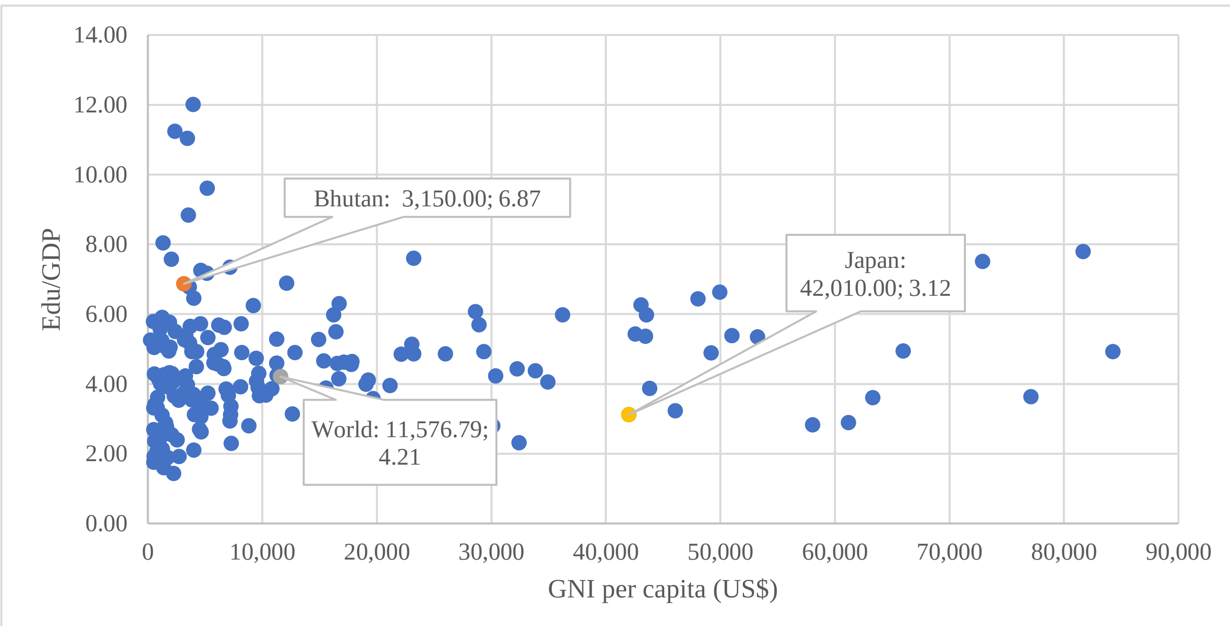

Figure 1.2: Education expenditure as percent of GDP and GNI per capita in US$ (5 years average*) for various countries.

Source: World Development Indicator, World Bank (2022).
**Note: 5 years average – from 2015 to 2019 – to remove pandemic effect.*

The government recognizes the importance of human capital accumulation through education in diversifying and improving the productivity of its economy, eventually laying a solid foundation for long-run economic growth. However, the policy for accelerating human capital accumulation in the economy has not been sufficiently realized. Despite its conviction, nearly half of the population never attended school and government education expenditure remains relatively low and stable, hovering at around 6 percent – 7 percent of GDP annually compared with hydropower investments. The hydropower investments range between 2 percent and 31 percent annually during the same period, as shown in Table 1.1. Moreover, even among those who have attended school, less than 15 percent of the population have skills or higher degrees, as shown in Table 1.2. Thus, it is worth investigating the effect of public education investment, in the form of an education subsidy, on human capital accumulation for the Bhutanese economy.

Table 1.1: Educational status of persons aged 3 years and older, and expenditure status

Particulars	2003	2007	2012	2017
Currently attending (in %)	24.3	27.7	30.8	27.2
Previously attended (in %)	12.8	19.4	23.3	27.8
Never Attended (in %)	62.9	52.9	45.9	45.0
Literacy Rate (in %)	42.9	55.5	63.0	66.0
Education expenditure (% of GDP)	4.0	6.7	7.6	7.0
Hydropower investment (% of GDP)	28.3	2.0	31.3	16.5

Source: National Statistics Bureau (2003; 2007; 2012; 2017) and Ministry of Finance (2004; 2008; 2012; 2018).

Note: The data for 2017 is for persons aged two years and above; Hydropower investments are capital investments in nature; thus, their flow remains erratic.

Table 1.2: Level of educational attainment for Bhutan's population aged six years and older

Education type	Pop	Total	Education type	Pop	Total
Non-formal education	13,580	3.2%	**Certificate/diploma**	12,660	3.0%
ECCD /primary	172,258	40.2%	**Bachelor's degree**	41,785	9.8%
Lower secondary	51,652	12.1%	**Masters and above**	8,426	2.0%
Middle secondary	65,219	15.2%	**Others**	2,218	0.5%
Higher secondary	60,163	14.1%	**Total population**	427,961	100.0%

Source: National Statistics Bureau (NSB).

With the objective of human capital development, and in the context of changing environment both globally and domestically, the government laid out a detailed plan to reform the education sector called the *Bhutan Education Blueprint 2014-2024*. In particular, one of the policy recommendations was to establish a central school program. The motivation for such a program was not only to enhance the quality of education but also to continue supporting the school feeding program (SFP) since WFP was scheduled to phase out in 2018 (Ministry of Education, 2014). WFP has supported SFP in Bhutan in collaboration with the government for the past 40 years and is credited with improving enrolment and attendance rates through improved nutrition and food.

In 2015, the government converted 24 existing schools to central schools covering about 14,998 students (Ministry of Education, 2015). Under the central school program, the government started budgetary support for uniforms, food, bedding, stationaries, and other miscellaneous items, in addition to expenses for teachers and staff and operation and maintenance (Ministry of Education, 2015). The resulting impact on the government budget from the central school program was that from the fiscal year 2014-15 to 2015-16, the education expenditure increased by 23 percent (Ministry of Finance, 2016). The difference in per capita expenditure between a regular school and a central school is about 24 percent. In 2016, the government added 27 additional schools to the central school program, and by the end of 2019, the number increased to a total of 64 schools covering 46,604 *students* (Ministry of Finance, 2019) and has remained the same to date.

With the phasing out of WFP support and significant level of stunting among the children and other nutrition deficiencies present, the government has committed to increasing the number of central schools or reviewing the program to maximize its coverage and efficiency. However, the program currently covers only 28 percent of the total students. If the central school program is extended to all the students, the real government expenditure per capita amounts to Nu. 12,215.085, against the existing expenses of Nu.10,207.189 in our calculation. The ratio of the increased government's education subsidy to the total education expenditure is about 70 percent. In this regard, it is essential to examine the effect of an increase in education subsidies and evaluate which financing method is sustainable for the economy in the long-run.

1.4. Bhutan's Economy and Hydropower

Bhutan embraced modernization with the start of its first five-yearly developmental plan in the 1960s. Along with modernization, the energy demand grew, resulting in exploring electricity production within the country. The exploration of hydropower to generate electricity started in

1967 with the installation of a 360 kW plant to supply power to the capital city, Thimphu (Tshering and Tamang, 2004). Subsequently, till the development of the first major hydroelectricity project, the Chukha hydropower project with a capacity of 336 MW, in 1974, the primary supply of electricity in major *Dzongkhags* (Districts) was through the construction of various mini hydropower plants (Tshering and Tamang, 2004). Since then, Bhutan has continued to develop major hydropower projects with different capacities, as shown in Figure 1.3. Currently, Bhutan has total hydropower production capacity of 2,344 MW, with additional four mega hydropower projects under construction with a production capacity of 2,938 MW upon completion. The commencement of hydropower projects came with significant progress in lifting the living standard of the people.

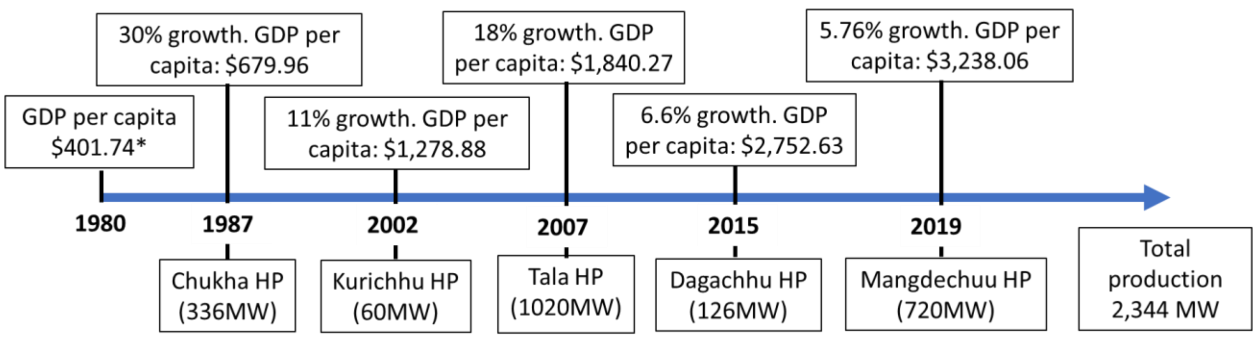

Figure 1.3: Timeline for commissioning of major hydropower projects in Bhutan

Hydropower is the primary driver of the economy of Bhutan. In 1980, agriculture contributed over 50 percent of the GDP, while industries, under which the construction and production of hydroelectricity are recorded, contributed only 15 percent of the GDP (Macroeconomic Framework Coordinating Committee [MFCC], 2022). A decade later, after the commissioning of the first major hydroelectricity, the industries' contribution to GDP was recorded at 36 percent, of which almost 50 percent was from electricity and construction. This development can be seen in Figure 1.4. The highest ever recorded contribution of the industry sector to GDP was about 48 percent in 2008, a year after the commissioning of the Tala hydropower plant, of which electricity and construction contributed about 76 percent. In 2020, a year into the COVID-19 pandemic, when the GDP shrank by 10 percent, the industries sector still contributed positively by over 38 percent, of which around 78 percent was contributed by electricity and construction (MFCC, 2022). This shows that hydropower was and still is an important source of economic growth.

Due to the importance of hydropower projects and the magnitude of investment required, and the need to secure markets for the sales of electricity upon production, the hydropower construction and operations are state undertaking. These hydropower constructions are financed through either Inter-Government (IG) or Joint Venture (JV) based on bilateral agreements (Ministry of Finance, 2021). These construction projects are executed by project authorities appointed by the involved stakeholders, who are empowered to implement and disburse funds to the project according to the work progress. The time needed to construct the hydropower projects varies according to the projects' scale, ranging from three years to more than ten years. The capital for the construction is financed partly as grants (30 percent of the project cost) and partly as external loans (70 percent of the project cost). Upon commissioning the hydropower plants, the operations depend on the type of financing modalities. Under the IG financing mode, the project authorities hand over the plant to the government within two years of commissioning. In contrast, the JV company operates for 30 years under JV financing mode, after which the control is reverted to the government (Ministry of Finance, 2021). Finally, the sale of electricity, for both domestic and export market, are executed at an agreed price negotiated between the stakeholders.

In addition to the direct contribution of hydropower electricity to the GDP, it also strengthens other equally critical macroeconomic variables. Though a government undertaking, the hydropower projects in Bhutan operate autonomously and like any other listed public company, it pays the applicable taxes and dividends. Thus, the revenue collected from the hydropower plants and projects is a significant source of government revenue, accounting for about 18 percent of the total revenue on average for the fiscal year 2017 to 2020. Having abundant electricity production has also helped the country provide electricity to 99 percent of its households, with 100 percent of urban households and 98 percent of rural households now having electricity (National Statistics Bureau, 2017). The rural electrification project of Bhutan has also served to increase living standards, among other positive outcomes (Asian Development Bank, 2010). Also, most of the hydropower electricity is exported to India and for the aforementioned fiscal year, the average export was 35 percent of the total. Furthermore, as Bhutan has endured a current account deficit for over ten years, the financial inflows on account of financing the ongoing hydropower projects helped fund the current account deficit by about 60 percent on average for the same fiscal years as above (MFCC, 2022). Nevertheless, to begin with, the massive capital-intensive hydropower projects are one of the reasons for the ongoing current deficit, in addition to Bhutan's economy being a less diversified and unproductive economy.

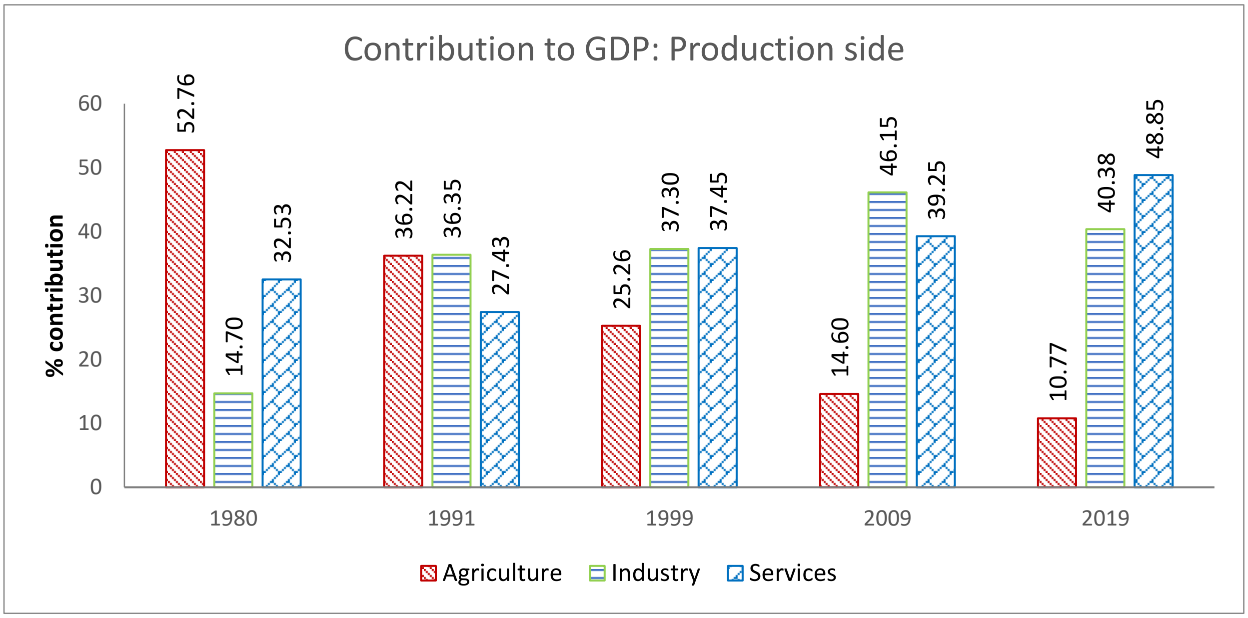

Figure 1.4: Contribution to GDP - Production method

The relatively considerable investments in hydropower are argued to have caused macroeconomic vulnerabilities in Bhutan (Mitra, Carrington, and Baluga, 2014; Nidup, 2015). One of the significant challenges the hydropower investment poses is the mounting public debt, mainly because the hydropower in Bhutan is financed mainly through external debt, mostly from India. The total public debt in the fiscal year 2021 stands at 135 percent of GDP, of which more than 70 percent is external debt on account of hydropower project construction. The considerable debt stock limits the government's fiscal space and is also debated as a source of macroeconomic vulnerability in the country. Additionally, as discussed above, Bhutan's import-dependent economy has been facing current account deficit of over 20 percent of GDP on average for over ten years. Facing the twin deficit – fiscal deficit and current account deficit – with pegged currency monetary policy imposes severe risk and burden on the foreign reserves, further resulting in strict capital control and limiting economic diversity.

Another primary concern surrounding Bhutan's hydropower projects is the escalating cost of the projects that are currently under construction worth Nu. 217,761.040 million, and one of the projects costing Nu. 93,755.750 million is under review due to the instability and safety of the dam

(Ministry of Finance, 2021). However, after examining 58 hydro dam projects globally financed by the World Bank from 1976 to 2005, Awojobi and Jenkins (2015) found a net positive and substantial contribution to economies, despite the project cost overruns and delays. Despite the issue surrounding hydropower projects, considering Bhutan's current economic structure and lack of economic diversity, hydropower electricity production will continue to remain a significant source of economic growth for Bhutan for the foreseeable future. Furthermore, in the densely populated but hugely electricity-deficit areas of the bordering northeastern region of India and with growing electricity demand in Bangladesh, the demand for electricity is forecast to increase by as much as three times in the former and 2.7 times in the latter (Anbumozhi, Kutani, and Lama, 2019), with such prospects providing an even greater impetus for hydropower development in Bhutan. Thus, it is worthwhile to investigate the trade-off of the hydropower development policy, especially the pricing policy, and evaluate its impact on the economy.

1.5. Research Purpose

This dissertation, therefore, focuses on the sustainability of Bhutan's economy by evaluating the impact of human capital accumulation and hydropower. As Bhutan will soon graduate from a low-income to a middle-income country, it would severely limit access to international aid and grants transfer. Thus, higher public debt is likely to pose severe fiscal challenges. This circumstance offers Bhutan an opportunity to diversify and pursue policies for more sustainable and equitable growth. Acknowledging past success and current and future challenges, we research the aspects that are a potential source of economic growth for Bhutan. Among various possible sources for economic growth, human capital and hydropower electricity remain the most important source.

More precisely, we investigate the effect of policy change in these two main sources on long-run economic growth. We first investigate how the change in government's education policy will affect the country's economic growth, both on the transitional and steady growth paths. Mainly, as the change in the education policy needs to be financed, we assess which financing strategy is sustainable for funding the education subsidy – tax financing or debt financing. Next, we analyze how different electricity pricing policies affect the country's economic growth, mainly the difference between the existing electricity price policy (debt endogenized case or policy) and a proposed price policy (price endogenized case or policy). We use a Diamond-type two-period overlapping generations model as a basic framework in all the above studies to evaluate Bhutan's economy.

In Chapter 2, we simulate the effect of an education subsidy and the change in population growth rate on economic growth through human capital accumulation in the Bhutanese economy. We firstly calibrate the model based on Bhutan's existing central school policies and then simulate by extending the coverage to all students and evaluating the effect on the growth rate. To simulate, we adopted the theoretical framework of Yanagihara and Nakabayashi (2010), who extended the Diamond-type two-period overlapping generations model in an endogenous growth model fueled by human capital accumulation. There we incorporate government bonds to simulate Bhutan's realistic economic circumstances. First, we calibrate two base cases, tax endogenized base case, and debt endogenized base case. Next, we simulate an increase in education subsidy to 70 percent for both base cases. Finally, we compare the results with the base case to investigate the effects. We also compare the tax-endogenized and debt-endogenized cases to investigate which financing mode is more sustainable.

In the following chapters, we shift the focus from human capital accumulation to hydropower electricity. Chapters 3 and 4 evaluate the impact of hydropower policies on Bhutan's macroeconomy and the welfare effect on the individuals. We firstly calibrate the model to reflect current Bhutan's economic circumstances: the government produces electricity through the issuance of government bonds and supplies the electricity at a fixed price. In other words, as a base case, we calibrate the theoretical model by endogenizing the debt. Next, we execute the simulation by endogenizing the electricity price and evaluating its effect on Bhutan's macroeconomy and individual lifetime utility. As a feature of our model, we adopted the production function adopted by Macias and Matilla-Garcia (2015), which is a mix CES-Cobb-Douglas function combining labor and capital services. The capital services take the form of constant elasticity of substitution production function combining capital and electricity. In both chapters, we investigate the effect of debt-endogenized policy versus price endogenized policy on Bhutan's macroeconomy.

It should be noted that there are significant differences between Chapters 3 and 4. First, in Chapter 3, we incorporate electricity into an individual's behavior as a labor productivity-enhancing factor. We assume that access to electricity enables individuals to access a wide range of opportunities that enhances productivity. We also incorporate electricity into an individual's behavior in Chapter 4; however, in this chapter, we assume that electricity as labor time-saving factor. We assume that access to electricity enables households to free up labor time from the none income-generating essential household chores, for example, collecting water and firewood. Second, in Chapter 3, we use the two-period overlapping generations model, while in Chapter 6, we use the six-period overlapping generations model. Finally, in Chapter 3, we investigate the impact during the transitional and steady growth paths, while in Chapter 4, we examine the effects only limited at the steady-state.

1.6. Literature Review

Before we conduct the numerical analysis of the Bhutanese economy, we survey the previous literature to take stock of prior studies on the subject matter covered in this dissertation to accentuate our research contributions.

1.6.1. OLG Model and The Simulation Analysis

This dissertation extensively uses the theoretical model framework that Diamond (1965) developed in his seminal paper after augmenting Samuelson's (1958) simplified version of the overlapping generations model. Diamond (1965) analyzes the effect of national debt, external and internal debt, on the long-run capital stock within an economy where physical capital is accumulated as a source of economic growth. The feature of this model is that there exist two kinds of people, that is, the young generation and the old generation, in the same period of time and their activities in this economy are different. From such feature of the framework, this model is called overlapping generations model (OLG model). Since then, many researchers have used the OLG model to study the effects brought by various fiscal policy changes. The model allows us to analyze the intergenerational conflicts caused by the difference in fiscal policies as it considers the actual individual's lifecycles.

Using the theoretical OLG model, Auerbach and Kotlikoff (1987) pioneered and popularized the use of the dynamic OLG model to simulate an economy to analyze various fiscal policies. The authors used a simple two-period model and subsequently showed the ability to perform numerical analysis on a large-scale dynamic model by simulating 55 generations. They analyzed the impact of change in critical fiscal policy instruments such as taxes, debts and social security on the macroeconomy and welfare of individuals. Following Auerbach and Kotlikoff (1987), many researchers conducted various numerical using dynamic simulation models. One such seminal work is the numerical simulation by Bouzahzah et al. (2002). These authors developed a six-period OLG model for the European economy to examine the effect of changing policies.

Following Auerbach and Kotlikoff (1987) and Bouzahzah et al. (2002), we conduct numerical simulations using the dynamic OLG model for Bhutan. To do that, we adopt the framework from previous studies relevant to Bhutan with respect to its structure and assumptions. In addition, we extend the model wherever necessary to match the modeled economy to the economic circumstances Bhutan currently faces. While, several existing numerical analyses using OLG with endogenous growth are conducted on advanced economies and emerging markets, this dissertation conducts a macroeconomic numerical simulation of an LDC in the form of Bhutan, as such analysis is lacking in the existing literature. One exception is Mitra et al. (2014), who focus on Bhutan's potential output simulation. However, they do not consider human capital accumulation in the framework of dynamic general equilibrium OLG model. Even for LDCs in general, to the best of our knowledge, such investigations are limited to a few countries, for example, Hermannsson and Lecca (2014) analyze Malawi's economy using OLG to evaluate human capital accumulation, but they focus on population change. In contrast, we concern ourselves with simulating Bhutan's economy fueled by human capital accumulation and electricity.

1.6.2. Human Capital Accumulation with Education

Generally, there is a consensus that education is one of the main sources of human capital accumulation. Romer (1986) and Lucas (1988) develop the theoretical foundation to establish human capital investment as an important factor for economic growth.

A wealth of investigation has followed the seminal work by Romer (1986) and Lucas (1988). For instance, Azariadis and Drazen (1990) show that differences in productivity across countries arise through differences in human capital accumulation. Glomm and Ravikumar (1992) showed that education is very important for human capital accumulation, financed either privately or publicly or a mix of both. They also reported that public education helps reduce income inequality faster than private education. Further, Eckstein and Zilcha (1994) added that the public policy to provide support in educating individuals financed by proportional taxes can enhance growth and an equal income distribution. In assessing the level of public education support in the form of an education subsidy, Bräuninger and Vidal (2000) assert that the initial level of education subsidy determines the efficacy of subsidy policies in a system of either pure private or subsidized education and conclude that the increase in public education reduces education costs and tends to promote growth in the long run. However, public education needs to be financed by the government through taxes, and Futagami and Yanagihara (2008) shows that if the government choses tax rates adequately, human capital grows faster and welfare levels become higher. In addition, there are quite a few theoretical literatures which consider private education expenditure as a source of human capital accumulation (Galor and Tsiddon, 1997; Gradstein and Justman, 1997; Zilcha, 2003; Soares, 2006; Docquier et al., 2007).

These theoretical frameworks have been duly presented in the form of various numerical analyses following the seminal work by Auerbach and Kotlikoff (1987). Docquier and Michel (1999) pioneered numerical simulation to investigate the European economy using three–period OLG models to study the optimal path with education subsidies and financing modalities. They show that, in light of the aging population, the increase in education subsidy – as education is considered to compensate for the decline in workforce number – should be financed through lump-sum taxes on retirees in that period. As mentioned previously, Bouzahzah et al. (2002) used a six-period dynamic OLG model. They conducted a numerical simulation to investigate the European economy by examining the effect of changing policies such as government debt, education, etc., and affirmed that education is indeed a source of growth. Investigating the impact of the education provided through public education in the US economy, de la Croix and Doepke (2004) demonstrate that human capital accumulation through the public education system results in a higher growth rate.

For Japan, Yanagihara and Nakabayashi (2010) investigate the economy to explore the effects of the governmental education subsidy policy on various aspects, especially concerning economic growth, considering the critical role of public education expenditure. They find that increasing education subsidies increases private education expenditure, further amplifying human capital accumulation in Japan. Shindo et al. (2012) followed the framework of Bouzahzah et al. (2002) to explore the effects of the heterogeneity of regional policies with a six-period OLG model, mainly education and education expenditure, on differences in economic growth in the Tokai region using an endogenous growth model fueled by human capital accumulation. This vast array of analyses establishes the contribution of education financed through an education subsidy on the growth of human capital accumulation.

1.6.3. Economic Growth and Electricity Energy

The role of energy in the modern-day globalized economy cannot be overstated. Nevertheless, the role of energy as a source of economic growth has been largely neglected in economic research (Stern and Kander, 2012). That is, most available literature implicitly assumes energy to be part of the total factor productivity (TFP) or the two factors of production – capital and labor. Such assumptions do not necessarily reflect the real-world scenario, especially considering the events that unfolded in 2022. To address such gaps in research, Stern and Kander (2012), using Solow growth model, incorporated two types of TFP – one as labor augmenting technology and the other augments energy – essentially including energy as a factor of production. They find that the expansion of energy services was a significant factor in the economic growth of Sweden before mid of 20th century.

Subsequently, Kander and Stern (2014) extend the model developed by Stern and Kander (2012), allowing multiple energy inputs that its technological efficiency could differentiate, that is allowing for traditional or modern energy–augmenting technological change. They adopt CES production technology aggregating traditional and modern energy carriers. Kander and Stern (2014) find that the modern energy-augmenting technological change's contribution to growth was negligible in comparison to the traditional-fuel-augmenting technological change. However, it should be noted that they assume exogenously given technological changes. Likewise, Macias and Matilla–Garcia (2015) used the elasticity of a Ramsey–Hotelling growth model with energy return on energy invested (EROI) by considering energy as an input in the production function. They were the first to fit EROI into a neoclassical growth model. Further, Macias and Matilla–Garcia (2015) proposes a mix CES-Cobb-Douglas production function whereby they combine "capital services" and labor to form Cobb-Douglas, and the capital services is the CES production function combining capital and energy.

While research on growth theories downplayed the role of energy as a source of economic growth, empirical studies on the causal relationships between energy consumption and economic growth can be traced back to Kraft and Kraft (1978). In a comprehensive literature survey conducted by Ozturk (2010), taking stock of results from various studies on the causal relationship between energy consumption and economic growth, it was observed that the results were mixed. Ozturk (2010) attributed such conflicting results to differences in data set, variables and methodologies used, and characteristics of countries. Nevertheless, the author reports a causal relationship from electricity consumption to economic growth for country-specific studies, thus, supply shock of energy could have a negative impact on economic growth.

When it comes to the impact of use or access to energy, particularly electricity, by individual households, it is noted that it positively impacts households by raising their welfare. A World Bank study in India reported that access to electricity reduced the time spent on collecting biofuel by more than 3.3 hours per month, resulting in an increase in household per capita income by 38.6 percent (Khandker et al., 2012). In other words, electricity access and consumption help individuals save labour time. Akin et al. (2018) conducted research at a global level by collecting data from 124 countries and claimed that a robust relationship exists between per capita income and household electrification. The same result was echoed by Han et al. (2020) in their research conducted in Cambodia. In the sense, these researches allude that electricity access and consumption help improve labour productivity.

Ironically, it has also been found that electricity consumption is a function of income and the price of electricity. Kharief et al. (2018), in their study, highlights such relationships. While there are various studies electricity-economic growth nexus with equally diverse and mixed results, many studies support the electricity-economic growth in an agrarian economy. Especially studies from parts of South Asia tend to support the nexus, either in the short run or long run or both (Hossain and Saeki, 2011; Khandker et al., 2012; Abbas and Choudhury, 2013).

1.7. Structure of Dissertation

Overall this dissertation is segregated into five different chapters. Chapter 2, a summary of which has been discussed in the preceding section and is titled "The effect of education subsidy and demographic changes on Bhutan's human capital accumulation: Macroeconomic simulation using a two-period overlapping generations model with endogenous growth." Chapters 3 and 4 have also been summarized in the preceding section and is titled "Hydropower and welfare in Bhutan: Short-run and long-run analysis using a two-period overlapping generations model" and "Electricity pricing and generational utility: Macroeconomic simulation for Bhutan using a six-period overlapping generations model" respectively. The dissertation's final chapter is Chapter 5, which concludes with a summary of the dissertation.

Chapter 2: The effect of education subsidy and demographic change on Bhutan's human capital accumulation: Macroeconomic simulation in an endogenous growth model

2.1. Introduction

We conduct a numerical simulation of Bhutan's economy to investigate the effects of the education subsidy on Bhutan's economy using a two-period dynamic overlapping generations model fueled with human capital accumulation.[1] Mainly, we extend the current central school program to cover all the students and see how this policy implementation would have an effect on the economy depending on the financial modalities. Extending the central school program increases the education subsidy level from 60 percent to 70 percent of total education expenditure per household. While most studies oscillate between using different key fiscal policy variables to finance the change in subsidies, we mainly focus on the wage tax and debt. This situation reflects the actual economic circumstances.

Additionally, we investigate a decrease in the population growth rate, as this is also a critical factor influencing the government's ability to enhance the education subsidy to accelerate human capital accumulation, especially in Bhutan's context. In fact, Bhutan's total population is about 735,553 persons, growing at 1.3 percent, and the total fertility rate (TFR) is 1.7,[2] which is below the replacement level of 2.1 (National Statistics Bureau, 2018).[3] This trend indicates that Bhutan's old-age population will soon be larger than its working population, a demographic situation detrimental to the long-run development of any low-income country. Further, Bhutan's debt stood at 111.2 percent of GDP in the fiscal year 2019/2020 (MFCC, 2020) and has been rated as a moderate risk in the Article IV Consultation report (International Monetary Fund [IMF], 2018). A

[1]This chapter is based on the paper entitled "The effect of education subsidy and demographic change on Bhutan's human capital," which has been accepted by the Studies in Regional Science.

[2] TFR is defined as an average number of children which a woman would bear during her entire reproductive life, at the prevailing age-specific fertility rate.

[3] This refers the number of children per women required to maintain the current population level.

low population growth rate in conjunction with a high debt level could challenge fiscal sustainability and further constrain Bhutan's future growth prospects.

The main results from the calibration and simulation of the chapter are summarized here. First, we calibrate the economy using current policy to establish two base case scenarios – the tax endogenized case and the debt endogenized case – and find that the economic growth rate, that is, the growth rate of human capital accumulation in Bhutan in the second period is about 218.549 percent for 30 years (3.938 percent annually) and 230.860 percent for 30 years (4.069 percent annually), respectively. These growth rates are almost the same with the actual growth rate observed from 2017 to 2019 (pre-pandemic).[4] Second, when we increase the education subsidy to be financed through taxes the economic growth rate is raised in comparison with the base case by 4.963 percent and 4.377 percent in the second period and at the steady growth path, respectively. Third, we increase the education subsidy to be financed through debt the economic growth rate is increased compared with its base case by 4.761 percent in the second period and 3.938 percent at the steady growth path. Fourth, comparing the two financing cases to finance the increase in education subsidy, we find that tax financing is preferable for the economy during the transition and at the steady growth path compared with debt financing, mainly because the latter causes the crowding-out effect in the capital market. Finally, we also investigate the effect of the decrease in the population growth rate on the economy and find that it increases the human capital, physical capital per effective labor unit, and tax/debt, irrespective of the endogenous variable being tax or debt, and the difference in the volume of these effects is not significant.

The remainder of the chapter is organized as follows. In Section 2.2, we describe the model. Section 2.3 calibrates the model and sets values for the model parameters. We present the results for the several patterns of the changes in fiscal policy, tax and debt, in the transition and steady growth paths in Section 2.4. Finally, we provide the conclusion in Section 2.5.

[4] As we used the two-period overlapping generations model, where individuals undertake economic activities for two periods, the values obtained from the simulation are the ones for 30 years (please note that, as we will explain in Section 2.5, we assume that young period starts from age of 21). When we show the values on an annual basis, those values are adequately converted into from the obtained values. In special, as for the gross economic growth rate, it is firstly calculated from $\xi_{t+1} \equiv \frac{h_{t+1}}{h_t}$, then the net annual rate of growth can be obtained by $\xi^{1/30} - 1$.

2.2. The Model

The model considers a closed economy with a perfectly competitive market with endogenous growth properties fueled by human capital accumulation following the framework in Yanagihara and Nakabayashi, 2010). The economy consists of individuals, firms, and the government. For simplicity, we assume that individuals undertake economic activities for two periods – young and old. Time evolves in discrete periods, and the economy is assumed to last forever. The population in period t is L_t and is assumed to grow at a constant rate of n.

2.2.1. Individuals

We consider the behavior of generation t, the individuals who spend period t as a young period. They supply labor inelastically in the young period and receive wages, w_t, for one unit of human capital, h_t. After deducting the wage tax at a rate of τ_t, they spend net wages, $(1-\tau_t)w_t h_t$, on children's education, $\hat{e}_t$, consumption during young, $\hat{c}_t^1$ and saving, $\hat{s}_t$, that is consumed during the old period, $\hat{c}_{t+1}^2$.[5] The government subsidizes a proportion of children's education expenditures, μ_t. The budget constraints for the young and the old periods are expressed as:

$$\hat{c}_t^1 + (1-\mu_t)\hat{e}_t + \hat{s}_t = (1-\tau_t)h_t w_t, \tag{1}$$

$$\hat{c}_{t+1}^2 = \hat{s}_t R_{t+1}, \tag{2}$$

where $R_{t+1} \equiv 1 + r_{t+1}$ is the (gross) interest rate and r_{t+1} is the net interest rate in period $t+1$.

Individuals derive their utility from consumption during the young and old periods and through education expenditure on their children. The lifetime utility of individuals in this model adopts a log-linear utility form:

$$U(\hat{c}_t^1, \hat{e}_t, \hat{c}_{t+1}^2; \theta, \rho) = ln\ \hat{c}_t^1 + \theta\ ln\ \hat{e}_t + \rho\ ln\ \hat{c}_{t+1}^2, \tag{3}$$

where $\rho(> 0)$ is the subjective discount factor and $\theta(> 0)$ is the weight of utility for education.

[5] The variables with hat, such as $\hat{e}_t$ and $\hat{s}_t$, represents per capita variables.

Given the lifetime utility function in equation (3), the individuals maximize their utility under the budget constraints given by equations (1) and (2). We then obtain per capita savings and education expenditure in period *t* as follows:

$$\hat{s}_t = \frac{\rho}{1+\theta+\rho}(1-\tau_t)h_t w_t, \tag{4}$$

and

$$\hat{e}_t = \frac{\theta}{(1+\theta+\rho)(1-\mu_t)}(1-\tau_t)h_t w_t. \tag{5}$$

This per capita education expenditure given in equation (5) can be rewritten in per effective labor unit by dividing both sides by h_t:

$$e_t = \frac{\theta}{(1+\theta+\rho)(1-\mu_t)}(1-\tau_t)w_t. \tag{5´}$$

Finally, we define the human capital accumulation dynamics in period *t+1* following Yanagihara and Nakabayashi (2010):

$$h_{t+1} = B(\hat{e}_t)^{\alpha}(h_t)^{1-\alpha}. \tag{6}$$

The expression takes the form of the Cobb-Douglas type human capital accumulation, where B (> 0, normalized to 1 later) and α (0< α <1) represent the productivity of human capital and education expenditure, respectively.

2.2.2. Firms

The market is assumed to consist of competitive firms with identical production technology, as given by the following Cobb–Douglas form:

$$Y_t = AK_t^{\gamma}(L_t h_t)^{1-\gamma}, \tag{7}$$

where Y_t, K_t and $L_t h_t$ are aggregate output, physical capital, and effective labor in period *t*, respectively. A (> 0) represents the exogenously given level of total factor productivity, and γ $(0 < \gamma < 1)$ is the capital intensity.

Dividing both sides of equation (7) by $L_t h_t$, we obtain the production function per effective labor unit in period *t* as $y_t = Ak_t^{\gamma}$, where $k_t \equiv \frac{K_t}{L_t h_t}$ is the capital per effective labor unit.

Given the production function per effective labor unit, the following two conditions are obtained from the firms' profit maximization:

$$\delta + r_t = A\gamma k_t^{\gamma-1}, \tag{8}$$

and

$$w_t = A(1-\gamma)k_t^{\gamma}. \tag{9}$$

Both equalities represent the equivalence between the prices of the factor of production and their productivities with depreciation at the rate of δ. We can see that the prices depend on the physical capital per effective labor unit.

2.2.3. Human capital growth

We can modify the human capital accumulation dynamics in period *t+1* by substituting equations (5) and (9) in equation (6) and setting B =1, as follows:

$$h_{t+1} = \left[\frac{A(1-\gamma)\theta(1-\tau)}{(1+\theta+\rho)(1-\mu_t)}\right]^{\alpha} {k_t}^{\alpha\gamma} h_t. \tag{10}$$

Thus, we obtain the growth rate of human capital or the economic growth rate that is dependent only on k_t as:

$$\frac{h_{t+1}}{h_t} = \left[\frac{A(1-\gamma)\theta(1-\tau_t)}{(1+\theta+\rho)(1-\mu_t)}\right]^{\alpha} {k_t}^{\alpha\gamma}. \tag{10′}$$

We define the growth rate of human capital as $\frac{h_{t+1}}{h_t} = \xi_{t+1}$.

2.2.4. Government

The government expenditure constitutes an education subsidy, government debt repayment – including interest – and other government expenditures. These expenditures are financed through wage taxes under a balanced budget. Thus, we define the per capita government budget constraint in period *t* as follows:

$$\tau_t w_t h_t + \hat{d}_{t+1} = \hat{g}_t + \mu_t \hat{e}_t + \frac{(1+r_t)}{(1+n)}\ \hat{d}_t, \tag{11}$$

where $\hat{d}_t$ is the per capita government debt repayment in period t and $\hat{d}_{t+1}$ is the issuance of government bonds and $\hat{g}_t = \phi \hat{k}_t$ is the other government expenditure per capita, where ϕ is the government expenditure to GDP ratio.

We convert equation (11) into per effective labor unit by dividing both sides by h_t as follows:

$$\tau_t w_t + d_{t+1}\left(\frac{h_{t+1}}{h_t}\right) = g_t + \mu_t e_t + \frac{(1+r_t)}{(1+n)}\ d_t, \tag{12}$$

Finally, we assume that the government determines μ_t, which implies that the wage tax rate or government debt is subsequently determined as the following part. Based on the above structure of the economy, we consider the two cases regarding the policy of the government: the one is the case where the tax rate is endogenously determined (hereafter referred to as the tax endogenized case) and the other is the case where the amount of date is endogenously determined (hereafter referred to as the debt endogenized case).

2.2.4.1.Tax endogenized case

First, we consider the tax endogenized case. More concretely, in period t the government budget constraint can be rewritten by using equations (5′) and (10′) and substituting r_t and w_t in equation (11′) as:

$$\tau_t = \frac{(1+\theta+\rho)(1-\mu_t)}{A{k_t}^{\gamma}(1-\gamma)(1+\theta+\rho-(1+\rho)\mu_t)}\left[g_t + \frac{d_t(1-\delta+A\gamma {k_t}^{\gamma-1})}{1+n} + \frac{A(\gamma-1)\theta {k_t}^{\gamma}\mu_t}{(1+\theta+\rho)(\mu_t-1)} - \frac{\beta\theta^{\alpha} d_{t+1}(A(1-\gamma){k_t}^{\gamma})^{\alpha}(k_t-1)^{\alpha}}{(1+\theta+\rho)^{\alpha}(\mu_t-1)^{\alpha}}\right]. \tag{12}$$

From equation (12), we can acknowledge that wage tax, τ_t, depends on μ_t and k_t, which is determined in the model. The budget constraint at the steady growth path will be as follows:

$$\tau^* = \frac{(1+\theta+\rho)(1-\mu)}{Ak^{*\gamma}(1-\gamma)(1+\theta+\rho-(1+\rho)\mu)}\left[g + \frac{\bar{d}(1-\delta+A\gamma k^{*\gamma-1})}{1+n} + \frac{A(\gamma-1)\theta k^{*\gamma}\mu}{(1+\theta+\rho)(\mu-1)} - \frac{\beta\theta^{\alpha}\bar{d}(A(1-\gamma)k^{*\gamma})^{\alpha}(k^*-1)^{\alpha}}{(1+\theta+\rho)^{\alpha}(\mu-1)^{\alpha}}\right]. \tag{12'}$$

At the steady growth path, τ^* is dependent on μ and the level of k^* . The variables with an upper bar represent the given (exogenous) variable. Here, because τ^* is assumed to be endogenously determined, debt, $\bar{d}$, is treated as given. Similarly, in the following subsection (2.2.4.2), d is endogenously determined, thus, we assume that τ is exogenously given.

2.2.4.2.Debt endogenized case

Likewise, under the debt endogenized case, the government budget constraint in period t can be rewritten by substituting r_t and w_t in equation (11′) as follows:

$$d_{t+1} = \frac{(1+\theta+\rho)^{\alpha}(\mu_t-1)^{\alpha}}{\beta {k_t}^{\alpha\gamma}(A(1-\gamma)\theta(\tau_t-1))^{\alpha}}\left[g_t + \frac{d_t\,(1-\delta+A\gamma {k_t}^{\gamma-1})}{1+n} - \frac{A(1-\gamma)\theta {k_t}^{\gamma}\mu_t(\tau_t-1)}{(1+\theta+\rho)(\mu_t-1)} + A(1-\gamma){k_t}^{\gamma}\tau_t\right], \tag{13}$$

and we can see that in transition, d_{t+1} is dependent on $\mu_t,\ k_t$ and d_t. It should be noted that the increase in d_t leads to an increase in d_{t+1}, which is magnified by the interest payment. This implies that the increase in debt has a crowding-out effect on capital, so it tends to emerge in the long-run in the debt endogenized case compared to the tax endogenized case. The budget constraint at the steady growth path will be as follows:

$$d^* = \frac{\left(Ak^{*\gamma}(-1+\gamma)\bar{\tau} + g - \frac{Ak^{*\gamma}(-1+\gamma)\theta\mu(-1+\bar{\tau})}{(-1+\mu)(1+\theta+\rho)}\right)}{\left(\frac{A^{\alpha}k^{*\alpha\gamma}\beta(1-\gamma)^{\alpha}\theta^{\alpha}(-1+\bar{\tau})^{\alpha}}{(-1+\mu)^{\alpha}(1+\theta+\rho)^{\alpha}} - \frac{1+Ak^{*-1+\gamma}\gamma-\delta}{1+n}\right)} \tag{13'}$$

The d^* at the steady growth path depends on the μ and level of k.

2.2.5. Equilibrium

In the capital market, the market attains equilibrium when the capital per capita demanded by the firm and the government in period *t+1* is equal to the individuals' savings per capita in period *t*. The capital market equilibrium condition is expressed as:

$$(1+n)k_{t+1}h_{t+1} + \hat{d}_{t+1} = \frac{\rho}{1+\theta+\rho}(1-\tau_t)w_t h_t. \qquad (14)$$

Through equation (14), we can obtain the value of k_{t+1} in the transition period. In the tax endogenized case, the level of d is constant and as discussed in subsection 2.2.4.1, and the level of μ_t and k_t, determines the τ_t. The level of τ affects k_{t+1} through savings, as seen in the right-hand side of equation (14). In the case of the debt endogenized case, we can see that the savings seen in the right-hand side of equation (14) need to fund the demand of capital for k_{t+1} and d_{t+1}. Thus, as discussed in subsection 2.2.4.2, the increase in d_t increases the interest expenses as well, thus increasing d_{t+1}, resulting in crowding-out of capital in the capital market, affecting the level of k_{t+1} in equation (14).

Substituting w_t and r_{t+1}, and the government's balanced budget, we can rewrite the capital market equilibrium condition in equation (14) in terms of the growth rate of human capital as follows:

$$\left(\frac{h_{t+1}}{h_t}\right) = \frac{\rho(1-\tau_t)A(1-\gamma)k_t^{\gamma}}{(1+\theta+\rho)((1+n)k_{t+1}+d_{t+1})} = \xi_{t+1}. \qquad (15)$$

If we substitute equation (12) into equation (15), we can obtain the growth rate in period t in the tax endogenized case. Similarly, by substituting equation (13) into equation (15), we can obtain the growth rate in period t in the debt endogenized case. Finally, by setting the variable in terms of per efficient labor unit without time subscript, we can obtain the capital market equilibrium condition at the steady growth path in two cases, which is given below:

$$(1+n)k^* + d^* = \frac{\rho}{1+\theta+\rho}(1-\tau^*)k^*. \qquad (16)$$

The economic growth rate at the steady growth path for the tax endogenized case can be written as:

$$\xi = \frac{\beta(Ak^{*\gamma}(1-\gamma))^{\alpha}\theta^{\alpha}(\tau^{*}-1)^{\alpha}}{(1+\theta+\rho)^{\alpha}(\mu-1)^{\alpha}}, \qquad (17)$$

and the growth rate is dependent on τ^* and k^*. If $\tau^*$and level of k^*, both increases, the growth rate at the steady growth path will increase.

Similarly, in the debt endogenized case, it can be written as:

$$\xi = \frac{\beta(Ak^{*\gamma}(1-\gamma))^{\alpha}\theta^{\alpha}(\tau-1)^{\alpha}}{(\mu-1)^{\alpha}(1+\theta+\rho)^{\alpha}}. \qquad (18)$$

As seen in equations (5) and (6), this human capital accumulation or economic growth, depends on education expenditure, which decreases with the increase in wages tax rate, and both are dependent on physical capital. In the tax endogenized case, though the changes in tax rate directly affect the after-tax wages, there is little effect on the capital market. In contrast, in the debt endogenized case, as the crowding-out effect prevails the capital accumulation in the long-run is affected, even though the effect on after-tax wages is not prominent in the short-run. The composition of these different effects determines economic growth. As we can see in the simulation later, the decrease in physical capital becomes prominent in the long-run in the debt endogenized case, and the economic growth rates are higher in the short-run in the debt endogenized case compared to in the tax endogenized case (when the education subsidy rate is increased) and vice-versa.

2.3. Model calibration

This section calibrates the model of the economy presented above section to simulate the transition and steady growth path for policy changes. We set values for the parameters and exogenous variables to reflect the real economy of Bhutan. Unfortunately, the macroeconomic indicators available in the public domain for Bhutan are limited, so most of the data used here are obtained from the quarterly updates of the MFCC (2020); a committee chaired by the Ministry of Finance, Bhutan and consisting of various stakeholders. Wherever possible, the parameters and exogenous variables are drawn from the literature, while the rest are computed.

The parameter values are summarized in Table 2.1. We compute the base education subsidy rate, μ_t, using data from the Bhutan Living Standards Survey Report (NSB, 2003; 2007; 2012; 2017) to derive the private education investment rate. We obtain government expenditure on education from 2003 to 2017 from the Annual Financial Statement (MoF, 2004; 2008; 2012; 2018). The parameters for education investment, α, and the education preference rate, θ, are determined to match the long-run economic growth rate for Bhutan. In addition, we set the values for taxes when the endogenous variable is debt per effective labor unit, and vice versa.

Table 2.1: Values for parameters

Parameters		**Value**	**Source(s)**
Output elasticity of capital	γ	0.30	Bouzahzah et al. (2002)
Technology parameter	A	269.258	Feenstra et al. (2015); Zeileis (2019)
Discount factor	ρ	0.84	Bouzahzah et al. (2002)
Human capital productivity	β	1	Yanagihara and Nakabayashi (2010)
Productivity for education investment	α	0.192	MFCC (2020)
Education preference rate	θ	0.089	Endogenously derived
Education subsidy rate	μ	0.600	MoF (2004; 2008; 2012; 2018)
Population growth rate	n	0.013	NSB (2018)
Depreciation rate	δ	0.050	Mitra et al. (2014)
Effective wage tax rate	τ	0.090	MFCC (2020)

Table 2.2: Values for exogenous variables

Exogenous variables		**Units**	**Value**	**Source(s)**
Other government expenditure	φ	Expenditure to GDP ratio	0.30	MFCC (2020)
Initial level of debt stock	d	Millions per capita (Nu)	0.165	MFCC (2020)
Initial level of physical capital stock	k	Millions per capita (Nu)	3.814	Feenstra et al. (2015); Zeileis (2019)

The exogenous variables are given in Table 2.2. We set the initial levels of capital stock per capita and government debt stock per capita (in the case where the endogenous variable is wage tax rate). To define the initial levels in per effective labor unit, we set the initial level of human capital, h_1, to unity. The initial level of capital stock per effective labor unit, k_1, is directly calculated from the Penn World Table (Feenstra et al., 2015; Zeileis, 2019) as Nu. 3.814 million per effective labor unit and the government debt per effective labor unit, d_1, Nu. 0.165 million by using the data obtained from MFCC (2020).[6] The value for other government expenditures is with respect to GDP averaged of 5 years given Bhutan follows a 5-year planning cycle and year-on-year government expenditure fluctuates dramatically. However, the government expenditure level is linear between the planning cycles.

These settings of the parameters and exogenous variables provide a realistic portrayal of the current economic circumstances in Bhutan. After calibrating the model, we obtain an annual growth rate of about 4 percent and an effective tax of around 9 percent in the first period, both of which are close to the average values observed in Bhutan from 2017 to 2019 (average), that is before the outbreak of the COVID-19 pandemic in 2020.

2.4. Simulation results

We simulate three difference cases to present the effects on the economy at the transitional and steady growth paths, and effect on welfare for the individuals. First, we calibrate the model under two base cases: the tax endogenized case and the debt endogenized case to compare the growth rates between these two cases. Second, we simulate an increase in the education subsidy financed through either taxes or debt and compare the results. Finally, we consider a case where the population growth rate decreases and analyze its effects on the economy in both cases. To execute the calibration and simulation, as mentioned in Section 2.2, we consider individuals taking economic activity for two periods and assume their lives are as follows. They start their young period at the age of 21 and old period at the age of 51. As for the first 20 years as childhood, they live with their parents and do not undertake any economic activity, thus, it is not treated in the model explicitly. We assume all policy changes are initiated in the first period and the changes are permanent.

[6] Nu. stands for Bhutanese Ngultrum and is also referred to as BTN. USD 1=Nu. 70 (end of 2019)

2.4.1. Base case

2.4.1.1. Tax endogenized case: Base

We calibrate the first base case model, where we endogenize the tax rate and obtain the steady growth path in the tenth period, as illustrated in Figure 2.1.

In the calibrated model, we obtain a tax rate in the first period as 8.4 percent, which is close to the observed effective tax rate in 2019. In addition, we obtain the economic growth rate for the second period as 3.940 percent annually (218.761 percent over for the entire period), and this

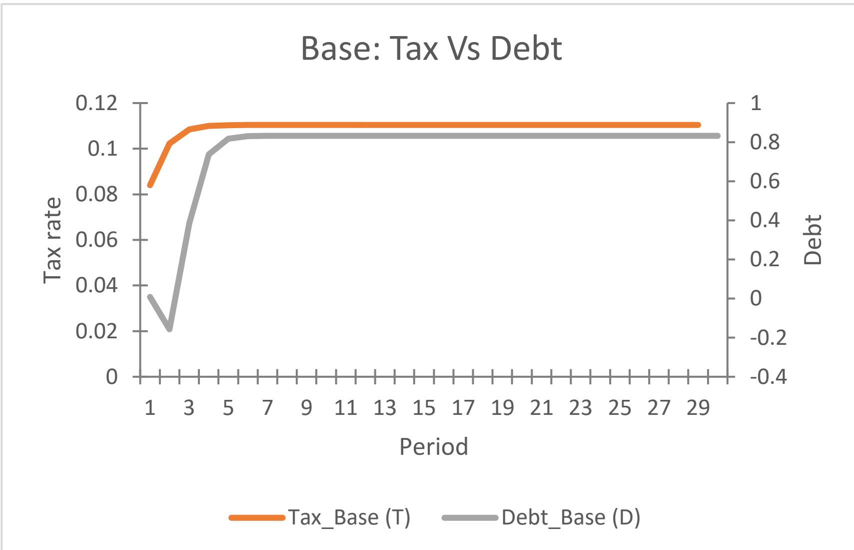

Figure 2.1: Base case - Tax vs debt

growth rate is also close to 4.49 percent, being the actual moving average growth rate in Bhutan from 2017 to 2019, that is, before the COVID-19 pandemic. The economy on the steady growth path grows at a rate of 4.100 percent annually (233.838 percent over the entire period) with a tax rate of 11.040 percent. As for physical capital accumulation, this grows from an initial level of Nu. 3.810 million per effective labor unit in the first period to Nu. 13.385 million per effective labor unit on the steady growth path, an increase of over 200 percent as depicted in Figure 2.2.

2.4.1.2. Debt endogenized case: Base

The second base case is the debt endogenized case, and the economy attains the steady growth path in the twelfth period, as also shown in Figure 2.1.

The economic growth rate for the debt endogenized case can be obtained as 4.073 percent annually (231.235 percent over the entire period) in the second period, which is also close to the actual growth rate, given previously. At the steady growth path, the economy grows at a rate of 4.102 percent annually (234.056 percent over the entire period). The physical capital also increases from an initial level of Nu. 3.810 million to Nu. 12.613 million per effective labor unit, an increase of about 230 percent. As for the debt level, it improves from an initial deficit level of Nu. 0.008 million per effective labor unit to a surplus Nu. 0.157 million per effective labor in the second period. That is because, the initial debt level is low so the human capital and physical capital increases rapidly. These increase the government expenditure which in turn increases the debt level. However, afterward the deficit increases to Nu. 0.832 million at the steady growth path, an increase of more than 400 percent over the entire period.

2.4.1.3. Comparison: Base

We compare the two cases, as presented in Figure 2.2. It shows the transitional path of physical capital accumulation, economic growth rate and individuals' utility under two difference base cases.

The economy grows at a higher rate for the debt endogenized case by 0.1331 percentage point in the second period and 0.0023 percentage point at the steady growth path when compared to the tax endogenized case. We interpret this as follows. In our model, human capital accumulation, or the economic growth rate, depends on physical capital and education subsidies. The increase in the tax rate works to lower the savings of individuals, thus resulting in a lower growth rate. In the case of debt, while it effects capital accumulation through crowding out in the capital market, it does not affect the savings behavior of individuals themselves directly.

By contrast, the physical capital accumulation is higher for the tax endogenized case than for the debt endogenized case at the steady growth path because the debt crowds out physical capital accumulation under the latter. While in the second period, the debt endogenized case entails higher physical capital accumulation, the tax endogenized case has higher physical capital accumulation in the latter periods. The physical capital accumulation is higher for the debt endogenized case in the second period by Nu.0.112 million per effective labor unit. However, in the third period, the tax endogenized case involves higher physical capital accumulation by Nu.0.205 million per effective labor unit over the debt endogenized case. The main reason for such phenomena is due to the crowding-out effect. In the initial period, the debt level (exogenously given) is relatively lower and, thus the subsequent interest rate is also lower. However, in later periods, the increase in the expenditure increases the debt stock and subsequently increases the interest rates, resulting in further debt accumulation. More debt accumulation means the government would absorb more capital from the capital market resulting in lower physical capital per effective labor unit.

Finally, the utility level is higher for the debt endogenized case compared to the tax endogenized case. The main reason for higher utility under the debt endogenized case is because during young period the increase in debt does not directly affect the young budget constraint like the tax increase. Similarly, during the old period, the increase in debt increases the returns on savings for the older generation, thus, having higher utility level compared to the tax endogenized case.

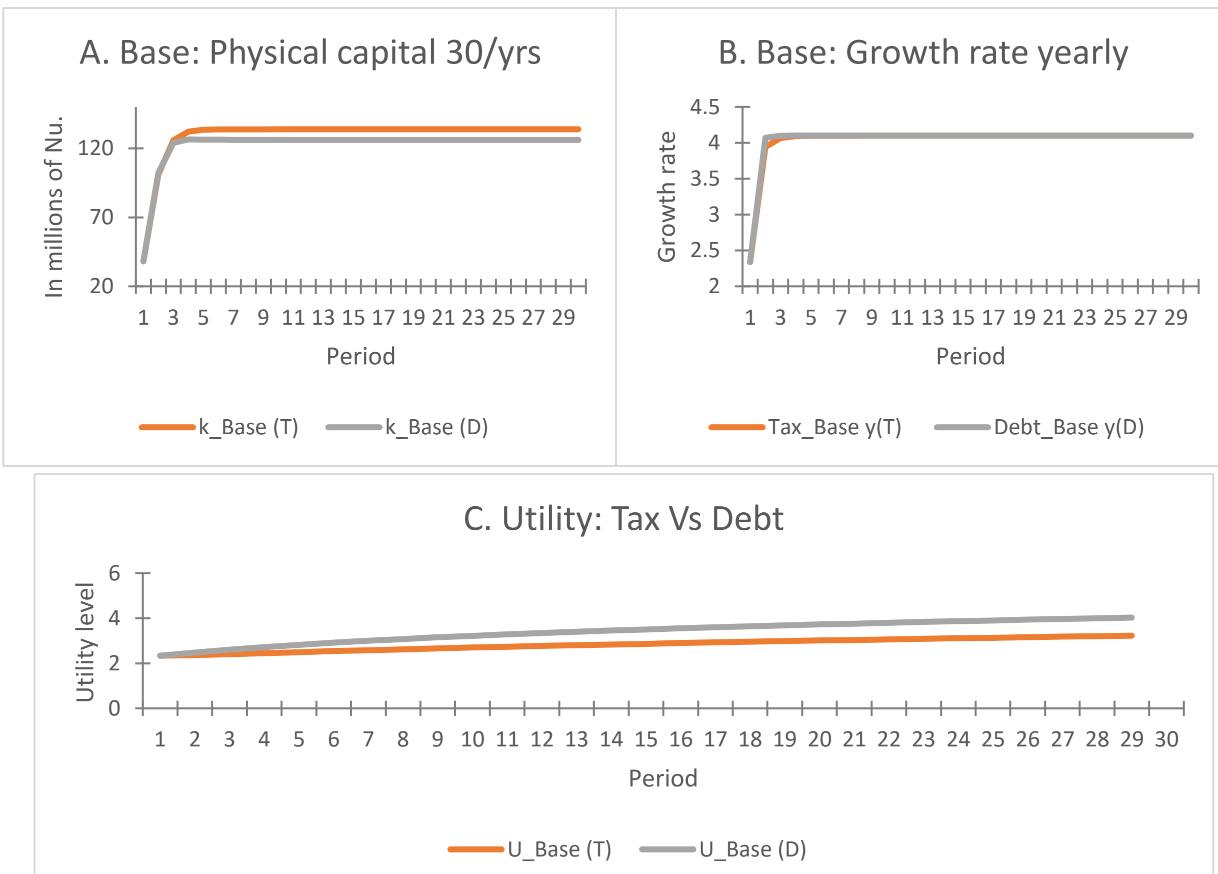

Figure 2.2: Base case: Tax vs debt comparison

2.4.2. Effect of an increase in the education subsidy rate

We simulate an increase in the education subsidy rate from 60 percent to 70 percent. This is because as we mentioned before, when we extend the central school program to cover all the students, the proportion of expenditure that government subsidizes education expenditure amounts to 70 percent.

2.4.2.1. Tax endogenized case

The first policy change is an increase in the education subsidy rate from 60 percent to 70 percent, financed through taxes. We obtain the steady growth path in the tenth period, as depicted in Figure 2.3.

As shown, the increase in the education subsidy directly and positively affects human capital accumulation. The increase in education subsidy brings about an increase in the level of human capital, that is the economic growth rate, from 218.761 percent (3.940 percent annually) in the base case to 229.604 percent (4.056 percent annually) in the second period. Compared with the base case, the economic growth rate increases from 233.838 percent (4.100 percent annually) to 244.101 percent (4.205 percent annually), at the steady growth path. At the same time, the increase in education subsidy requires the tax rates to increase. Thus, the tax rates increase from 8.399 percent to 11.577 percent in the first period, and it increases from 11.040 percent to 13.810 percent at the steady growth path.

In contrast to the effect on increase in education subsidies on the level of human capital over the base case, physical capital decreases as education subsidies increase. As the taxes increase, the savings decrease, and, accompanying with it, physical capital per effective labor unit. As a result, compared with the base case, the physical capital in the second period decreases by 8.035 percent (from Nu. 10.104 million per effective labor unit to Nu. 9.292 million per effective labor unit). This difference increases at the steady growth path to 10.112 percent (from Nu.13.385 million per effective labor unit to Nu. 12.031 million per effective labor unit). Overall, we find an increase in the education subsidy, on one hand, accelerates human capital accumulation and, on the other hand, decelerates physical capital accumulation. Because the former effect dominates the latter, the economic growth rate is raised, as a whole.

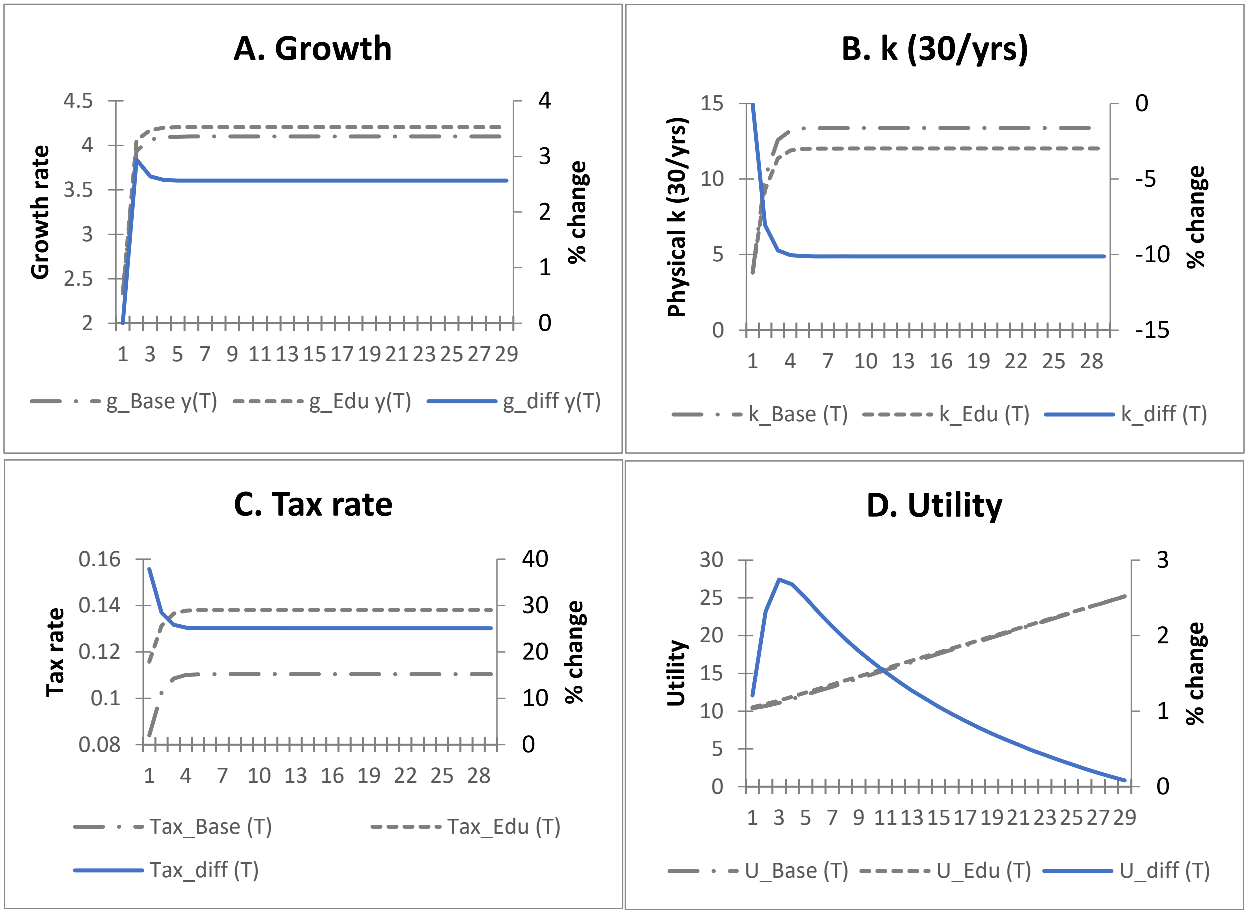

Figure 2.3: Increase in education under the tax endogenized case

The increase in education subsidy, on the one hand increases the utility level as individuals also increase utility from education investment. On the other hand, increasing education subsidy increase the tax rate under the tax endogenized case, as a result the utility level decreases. As shown in Figure 2.3.D, up until the fourteenth period, the former effect bolstered by the higher economic growth rate gives the individuals higher utility level. However, after that period, the economy attains steady growth path, thus the higher level of tax rates over takes the former effect, resulting in a decline in the utility level.

2.4.2.2. Debt endogenized case

As before, we increase the education subsidy rate from 60 percent to 70 percent but now financed it through debt. Bhutan's debt to GDP ratio is high compared with similar economies, with more than 70 percent of the total debt used for hydropower projects, all being external debt (MFCC, 2020). Thus, we simulate debt as an endogenous variable because a high debt level could expose the economy to various risks and shocks, including constraining the government's fiscal space. In this case, the economy attained a steady growth path in the fifteenth period, as illustrated in Figure 2.4.

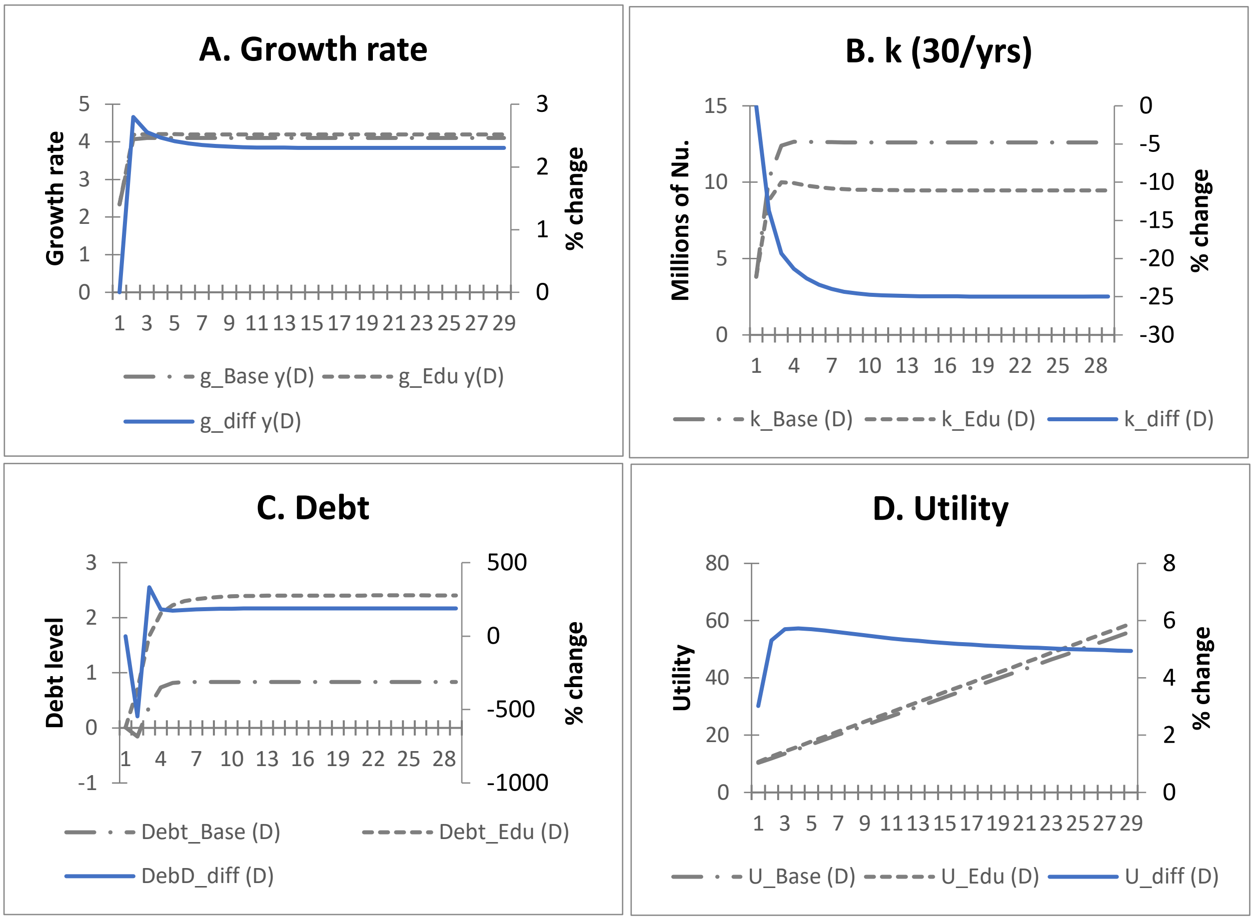

Figure 2.4: Increase in education subsidy under the debt endogenized case.

As shown, the increase in education subsidy also raises the level of human capital under the debt endogenized case. The level of human capital increases from 231.235 percent (4.073 percent annually) in the base case to 242.284 percent (4.187 percent annually) in the second period. At the steady growth path, the economic growth rate increases from 234.056 percent (4.102 percent annually) in the base case to 243.274 percent (4.197 percent annually). Unlike the tax-endogenized base case, under the debt endogenized base case, the economic growth peaks in the third period with a growth rate of 244.040 percent, subsequently declining and stabilizing at 243.274 percent after the nineteenth period. The intuitive explanation is as follows. When the education subsidy increases, it directly accelerates human capital accumulation and indirectly decelerates physical capital accumulation. As discussed in the next paragraph, the government indirectly causes a crowding-out effect by issuing the debt. The former (positive) effect outweighs the latter (negative) effect from the decline in the physical capital until the third period, after which the former effect becomes slightly weakens and the latter becomes stronger, and the growth rate converges to a steady growth level.

The physical capital per effective labor unit decreases because of the increase in debt per effective labor unit. The rise in the education subsidy increases debt per effective labor unit, crowding-out private capital in the capital market, thereby decelerating the physical capital accumulation. The physical capital in the second period decreases from Nu. 10.215 million per effective labor unit in the base case to Nu. 8.816 million per effective labor unit. On the steady growth path, the physical capital decreases from Nu. 12.613 million per effective labor unit in the base case to Nu. 9.463 million per effective labor unit. During the transition, the physical capital per effective labor unit peaks in the third period reaching Nu. 9.996 million per effective labor unit, after which it decreases and stabilizes at the steady growth path. The reason is that the debt levels in the first period are relatively low, Nu. 0.079 million per effective labor unit, so the crowding-out effect is minimal. However, in the second period, the debt level increases to Nu. 0.702 million per effective labor unit and continues to increase until it reaches Nu. 2.404 million per effective labor unit at the steady growth path, the crowding-out effect becomes significant, and this results in lower physical capital accumulation.

The increase in education subsidy financed through debt increases the utility level significantly compared to the base case, as shown in Figure 2.4.D. That is because, during the young period, the younger generation's utility increases due to increased education spending. During the old period, the interest rate increases the older generation's income resulting in higher utility.

2.4.2.3. Comparison

From the above findings, we can see that an increase in the tax rate is a preferable way of financing the increase in the education subsidy compared to an increase in debt concerning the economic growth at the steady growth path. Figure 2.5 clearly illustrates this. As shown, while the increase in the education subsidy accelerates the economic growth rate in both cases, there are significant differences in the values and the trajectory of the growth paths.

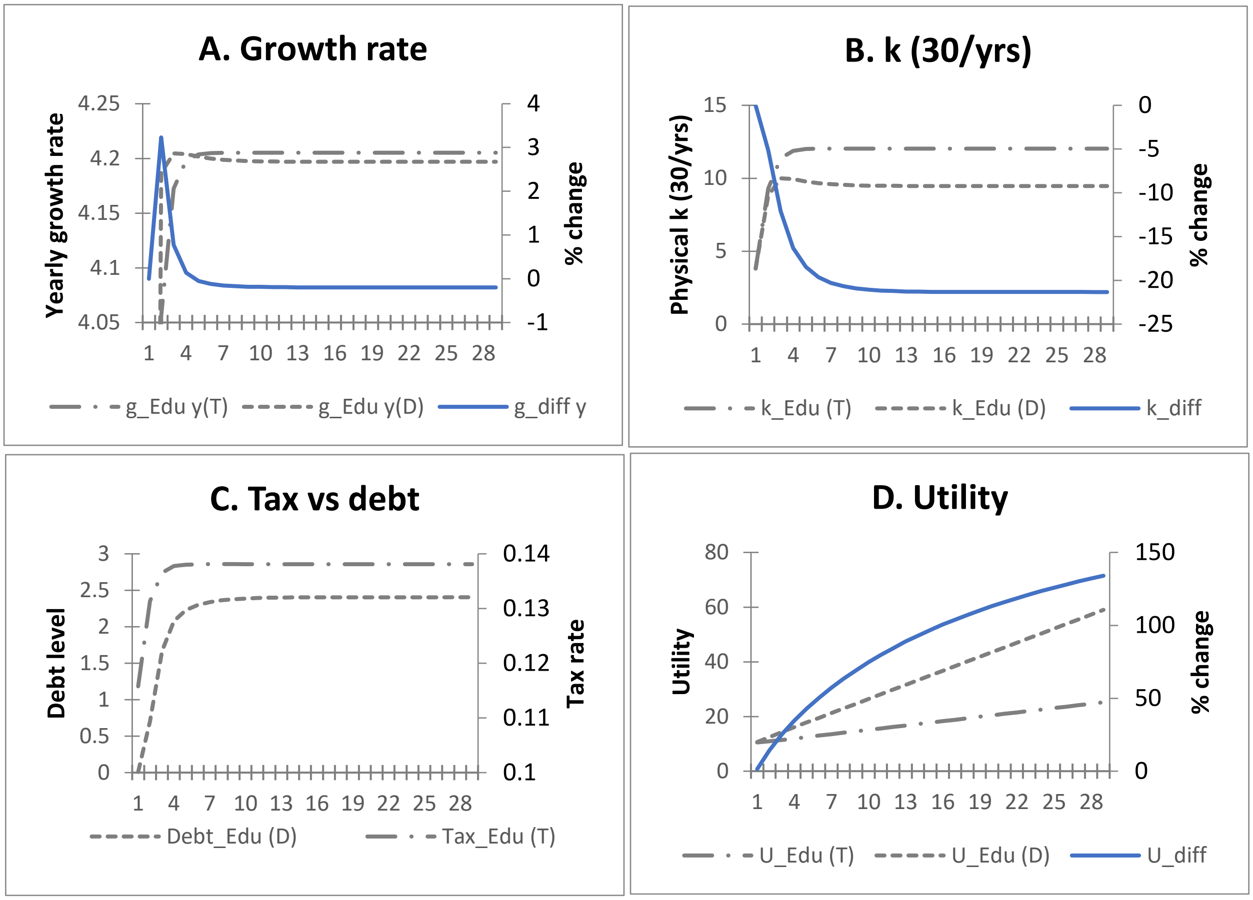

Figure 2.5: Comparison between tax vs debt endogenized case when increasing education subsidy.

In sum, the economic growth rates are higher for debt financing (the debt endogenized case) than for tax financing (the tax endogenized case) from the second to the fourth period. The difference from second to fourth period is 0.1310, 0.0322 and 0.0058 percentage points per year, respectively. However, after the fourth period, the growth is higher for the tax financing case (tax endogenized case) by 0.0939 percentage points on average until the seventeenth period, and then by 0.0085 percentage points at the steady growth path. This occurs because when the increase in education subsidy is financed through debt, where the debt level is low, the economy grows at a higher rate than in the tax financing case as higher taxes result in lower savings in the earlier periods. Furthermore, with a lower debt level, the interest rate is also low during the initial transition periods. However, in the latter transition periods, as the debt level increases resulting in higher interest rates, accelerating the crowding-out effects in the capital market. Thus, the government would absorb more funds out of the capital market, resulting in lower physical capital accumulation and economic growth, compared with the tax endogenized case.

As for the movement of physical capital, it is significantly higher for tax financing across all periods because the crowding-out effect works in the debt financing case as shown in Figure 2.5.B. The level of physical capital for the tax financing case is higher than that of the debt financing case by 5.1232 percent in the second period and 21.340 percent at the steady growth path. This shows that an increased education subsidy is more effective when financed through taxes rather than debt.

In the case of utility level, individuals attend a higher level of utility where the education subsidy is financed with debt. The reason is that, during the young period, any increase in education investment increases the utility level. However, the utility is higher when the increase in education subsidy is financed through debt rather than taxes, as the latter directly reduces the income of the younger generation. Further, as the tax rate increases under the tax endogenized case, it reduces the education expenditure as the wage decreases, resulting in lower utility compared with the debt endogenized case. During the old, the higher debt level results in higher interest rates, resulting in higher revenue for the older generation, thus yielding a higher utility level.

2.4.3. Effect of decrease in population growth rate

Finally, we simulate a decrease in the population growth rate in Bhutan, from the current growth rate of 1.3 percent to 1 percent as projected by the National Statistics Bureau (2018). We first simulate the effect of the decreased population for the tax endogenized case, followed by the debt endogenized case, and compare the economic growth rates in the two cases. As discussed, this is important because Bhutan's population is small and the population growth rate has been declining, which is a source of growing concern for the long-run sustainability of Bhutan's economy. For analytical convenience, we assume that the population growth rate is constant over time.

2.4.3.1. Tax endogenized case

The decrease in the population growth rate in our model with the tax endogenized case has a positive effect on the economic growth rate, though the magnitude is not significant, on the economy, as depicted in Figure 2.6.

As shown in the figure, the decrease in the population growth rate results in an increase in the economic growth rate, physical capital per effective labor unit, and tax rates compared with the base case. That is because, on one hand, the reduction in population growth rate, human capital, and physical capital per effective labor unit for the next period tends to increase because resources in the earlier period can be allocated across a fewer population. This brings about an increase in wages, which leads to an increase in education expenditure. On the other hand, with regards to the effect on the government budget, the increase in the amount of education expenditure requires an increase in the amount of education subsidy. In addition, the decrease in population growth directly increases the repayment of the debt per effective labor unit, including interest payment. Both of these two effects need more amount of tax, which tends to have a negative effect on human capital accumulation. This leads to an increase in the tax rate, as shown in Figure 2.6. Therefore, in this numerical example, because the former positive effect dominates the latter, it results in the acceleration in the human capital accumulation.

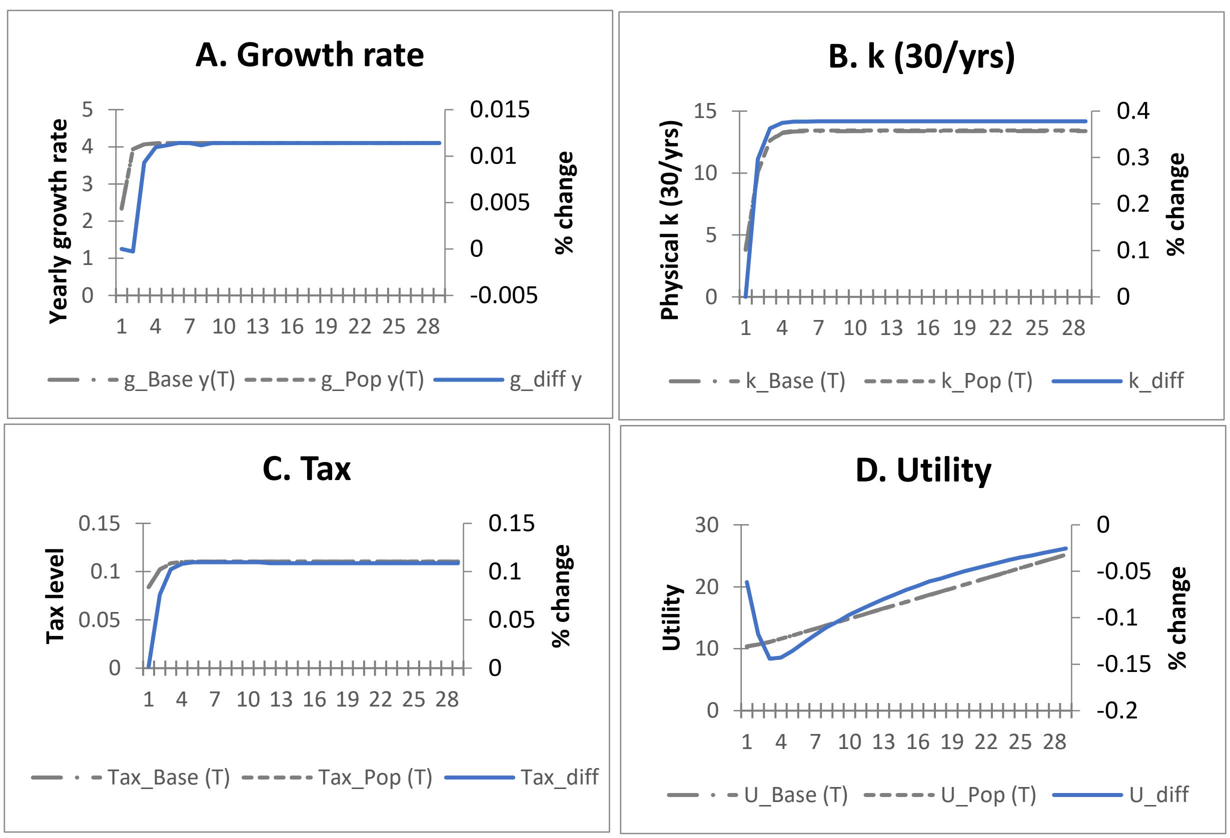

Figure 2.6: Tax endogenized case under decrease in population

More specifically, with the decrease in the population growth rate, the economic growth rate increased by 0.0036 percentage point per year on average during the transition period and 0.0001 percentage point on the steady growth path when compared with the base case. Similarly, the physical capital per effective labor unit is increased on average by Nu. 0.2767 million per period during the transition and Nu. 0.0506 million per period on the steady growth path. Finally, the tax rate increases on average by 0.019 percentage point during the transition and by 0.012 percentage point on the steady growth path. The utility level is higher for the lower population until the 11th period, after which the base case is higher.

2.4.3.2. Debt endogenized case

As in the previous section, the debt endogenized case also bring about a positive effect on the economic growth rate, though the magnitude is not significant, as shown in Figure 2.7. Here, the steady growth path is also achieved in the tenth period.

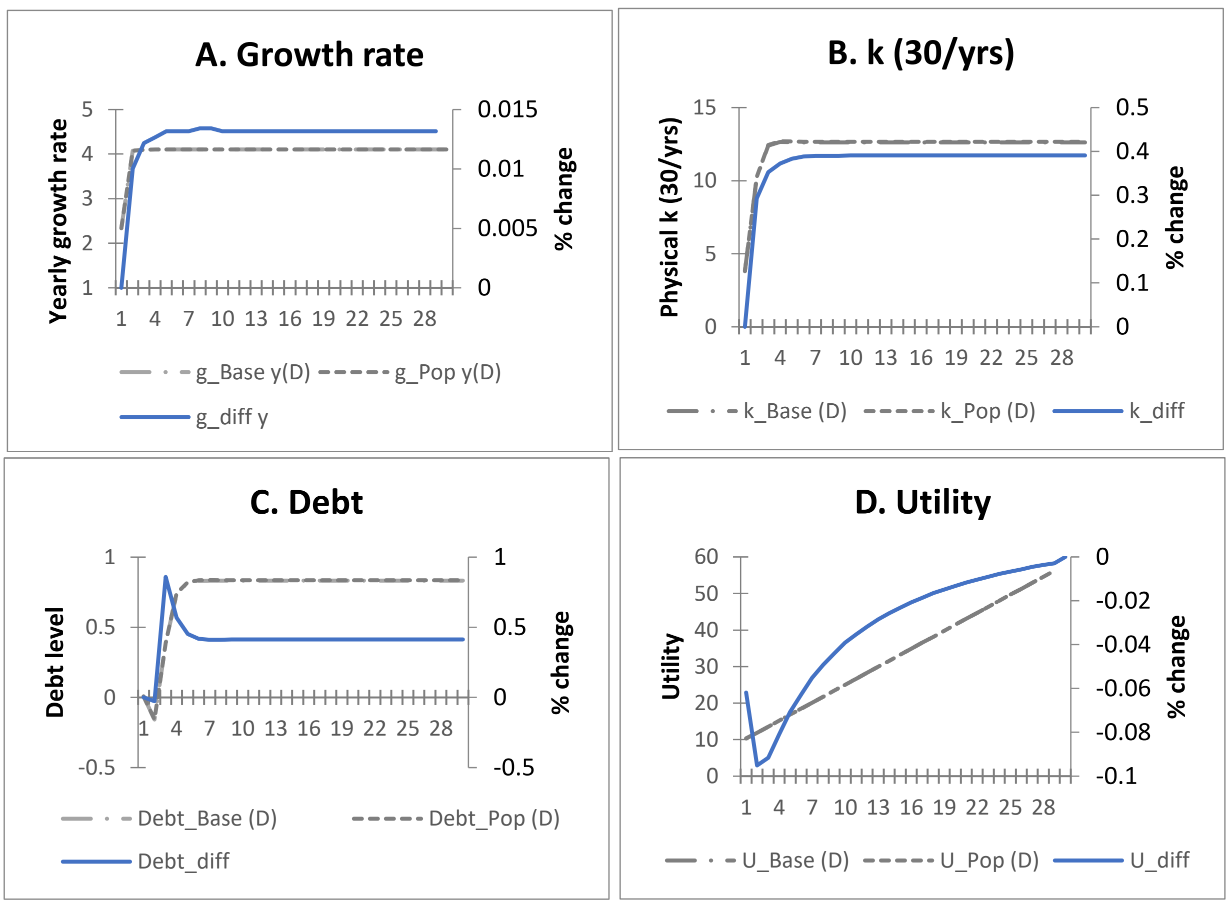

Figure 2.7: Debt endogenized case under decline in population growth rate.

We obtain similar results here as those in the tax endogenized case, that is the decrease in the population growth rate increases the economic growth rate, physical capital per effective labor unit, and debt per effective labor unit with respect to its base, as the resources are distributed across a fewer population in subsequent periods. The economic growth rate under the debt endogenized case increased on average by 0.0005 percentage points during the transition and at the steady growth path compared to the base case. The physical capital per period is increased on average by Nu. 0.046 million per effective labor unit during the transition and Nu. 0.049 million per effective labor unit at the steady growth path. Finally, the debt per period is increased on average by Nu. 0.029 million per effective labor unit during the transition and Nu. 0.034 million per effective labor unit at the steady growth path.

2.4.3.3. Comparison

Comparing the effect of a decrease in the population growth rate for both the tax and debt endogenized cases, we can see that the debt endogenized case involves a higher economic growth rate at the steady growth path: 233.883 percent and 234.108 percent for 30 years: 4.101 percent and 4.103 percent annually, respectively, at the steady growth path. The reason for the higher economic growth rate for the debt endogenized case is as follows. Both the increases in taxes and debt have adverse effects on education expenditure. However, through the former effects it directly, the latter does indirectly through the capital market by crowding-out the physical capital. As a result, the former direct effect dominates the later indirect effect, resulting in a higher economic growth rate for the debt endogenized case compared to the tax endogenized case. Nevertheless, the difference in growth rates in these two cases becomes smaller over the transition period and the steady growth path: the growth rate for the debt endogenized case is higher by 0.1335 percentage points in the second period, 0.0085 percentage points during the transition, and 0.0023 percent point on the steady growth path.

When it comes to physical capital accumulation, it is higher for the tax endogenized case in the steady growth path, and in most of the transitional periods, due to the crowding-out effect of debt. The decline in population growth rate results in higher debt per effective labor unit as the previous debt stock and interest rate need to be repaid by fewer people in the present period. Starting from the same levels of debt, except in the second period where the physical capital is higher for the debt endogenized case by Nu. 0.111 million per effective labor unit, from the third period onwards, the increase in debt accelerates the crowding-out effect in the capital market resulting in higher physical capital accumulation under the tax endogenized case. Concretely, it is higher on average by Nu. 0.009 million per effective labor unit during the transition and Nu. 0.002 million per effective labor unit on the steady growth path. Though the difference in the effects on the economic growth rate is not as large, we can acknowledge that the economic growth rate in the debt endogenized case becomes generally higher than that in the tax case.

2.5. Conclusion

We simulate Bhutan's economy to evaluate the effect of education subsidies with different financing modalities on human capital accumulation along the transition and steady growth path using the two-period overlapping generations model after considering the current macroeconomic conditions. In addition, given the change in demographics, we also simulate a scenario where the population growth rate decreases and evaluate its effect on the economy. The following conclusions are made from the simulation results.

When increasing the education subsidy by extending the central school program to all the students, we find that increasing the education subsidy financed through taxes is preferable from the perspective of economic growth than when financed through debt. The economic growth rate is higher under the debt financing case from the second period to the fourth period, that is, 12.456, 3.002, and 0.432 percentage points per 30 years, respectively. However, after the fourth period, economic growth is higher in the tax financing case by 0.660 percentage points per 30 years, on average, during the transition period and by 0.853 percentage points per 30 years, at the steady growth path. This results from a crowding-out effect caused by government debt in the capital market. Because of this crowding-out effect, the physical capital is higher for the tax endogenized cases by an average of 11.608 percent (amounting to Nu. 1.285 million per effective labor unit) during the periods second to the fourth period and 20.098 percent (amounting to Nu. 2.387 million per effective labor unit) after the fourth period.

We also find that a decrease in the population growth rate increases the human capital, physical capital per effective labor unit, and tax/debt, irrespective of the endogenous variable being tax or debt. Comparing the two cases, we find that the economic growth rate is higher for the debt endogenized case compared to the tax endogenized case: 234.108 percent and 233.939 percent for 30 years; 4.103 percent and 4.101 percent annually, respectively, at the steady growth path. As for the level of physical capital accumulation is higher for the tax endogenized case, compared to the debt endogenized case by Nu. 0.629 million per effective labor unit on the steady growth path.

Through the simulation of Bhutan's economy in this chapter, we can obtain the following policy implication, which may be beneficial for the public finance system of Bhutan. Since Bhutan is a low-income country, it has access to concessional borrowings with zero or very low-interest rate on government bonds. In contrast, as highlighted by IMF (2018) in their staff consultation report, the tax system is outdated and cost of tax collection is relatively high. Thus, as indicated by our results, in the short-run, it is acknowledgeable that Bhutan borrows to finance the extension of central school program and achieve higher economic growth compared to the program being financed by taxes. However, in the long-run, since the tax financing brings about higher economic growth, such program should be financed through taxes rather than government bonds. From this standpoint, the taxation policies and administration should be modernized to improve the efficiency of tax collection system.

Finally, this analysis here is subject to a few limitations. First, the model considers only two generations, thus, it may not appropriately capture the full effect of education on individual lifecycles. Second, it might also be beneficial to evaluate education policy from the viewpoint of Gross National Happiness, as applied in Bhutan. Finally, the debt for Bhutan is generally not considered risky, since the hydropower debts are considered investments, and the debt is self-liquidating. However, this debt is still recorded as public debt, and this study makes no segregation of such debts. Despite these limitations, our analysis suggests useful opportunities for future research for others interested in investigating Bhutan's economy or other economies at a similar level of development.

While human capital accumulation through education subsidy remains important for Bhutan in the long-run, hydropower continues to play a major role in shaping the Bhutanese economy. Thus, in the following chapters, we calibrate and simulate Bhutan's economy by incorporating electricity in the model.

Appendix 2.1. Using "per child" education expenditure instead of "per household"

We assume that the education expenditure investment is incorporated in the young budget constraint in section 2.1. is "per household". If in case we consider "per child", then the young budget constraint will be as follows:

$$\hat{c}_t^1 + (1-\mu_t)(1+n)\hat{e}_t + \hat{s}_t = (1-\tau_t)h_t w_t. \tag{1A}$$

Similarly, the government budget constraint given in equation (11') will change as follows:

$$\tau_t w_t + d_{t+1}\left(\frac{h_{t+1}}{h_t}\right) = g_t + \mu_t(1+n)e_t + \frac{(1+r_t)}{(1+n)}\, d_t. \tag{2A}$$

From equations 1A and 2A, along with the equations given under section 2.2.5, we can simulate and obtain the results presented in Figure 2.8 below.

The main difference is that the growth rate is higher for the case of "per child" rather than "per household", while physical capital per effective labor unit is lower. The difference is mainly a result of increased education investment, causing a higher level of human capital while at the same time reducing the savings resulting in lower savings.

The results here is quite similar to the one under section 2.4, that is the debt endogenized case has higher economic growth than the tax endogenized case for the same reason given under sub-section 2.4.1.3.

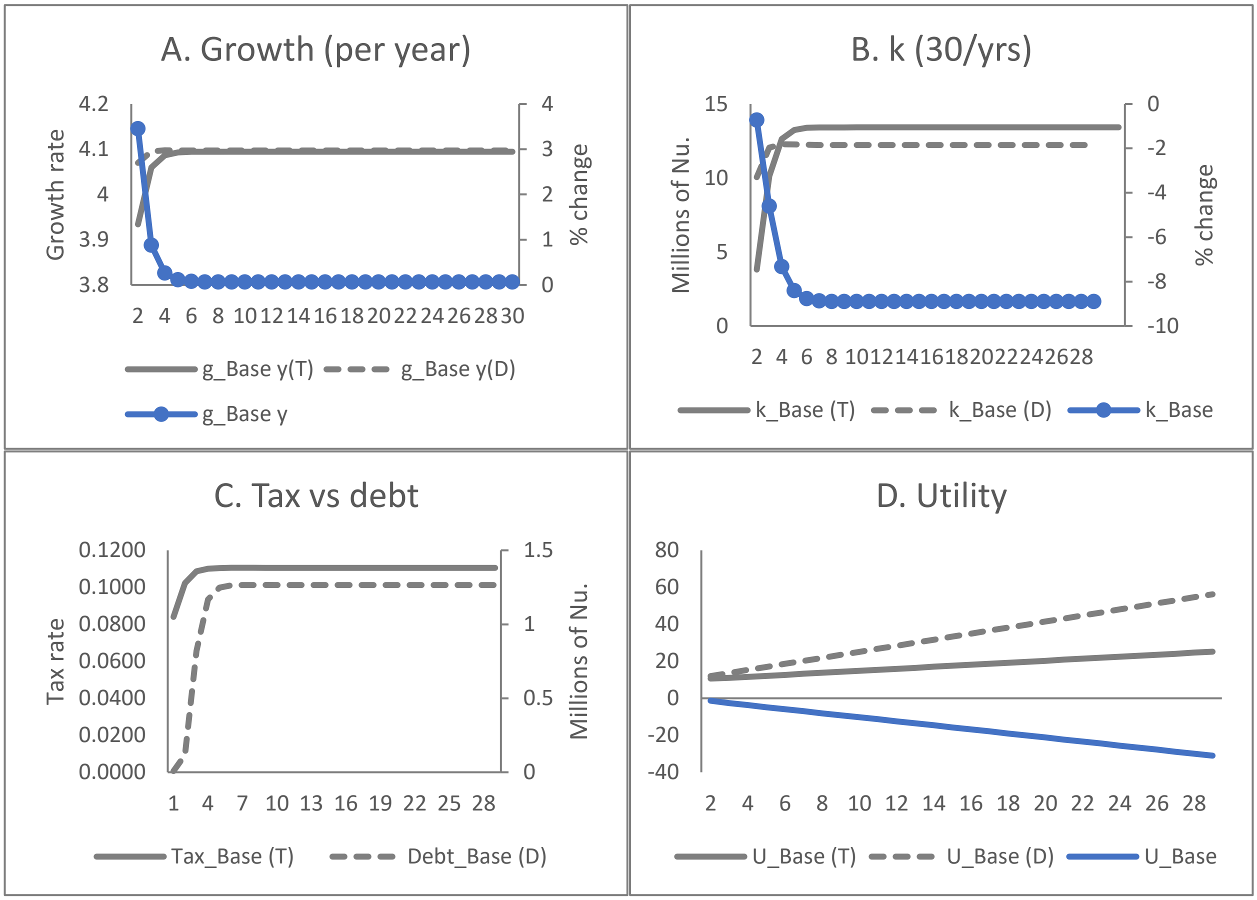

Figure 2.8: Base case for "per Child" - Tax vs debt

Chapter 3: Hydropower and welfare in Bhutan: short-run and long-run analysis in a two-period overlapping generations model

3.1. Introduction

In this chapter, we simulate the Bhutanese economy in a two-period Diamond-type overlapping generations (OLG) model incorporating electricity as an input in the production function and as a factor for improving individual living standards and labor productivity. Notably, we examine the effect of two different types of electricity pricing policies adopted by the government, namely fixing the price of electricity while issuing bonds to balance its budget (hereafter referred to as the debt endogenized case, or the debt endogenized policy) and keep the level of debt unchanged while balancing the budget using revenues from the sales of electricity (hereafter referred to as the price endogenized case, or the price endogenized policy).

Hydropower electricity is the most important lifeline for Bhutan's economy, as discussed in Chapter 1. Since Bhutan's technical and market capacity is beyond the private sector's capabilities, which is still in its infancy, hydropower has been a government undertaking. Specifically, with the objective to further strengthen the economy through the sustainable development of hydropower, Bhutan adopted the *Bhutan Sustainable Hydropower Development Policy* (Ministry of Economic Affairs, 2021), an updated version of the Sustainable Hydropower Development Policy of 2008. The two most crucial hydropower development policies that concern us in this dissertation are as follows: first, about 70 percent of all the hydropower project constructions are financed with debt (external debt), and second, upon production, the selling price of the electricity is fixed by the government through a state-owned enterprise.

Our main motivation for examining the above two policies, debt endogenized policy and price endogenized policy, is that the salient characteristics of these policies serve the government as a financing mechanism, in addition to tax revenues, to finance its developmental activities. Hydropower is a government undertaking, and the revenue from electricity sales plays a vital role in funding government activities. Similarly, the issuance of bonds is the main mechanism used by the government to finance its deficit spending to balance its budget. Thus, when the electricity price is endogenously determined in our price endogenized case, then it is not determined as a market clearing price but as a price for government to balance its budget in that period. Therefore, the electricity price determined under the price endogenized case will be above the marginal cost of producing the electricity, similar to the case under monopoly or monopolistic competition. For this reason, in our model, we incorporate the electricity production activity in the government budget constraint explicitly, rather than in different production activity by the private firm's behavior, as we generally assume a perfectly competitive market for the firms.

To integrate electricity into OLG model framework, we incorporate the following features and adopt the government budget constraint as discussed above. First, we adopt the mix CES-Cobb-Douglas production function as in Macias and Matilla-Garcia (2015). This kind of production function enables us to adopt electricity as a factor of production. Next, motivated by the findings of Akin et al. (2018), Han et al.(2020), and others, we incorporate electricity consumption as a labor income-enhancing factor for individuals. Such an assumption is different from integrating electricity as a factor of production, as mentioned above as the first feature. While electricity as a factor of production increases firms' productivity, our production function assumes electricity has a relationship with capital, whereby electricity is substituted with capital, and vice versa, depending on the elasticity of substitution. As for individuals, access to electricity generally enhances general productivity, enabling them to earn higher incomes, so it becomes an innate part of labor. For example, access to internet and longer time to study and learn (night time), to name a few. Both of these features in our model the first effort to incorporate into an OLG model as far as we are concerned.

The simulation of the modeled economy shows that the existing policy of debt endogenized case is preferable to the simulated case under price endogenized case. The capital accumulation is greater for the debt endogenized case during the transition and at the steady-state by 1.1 percent on average and 1.27 percent, respectively. Due to the higher electricity demand in the debt endogenized case, the government debt increases from Bhutanese Ngultrum (Nu.) 9.000 million per capita to Nu. 14.989 million per capita at the steady-state. As for the price of electricity, which is endogenized in the simulated case, the electricity price level increase from the current level Nu. 5.5 million per GW to Nu. 5.722 million per GW in average during the transition, and Nu. 5.784 million per GW at the steady-state. Similarly, the level of lifetime utility is higher for the debt endogenized case by 3.33 percent on average during the transition and 3.65 percent on average at the steady-state.

This chapter is presented in the following sequence. Section 3.2 gives the model. In section 3.3, we set the values for the parameters, followed by section 3.4, where we provide the results. Finally, we conclude the chapter by giving a summary in section 3.5.

3.2. The model

Our modeled economy consists of individuals, firms and government in a closed economy with a perfectly competitive market. Individuals live for two periods, young and old, and each period consists of 30 years (from 21 to 50 years and 51 to 80 years, respectively), and no bequest is considered. Firms uses electricity as a factor of production along with capital and labor. Finally, the government constructs hydropower projects and supplies the electricity in the market at a fixed price (different for individuals and firms). We adopt a constant population of n all throughout the periods. We describe the behavior of economic agents in the subsequent section.

3.2.1. Individual behavior

The individuals will maximize their lifetime utility function beginning from the age of 21 in period t subject to their inter-temporal budget constraint. The lifetime utility function for the individuals is assumed to be an additively separable CES form as follows;

$$U_t = \frac{c_{1,t}^{1-1/\sigma} - 1}{1 - 1/\sigma} + \gamma \frac{c_{2,t+1}^{1-1/\sigma} - 1}{1 - 1/\sigma}, \tag{1}$$

where $c_{1,t}$ and $c_{2,t+1}$ are the per capita goods consumption levels for the young and the old in period t and $t+1$, respectively. γ $(0 < \gamma < 1)$ and $\sigma \in R_+$ are the time preference and an intertemporal elasticity of substitution rate, respectively.

The lifetime consumption expenditure of the individuals of generation t in present value terms is given as;

$$E = c_{1,t}(1 + \tau_{c,t}) + pi_t\, e_t + \frac{c_{2,t+1}(1 + \tau_{c,t+1})}{1 + r_{t+1}}, \tag{2}$$

where r_{t+1} and $\tau_{c,t}$ $(0 < \tau_{c,t} < 1)$ is the interest rate and consumption tax rate on goods consumption in period t. We can see that individuals in our model also consume electricity, e_t, along with goods consumption at the price faced by the individuals, pi, fixed by the government.

The present value of the lifetime income of the individuals of generation t is given below;

$$W = (1 - \tau_w) w_t l_t \left(\eta\, e_t^{\rho}\right), \tag{3}$$

where $\tau_{w,t}(0 < \tau_{w,t} < 1)$ and l_t is the wage tax rate and the individuals' labor time supplied in period t, by the young. We assume that during the old, the individuals do not work. We incorporate $\eta\, e_t^{\rho}$ as the income-enhancing factor by consumption of electricity. Where η and ρ are the parameters for transforming electricity units consumed into labor efficiency and elasticity of electricity, respectively.

Next, we define the inter-temporal budget constraint of the individuals, which is as follows:

$$E_t \leq W_t. \tag{4}$$

Given the inter-temporal budget constraint, individuals will choose the optimal electricity consumption. The optimal electricity consumption, e_t can be obtained as follows:

$$e_t = \left(\frac{\eta\, \rho\, w_t \left(1 - \tau_{w,t}\right)}{pi_t}\right)^{\frac{1}{1-\rho}}. \tag{5}$$

Upon choosing the optimal electricity consumption, the individuals will simultaneously choose their consumption levels in the young and the old periods. We can obtain the individual level of consumption by maximizing the lifetime utility to obtain the following Euler equation:

$$c_{t+1} = \left(\frac{1 + \tau_{c,t}}{1 + \tau_{c,t+1}}\, \gamma\, r_{t+1}\right)^{\alpha} c_t, \tag{6}$$

Through the procedure, we obtain the levels of the asset in per capita terms at the end of each period as follows:

$$a_{1,t} = (1 - \tau_w) w_t l_t \left(\eta\, e_t^{\rho}\right) - c_{1,t}\left(1 + \tau_{c,t}\right) - pi_t e_t, \tag{7}$$

and

$$a_{2,t+1} = a_{1,t}\,(1 + r_{t+1}) - c_{2,t+1}\left(1 + \tau_{c,t+1}\right). \tag{8}$$

The optimal level of assets for young, $a_{1,t}$, and old, $a_{2,t+1}$, is obtained by substituting c into equation (7) and equation (8) above. Individuals being to accumulate asset when young and in the old period, in period t 1, they are endowed with that assets for consumption in period $t+1$. As there is no bequest in our model, the stock of asset at the end of period $t+1$ is 0.

3.2.2. Firm's behavior

We incorporate a mix CES-Cobb-Douglas production function proposed by Macias and Matilla-Garcia (2015), where labor and "capital services" are combined to form Cobb-Douglas production function, and the "capital services" combining capital and electricity forms a CES production function. In this model the representative firm, at the end of each period, uses aggregate capital, K_t, labor L_t, and electricity $\hat{E}_t$, to produce goods Y_t. The production function is given as follows:

$$Y_t = A[(\alpha K_t^{-\beta} + (1-\alpha)\hat{E}_t^{-\beta})^{-1/\beta}]^{\alpha} L_t^{1-\alpha},$$

which can be rewritten in per capita term as (capital, $k_t = \frac{K_t}{L_t}$, electricity, $\hat{e}_t = \frac{\hat{E}_t}{L_t}$, and output $y_t = \frac{Y_t}{L_t}$);

$$y_t = A[(\alpha k_t^{-\beta} + (1-\alpha)\hat{e}_t^{-\beta})^{-\frac{1}{\beta}}]^{\alpha}, \tag{9}$$

where $A > 0$ and $\beta \in (-1, \infty)$ are exogenously given technology parameter and the capital-energy substitutability parameter, respectively. α and $(1-\alpha)$ is the output elasticity of capital and labor, respectively.

Given the above production function the firms maximize their profit so that the following conditions can be obtained:

$$\delta + r_t = \frac{A\hat{e}_t^{\beta}\alpha^2[(\hat{e}_t^{-\beta}(1-\alpha) + k_t^{-\beta}\alpha)^{-\frac{1}{\beta}}]^{\alpha}}{k_t(\alpha\,\hat{e}_t^{\beta} + (1-\alpha)\,k_t^{-\beta})}, \tag{10}$$

$$w_t = A(1-\alpha)[((1-\alpha)\hat{e}_t^{-\beta} + \alpha k_t^{-\beta})^{-\frac{1}{\beta}}]^{\alpha} \tag{11}$$

and

$$p_t = \frac{Ak_t^{\beta}\alpha\,(\alpha-1)[(\hat{e}_t^{-\beta}(1-\alpha) + k_t^{-\beta}\alpha)^{-\frac{1}{\beta}}]^{\alpha}}{\hat{e}_t(k_t^{\beta}(\alpha-1) - \hat{e}_t^{\beta}\alpha)}. \tag{12}$$

The r_t and w_t are the rate of returns for capital and labor, respectively, that are determined in the market. p_t is the price charged by the government on electricity, $\hat{e}_t$, supplied to the firms. Since the price of electricity is set by the government, the firm is required to equalize their marginal productivity of the electricity consumption to its marginal cost. δ is the capital depreciation rate.

3.2.3. Government behavior

In period, t, the government produce electricity by hydropower with a constant marginal cost, ν, depending on the endogenously determined demand of electricity from firms, $\hat{e}_t$, and household, e_t, along with the spending on debt repayment, d_t, and providing other public goods, o_t (we assume that they depend on the level of capital, that is, $o_t = \phi\ k_t$). These activities are financed by revenue collected from supply of electricity at the price, p_t for the firms and pi_t for individuals. The government also levies taxes on income and consumption, and balances its budget through issuance of bonds:

$$\sum_{j=1}^{2} \frac{w_{j,t}\tau_w}{(1+n)^{j-1}} + \sum_{j=1}^{2} \frac{c_{j,t}\tau_c}{(1+n)^{j-1}} + d_{t+1}(1+n) + pi_t \sum_{j=1}^{2} \frac{e_{j,t}}{(1+n)^{j-1}} + p_t \sum_{j=1}^{2} \frac{\hat{e}_t}{(1+n)^{j-1}} = \nu \left(\sum_{j=1}^{2} \frac{e_{j,t}}{(1+n)^{j-1}} + \sum_{j=1}^{2} \frac{\hat{e}_t}{(1+n)^{j-1}} \right) + \sum_{j=1}^{2} \frac{o_t}{(1+n)^{j-1}} + (1+r_t)d_t. \quad (13)$$

The government in our model, balances its budget depending on their policies. Firstly, we calibrate a base case where the debt is endogenized, the price of electricity is fixed. We then simulate for the price endogenized case where the debt level is kept constant.

3.2.4. Intertemporal equilibrium

The capital market in our economy is at equilibrium when the accumulated assets over time adequately meet the capital demanded by the firms and the bonds raised by the government from the market. The capital market equilibrium in per capita terms is given as follows;

$$k_{t+1}(1+n) + d_{t+1}(1+n) = a_{1,t}. \quad (14)$$

Using equations (12), (13) and (14), and the parameters given in the next section, we obtain the values for endogenous variables k_{t+1} , $\hat{e}_t$ and d_{t+1} or p_t during the transition and at the steady-state.

3.3. Parameters

We calibrate the model to reflect the realistic economic circumstances of Bhutan using the available parameters and initial values as given in Table 3.1.A and B as a base case. When determining the parameters and initial values, we consider the following sources: The data from a quarterly macroeconomic update by the Macroeconomic Framework Coordinating Committee (MFCC) and the existing macroeconomic simulation literature.

We first try to obtain and compute as many parameters and values for Bhutan as possible to make the study pragmatic and relevant. The effective tax rates – consumption tax rate, τ_c, and wage tax rate, τ_w – we obtain it from Sales Tax Division (2020) and MFCC (2020). The population growth rate is obtained from National Statistical Bureau (2018). The expenditure to GDP ratio (ϕ) is for the fiscal year 2018/19, right before the COVID-19 pandemic, obtained from MFCC and multiplied with capital at that period to get the value for other expenditures for the government in the model. We do this because we assume that government expenditure is a function of total investment in the economy, that is the capital accumulation. In addition to the parameters, we also obtain the initial values for our model. We obtain the initial debt values from MFCC and convert them to 30 years per capita. Further, from the MFCC data, we also calculate the marginal cost of supplying electricity (ν), and the selling price of electricity for individuals (pi) and firms (p). It is worth noting that we assumed a closed economy model. However, the actual circumstances of Bhutan is that more than 80 percent of its electricity production are exported to India. To make the model more realistic, we incorporate the export price of electricity (including royalty) as the firm's price.

Next, we obtain the remainder of the parameters from the literature on similar studies. We set the initial levels for capital stock (k_1) and technology parameter (A) from Penn World Table (Feenstra et al., 2015; Zeileis, 2019). The parameter for the discount factor (γ) and intertemporal elasticity of substitution rate (σ) is from Bouzahzah et al. (2002). Lastly, the long–run capital–

energy substitutability (β) parameter used in the CES production function is from Kander and Stern (2014).

Table 3.1.A: List of parameter values

Parameters		Values	Source
γ	Discount factor	0.84	Bouzahzah, et al. (2002)
σ	Intertemporal elasticity of substitution rate	1.5	Bouzahzah, et al. (2002)
τ_c	Consumption tax rate	0.05	Sales Tax Division (2020)
τ_w	Income tax rate	0.07	MFCC (2020)
η	Electricity to hours ratio	0.4	Calibrated in the model
ρ	Output elasticity of electricity	0.5	Calibrated in the model
A	Technology parameter	93	Feenstra et al (2015), Zeileis (2019)
α	Output elasticity of capital	0.4	Calibrated in the model
β	Long–run capital–energy substitutability	0.41	Kander and Stern (2014)
n	Population growth rate	0.013	NSB (2018)
ϕ	Expenditure to GDP ratio	0.250	MFCC (2020)
δ	Depreciation	0.05	MFCC (2020)

Table 3.1.B: List of exogenous and initial values

Variables		**Unit**	**Values**	**Source**
d_1	Initial debt stock	Millions of Nu. per capita per 30 years	9.000	MFCC (2020)
k_1	Initial capital stock	Millions of Nu. per capita per 30 years	21.000	Feenstra et al (2015), Zeileis (2019)
ν	Cost of electricity supply	Millions of Nu. per GW	2.000	MFCC (2020)
pi	Household electricity price	Millions of Nu. per GW	1.568	MFCC (2020)
p	Firm electricity price	Millions of Nu. per GW	5.532	MFCC (2020)

Using the parameters and exogenously given values, we calibrate the model to obtain values for three other parameters. The output elasticity of electricity (ρ), electricity to labor-hours ratio (η) and output elasticity of capital (α) have been calibrated so that the model reflects the current economic circumstances for Bhutan.

3.4. Simulation results

We calibrate the model and then simulate the economy with an alternative electricity pricing policy. As a base case, we endogenize the debt and then simulate the case where we endogenize the electricity price. It is important to note that we only endogenize the price of electricity for firms and not individuals.

3.4.1. Effect of change in policies on the economy: transition and steady-state

The transition and steady-state values of the simulation are presented in Figure 3.1.

Under the debt endogenized case, we find that the debt increases from the initial level of Nu. 9.000 million per capita to Nu. 14.989 million per capita at the steady state. Despite the increase in debt by 66 percent, we see that capital per capita also increased by 17 percent from an initial value of Nu. 21.000 million to Nu. 24.641 million per capita at the steady state, peaking in the third period. The demand for electricity obtained in the first period at the exogenously given price is 12.055 GW, after which the demand for electricity during the transition and steady state declines slightly by 0.12 percent. This is because the increase in capital accumulation in the second period substitutes for electricity usage resulting in the decline of electricity demand from the second period onwards. Nevertheless, the increase in debt due to increased government expenditure crowds out the market, slowing down the rate of capital accumulation from the third period onwards. The economy attains a steady-state in the 14th period, as shown in Figure 3.1.

Next, we simulate the price endogenized case. We find that the price increases from Nu. 5.008 million per GW in the first period to Nu. 5.784 million per GW at the steady-state, peaking at Nu. 5.822 million per GW in the second period. The increase in the electricity price results in a fall in demand for electricity from 12.022 GW in the first period to 9.427 GW at the steady-state, a decline of about 22 percent. Despite the increase in the price of electricity and the decrease in demand, capital accumulation increased from the initial value of Nu. 21.000 million per capita to Nu. 24.327

million per capita at the steady-state, an increase of 16 percent, peaking in the second period. This is because we use a CES production function. Thus, a decline in electricity demand would increase the capital accumulation to the tune of the long–run capital–energy substitutability (β) parameter.

Figure 3.1: Debt vs price endogenized case

Comparing the two cases, overall, we can see that capital accumulation is higher for the debt endogenized case. However, in the second period, the capital accumulation is higher for the price endogenized case by 0.37 percent, after which the debt endogenized case is higher by 1.37 percent during the transition and 1.27 percent at the steady-state. There are two reasons behind such an outcome. First, under the debt endogenized case, increases in debt from the initial level crowd out the capital in the market, suppressing capital accumulation. Second, under the price endogenized case, the drastic decline in the demand of electricity due to a price increase results in increase in capital accumulation, as explained previously. The combined effect in these two cases results in higher capital accumulation for price endogenized case in the second period. However, from the third period onwards, the crowding-out effect of debt diminishes, resulting in higher capital accumulation under the debt endogenized case compared with the price endogenized case. Regarding the electricity demand, although the electricity demand declines under both cases, the decline is much more severe for the price endogenized case. In both cases, the decline in electricity demand can be attributed to the increase in debt or price.

3.4.2. Effect of change in policies on the welfare: transition and steady-state

We also look at the welfare effect of the change in hydropower policy for the cases we considered. We obtain the value of the lifetime utility, the individual utility for young and old generations during the transition and at the steady-state.

In the debt endogenized case, the present value of lifetime utility increases from 26.75 in the

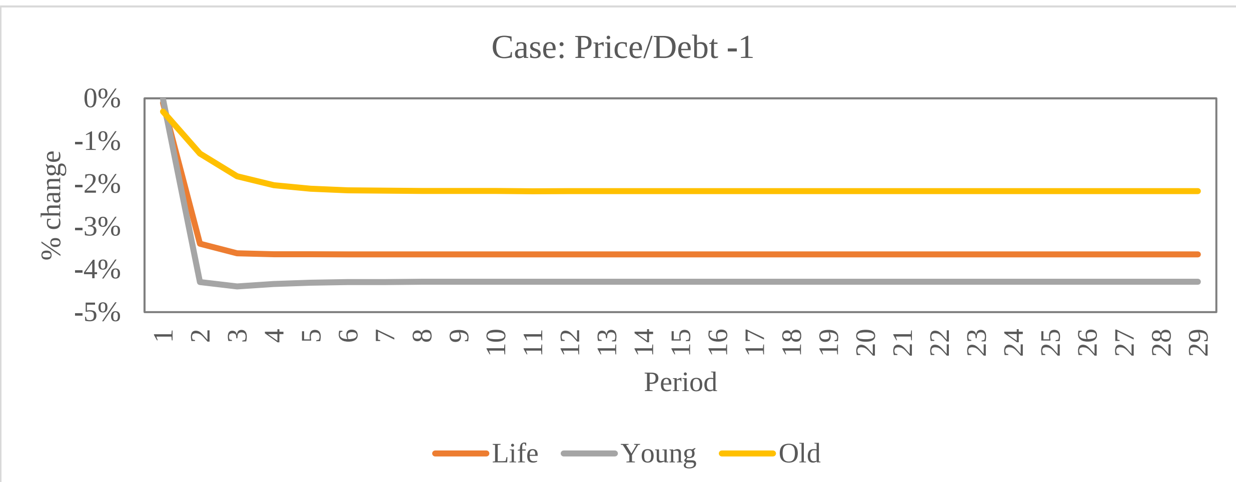

Figure 3.2: Welfare: Debt vs price case

first period to 27.35 at the steady-state, an increase of 2.26 percent. The lifetime utility comprises of utility during the young and old. During the young, the lifetime utility increases from 18.64 in the first period to 19.08 at the steady-state, an increase of 2.37 percent. At the same time, the present value for the lifetime utility of the old generation increases from 8.10 in the first period to 8.27 at the steady-state, an increase by 2.01 percent.

The opposite is true for the price endogenized case. The present value of lifetime utility decreases from 26.72 in the first period to 26.35 at the steady-state, a decline by 1.36 percent. This decline mainly comes from the utility level of the young. The utility level of the young age declined from an initial level of 18.64 in the first period to 18.27 at the steady-state, a decline by 2.00 percent. Nevertheless, the old still enjoys the increase in utility. The utility for the old increase from 8.08 in the first period to 8.09 at the steady-state, an increase by 0.11 percent.

Comparing the utility, we can see the differences between the two cases in Figure 3.2. The debt endogenized case has a higher level of lifetime utility when compared with the price endogenized case, and the same is true for individual utility for young and old. The main reason for higher level of utility under the debt endogenized case is because of following three reasons. First, under the price endogenized case, the decline in electricity demand reduces the utility during the young. Second, capital accumulation is higher for the debt endogenized case, resulting in a higher utility level of young. Finally, due to the increase in debt, the old under the debt endogenized case has higher utility level as a result of increased interest rates.

3.5. Conclusion

This chapter simulates Bhutan's macroeconomy in a two-period OLG model incorporating electricity in the behavior of individuals, firms and government. We firstly calibrate the base case, that is, the debt endogenized case, the current policy adopted by the government where the electricity price is fixed. We then simulate a case where we endogenized the price, and the debt is kept at the same level. We obtain the transition and steady-state for both cases.

Comparing the base case with the simulated case shows that the debt endogenized case is better than the price endogenized case. That is because of the following three reasons. First, the capital accumulation is higher for the debt endogenized case by 1.10 percent on average during the transition and 1.27 percent at the steady state, although the difference is negligible. Second, electricity demand is higher for the debt endogenized case by 19.99 percent on average during the transition and 21.70 percent on average at the steady state. Finally, the level of lifetime utility is also greater debt endogenized case by 3.33 percent on average during the transition and 3.65 percent on average at the steady-state. The utility during the young appears to be greater than the old's. Concerning the policy variables, debt and price, we see both increases in our modeled economy. Under the debt endogenized case, the government debt increases from an initial level of Nu. 9.000 million per capita to Nu. 14.989 million per capita at the steady-state. As for the price of electricity, it increases from the current level from Nu. 5.008 million per GW in the first period to Nu. 5.784 million per GW at the steady state, peaking at Nu. 5.822 million per GW in the second period. We also see that the value of lifetime utility is higher for the debt endogenized case than the price endogenized case.

The numerical analyses show that the existing electricity policy is preferable. That is mainly because the debt or the electricity price, when endogenized, reflects the government's financing needs, including expenditure over and above marginal cost of hydropower construction. As a result, the electricity price increases under the price endogenized case leading to lower electricity demand and capital accumulation. It should be also noted that the current electricity price level is much higher than the marginal cost of supplying the electricity, which further reinforces the fact that the electricity price obtained in our model is the price for balancing the government budget. Although such cases look hypothetical, hydropower revenue serves as revenue for the government in Bhutan, making the case in our model pragmatic. Based on the result of numerical analysis, it is important to consider that hydropower revenue should not be viewed as a tool to balance the government budget.

This chapter can serve as an additional tool for the practitioners while making decisions on drafting the detailed project report (DPR) and negotiating loans for new hydropower projects, and negotiating electricity prices for the existing hydropower stations in operation. While the result gives insight into the hydropower policy for Bhutan, we also acknowledge that it does not adequately capture the lifecycle of individuals. In this regard, in the next chapter, we construct a six-period OLG model incorporating the salient features from this chapter.

Chapter 4: Electricity pricing and generational utility: a macroeconomic simulation for Bhutan using a six-period overlapping generations model

4.1. Introduction

In this chapter, we conduct a macroeconomic simulation of Bhutan's economy using a dynamic general equilibrium framework, a six-period overlapping generations (OLG) model, to examine the effects of two different types of electricity pricing policies on long-run economic growth and individuals' lifetime utility. As in Chapter 3, our base case is the debt endogenized case, and the simulated case is the price endogenized case.

For investigating a sustainable electricity pricing policy to encourage a sound fiscal position and achieve sustainable economic growth, we simulate the effect of hydropower plants on Bhutan's economy by adopting the framework in Shindo (2010). Shindo (2010) conducts a simulation of two regions in China focusing on education and foreign direct investment (FDI), which we also consider helpful for our study because it considers the actual individual lifecycles. The approach used in this chapter differs from that of Shindo (2010) in two main aspects. First, we introduce electricity into the model: we incorporate electricity into the economic activities of individuals, firms and a government. Next, we adopt the production function in Macias and Matilla-Garcia (2015), where labor and capital services are combined in a Cobb–Douglas production function. Capital services combine capital and electricity to form a constant elasticity of substitution (CES) production function.

While the study in this chapter seems similar to one covered in Chapter 3, which investigated the effect of the same energy pricing policy, there are a few differences between the two. First, we use a six-period OLG model in this study to further look into the effect of the change in electricity policies for individuals in an extended life cycle. Next, motivated by Khandker et al.'s (2012) study in India, we incorporate electricity into an individual's behavior as a labor-time saving factor. The electricity consumption enhances their income by reducing the time spent on non-income generating work, which is essential for survival, such as collecting firewood and timbers.

This assumption is made given that Bhutan is a low-income country, which is a reasonable assumption for all low-income countries.

We evaluate the economy at the steady state and obtain the following results.[7] First, in the debt endogenized case, base case, the capital per capita at the steady-state amounts to Nu. 628.653 million, and the income per capita amounts to Nu. 1,860.771 million. Second, in the price endogenized case, the capital per capita increases to Nu. 914.573 million, an increase of 45.48 percent and the income per capita increases to Nu. 2,082.261 million. Third, in the price endogenized case, the electricity price decreases from an initial level of Nu. 5.5 million to Nu. 4.540 million per GW. Fourth, the electricity demand under the debt endogenized case and the price endogenized case are 13.827 and 37.715 GW per capita, respectively. The higher level of electricity demanded in the price endogenized case is due to the lower price. Finally, the change in policy increases lifetime utility, in our measure, from 125 in the debt endogenized case to 131 under the price endogenized case.

The chapter is organized as follows. Section 4.2 presents the model, and Section 4.3 provides the model calibration and values for the parameters. Section 4.4 discusses the simulation results, and Section 4.5 details the conclusion.

4.2. The model

We consider a closed economy with a perfectly competitive market. The individuals in the model live for six periods, each constituting ten years (i.e., from 18 years to 78 years), and are homogeneous within generations. In every period, six groups of individuals differentiated by their ages, which we call age groups, overlap. The model considers no bequests, and individuals consume from their savings during the sixth period. The population is assumed to grow at a constant growth rate of n in period t; thus, the size of generation t increases over time by $L_t = n_t L_{t-1}$. The model also incorporates firms and the public sector. The behaviors of the economic agents are described below.

[7] The definitions of two cases, the debt endogenized case and the price endogenized case, are given in Chapter 3.

4.2.1. Individual behavior

Individuals maximize their intertemporal utility function in period t, derived through consumption expenditure during their lifetime, starting from the first period of their lives. We assume the lifetime utility function to be an additively separable CES form:

$$U = \sum_{j=1}^{6} \gamma^{j-1} \frac{1}{1-1/\sigma} (c_{j,t+j-1}^{1-1/\sigma} - 1), \tag{1}$$

where $c_{j,t+j-1}$ is the per capita consumption level of age group j in period t. γ $(0 < \gamma < 1)$ and $\sigma \in \mathbb{R}_+$ are the time preference and intertemporal elasticity of the substitution rate, respectively.

The present value of the lifetime consumption expenditure of individuals is given as follows:

$$E = \sum_{j=1}^{6} \left(c_{j,t+j-1}\left(1 + \tau_{c,t+j-1}\right) + pi_{t+j-1}\, e_{j,t+j-1} \right) R_t^{t+j}, \tag{2}$$

where r_{t+1} and $\tau_{c,t}$ $(0 < \tau_{c,t} < 1)$ are the interest rate and consumption tax rate in period t, respectively. Based on r_{t+1}, $R_t^{t+j} = \prod_{s=t+1}^{t+j} \frac{1}{1+r_s}$ represents the discount factor applied to the values in period $t + j$, evaluated in period t. In our model, we assume that individuals consume electricity along with other consumption, where pi is the electricity price that individuals pay and e_t is the unit of electricity consumed by individuals.

Individuals meet their lifetime expenditure through the lifetime income as:

$$W = \sum_{j=1}^{6} \left((1 - \tau_{w,t}) w_{t+j-1} l_{j,t+j-1} + T_{j,t+j-1} \right) R_t^{t+j}, \tag{3}$$

where $\tau_{w,t}(0 < \tau_{w,t} < 1)$ is the wage tax rate in period t, $l_j$is the individual labor time supplied in period t by age group j and $T_{j,t}$ are the exogenously given public transfers in period t for age group j.

The individual labor time supply is given as follows:

$$\begin{aligned} &(l_t^1, l_{t+1}^2, l_{t+2}^3, l_{t+3}^4, l_{t+4}^5, l_{t+5}^6) \\ &= (1 - (\epsilon - \eta\, e_{1,t}^{\rho}), 1 - (\epsilon - \eta\, e_{2,t+1}^{\rho}), 1 - (\epsilon - \eta\, e_{3,t+2}^{\rho}), 1 \\ &- (\epsilon - \eta\, e_{4,t+3}^{\rho}), 1 - (\epsilon - \eta\, e_{5,t+4}^{\rho}) - \zeta_{t+4}, 0), \end{aligned} \tag{4}$$

where $0 \leq (\epsilon - \eta\, e_{j,t+j-1}^{\rho}) \leq 1$. In the fifth age group, the individuals supply only $1 - (0 < \zeta < 1)$ per time unit of labor, where ζ can be defined as the retirement ratio. We assume that electricity will enable individuals to spend more time in income-generating work. ϵ is a constant time spent on non-income generating household work that is essential for survival. η and ρ are the parameters for transforming electricity units consumed into labor efficiency and the elasticity of electricity, respectively.

The government provides a public pension for the fifth and sixth age groups:

$$(T_{1,t}, T_{2,t+1}, T_{3,t+2}, T_{4,t+3}, T_{5,t+4}, T_{6,t+5}) = (0,0,0,0, \zeta_{t+4} m_{t+4}, m_{t+5}), \tag{5}$$

where m is the pension received during old age.

The intertemporal budget constraint of the household can be summarized as:

$$E_t \leq W_t. \tag{6}$$

The individuals whose first period of life in this model is period *t* maximizes the lifetime utility given in equation (1), subject to the intertemporal budget constraint in equation (4), by choosing both consumptions of goods and electricity.

The optimal electricity consumption, $e_{j,t+j-1_t}$ can be obtained as:

$$e_{j,t+j-1} = \frac{\eta\, \rho\, (1-\tau_{w,t}) w_{t+j-1}}{pi_{t+j-1}}. \tag{7}$$

Next, for each age group, we determine the individual level of consumption by maximizing lifetime utility. The following five Euler equations hold:

$$c_{j,t+j-1} = \left(\frac{1+\tau_{c,t+j-2}}{1+\tau_{c,t+j-1}}\, \gamma R_{t+j-2}^{t+j-1}\right)^{\alpha} c_{j-1,t+j-2}, \forall\, j = 2,3,4,5,6. \tag{8}$$

Thus, we obtain the level of assets in per capita terms at the end of each period:

$$\begin{aligned} a_{j,t+j-1} = a_{j-1,t+j-2} R_{t+j-2}^{t+j-1} + \left(1-\tau_{w,t}\right) w_{t+j-1} l_{j,t+j-1} + T_{j,t+j-1} \\ - \left(c_{j,t+j-1}\left(1+\tau_{c,t+j-1}\right) + pi_{t+j-1} e_{j,t+j-1}\right), \end{aligned} \tag{9}$$

where $a_{j,t+j-1}$ denotes individuals' asset at the end of age j, and the optimal asset level is obtained by substituting *c* into equation (9) above. Our economy starts at t = 1, where one born in period 1 will live for six periods, and each of the older generations will accumulate and be endowed with a level of assets from periods two to five. Upon reaching the sixth period, they are endowed with assets for consumption. The stock in the sixth period is zero because we do not consider bequests in our model.

4.2.2. Firm behavior

We incorporate the production function proposed by Macias and Matilla-Garcia (2015) in our model, where a Cobb–Douglas production function is the combination of labor and capital services. Capital services are produced by a CES production function combining capital and electricity. The CES–Cobb–Douglas form production technology is given as follows:

$$Y_t = A[(\alpha K_t^{-\beta} + (1-\alpha)\hat{E}_t^{-\beta})^{-1/\beta}]^{\alpha} L_t^{1-\alpha}, \qquad (10)$$

where Y_t, K_t, $\hat{E}$, and L_t, are aggregate output, capital, labor, and hydropower electricity delivered to the firms in period *t*, respectively. $A\ (> 0)$ is an exogenously given technology parameter, while α is the output elasticity of capital ($[1-\alpha]$ is the output elasticity of labor). β is the long-run capital–energy substitutability parameter where $\beta \in (-1, \infty)$.

The aggregate labor supply in period t is given as $L_t = \sum_{j=1}^{5} l_{j,t}$, capital stock per capita is $k_t = \frac{K_t}{L_t}$ and per capita electricity consumption by firms is $\hat{e} = \frac{\hat{E}_t}{L_t}$. The firms maximize profit given the following conditions:

$$\delta + r_t = \frac{A\hat{e}_t^{\beta}\alpha^2[(-\hat{e}_t^{-\beta}(\alpha-1) + k_t^{-\beta}\alpha)^{-\frac{1}{\beta}}]^{\alpha}}{k_t(-k_t^{-\beta}(\alpha-1) + \hat{e}_t^{\beta}\alpha)}, \qquad (11)$$

$$w_t = -A(1+\alpha)[(-\hat{e}_t^{-\beta}(\alpha-1) + k_t^{-\beta}\alpha)^{-\frac{1}{\beta}}]^{\alpha}, \qquad (12)$$

and

$$p_t = \frac{Ak_t^{\beta}\alpha\,(\alpha-1)[(-\hat{e}_t^{-\beta}(\alpha-1) + k_t^{-\beta}\alpha)^{-\frac{1}{\beta}}]^{\alpha}}{\hat{e}_t(k_t^{\beta}(\alpha-1) - \hat{e}_t^{\beta}\alpha)}, \qquad (13)$$

where $\delta\ (0 < \delta < 1)$ is the depreciation rate, w_t is the rate of return for labor determined by the market. In our model, p_t is set by the government as the electricity price used by firms, such that firms match the marginal productivity of their electricity consumption, $\hat{e}_t$, to its marginal cost.

4.2.3. Government behavior

In our model, the government operates under a balanced budget. The government levies taxes on income and consumption and receives revenue from the hydroelectricity supplied to finance its spending, as given in the left-hand side of the equation (14). With these revenues, the government funds the expenditure as represented in the right-hand side of the equation (14). The government expenditures are the cost of electricity production with the marginal cost, ν, other public consumption, o_t, pensions, and the repayment of the debt, d_t. The per capita government budget constraint in period *t* is:

$$\sum_{j=1}^{6}\frac{w_{j,t}\tau_w}{(1+n)^{j-1}}+\sum_{j=1}^{6}\frac{c_{j,t}\tau_c}{(1+n)^{j-1}}+\sum_{j=1}^{5}\frac{d_{t+1}}{(1+n)^{-j}}+pi_t\sum_{j=1}^{6}\frac{e_{j,t}}{(1+n)^{j-1}}$$
$$+p_t\sum_{j=1}^{5}\frac{(1-l_t^j)}{(1+n)^{j-1}}\bar{e}_t$$
$$=\nu\left(\sum_{j=1}^{6}\frac{e_{j,t}}{(1+n)^{j-1}}+\sum_{j=1}^{5}\frac{(1-l_t^j)}{(1+n)^{j-1}}\bar{e}_t\right)+\sum_{j=1}^{6}\frac{o_t}{(1+n)^{j-1}} \tag{14}$$
$$+\sum_{j=5}^{6}\frac{m_t}{(1+n)^{j}}+\sum_{j=1}^{5}\frac{\left(1+r_{t+j-1}\right)d_t}{(1+n)^{1-j}}.$$

Depending on the level of policy parameters determined by the government, the levels of debt (debt endogenized case) or price (price endogenized case) can be adjusted.

4.2.4. Intertemporal equilibrium

Our economy evolves with the accumulation of capital stock over time. Given the exogenous variables and parameters in Tables 4.1 and 4.2, we evaluate the pricing policy's effect on capital stock accumulation in the long run. The capital market equilibrium equation is given as follows:

$$\sum_{j=1}^{5}\frac{k_{t+1}(1+n)}{(1+n)^{-j}}=\sum_{j=1}^{6}\frac{\hat{a}_{j,t}}{(1+n)^{j-1}}-\sum_{j=1}^{5}\frac{d_{j,t+1}}{(1+n)^{-j}}. \tag{15}$$

Using equations (13), (14) and (15), we calibrate and simulate to obtain the values for d or p, k and $\bar{e}$ at the steady states.

4.3. Model calibration

We set the parameters to depict the current macroeconomic circumstances in Bhutan. We set ten years as one period; therefore, we obtain the most recent data for the past ten years as the initial values. When determining the parameters and initial values, we consider the following sources: the data from a quarterly macroeconomic update by the Macroeconomic Framework Coordinating Committee (MFCC) and the existing macroeconomic simulation literature.

Table 4.1**:** Parameters values

Parameters		**Values**	**Source**
γ	Discount factor	0.84	Bouzahzah et al. (2002)
σ	Intertemporal elasticity of substitution rate	1.5	Bouzahzah et al. (2002)
τ_c	Consumption tax rate	0.05	MFCC (2020)
τ_w	Income tax rate	0.07	Sales Tax Division (2020)
ϵ	Time spent on non-income generating work essential for survival	0.33	Statistics Bureau of Japan (2016)
η	Electricity to hours ratio	0.786	Calibrated in the model
ρ	Output elasticity of electricity	0.17	Khandker, et al. (2012)
A	Technology parameter	269.258	Feenstra, et al. (2015); Zeileis (2019)
α	Output elasticity of capital	0.30	Bouzahzah et al. (2002)
β	Substitution parameter (Long-run capital–energy substitutability)	0.41	Kander and Stern (2014)
ζ	Retirement ratio	0.5	Assumption
n	Population growth rate	0.013	National Statistics Bureau (2018).

Using the MFCC data, we calculate the values for the level of public debt per capita, d_1, cost of electricity supply, ν, electricity price paid by households, pi, electricity price paid by firms, p, pension, m, and effective income tax rate, τ_w (MFCC, 2022). The value for other government consumption, o_t, is from the government expenditure to GDP ratio, ϕ, and capital per capita. The effective consumption tax rate, τ_c, is from the performance indicator report (Sales Tax Division, 2020) and the population growth rate from the population and housing census report (National Statistics Bureau of Bhutan, 2018).

Because some parameter values for Bhutan or comparable economies are not readily available, we also use values widely available in the existing macroeconomic simulation literature. We borrow the values for the time preference rate, γ, intertemporal elasticity of substitution rate, σ, and output elasticity of capital, α, from Bouzahzah et al. (2002). Similarly, we use the elasticity of substitution between aggregate capital-labor and aggregate energy obtained by Kander and Stern (2014) to determine the long-run capital–energy substitutability parameter, β. The output elasticity of electricity, ρ, is from Khandker et al. (2012). The technology parameter, A, is calculated from the Penn World Table (Feenstra et al., 2015; Zeileis, 2019). Finally, the parameter for the time spent on non-income generating work essential for survival, ϵ, is from the 2016 Survey on Time Use and Leisure Activities published by the Statistics Bureau of Japan (2016). Although the lifestyle and time-use may differ between Japanese and Bhutanese, given the general allocation of hours of the day for an individual, being 8 hours each of sleep, work, and leisure, we assume that they are also applicable to Bhutan.

Table 4.2: Exogenous variables and initial values

Variables		**Unit**	**Values**	**Source**
d_1	Initial debt stock	Millions of Nu. per capita	0.345	MFCC (2020)
ϕ	Government expenditure to GDP ratio	Ratio	0.250	MFCC (2020)
ν	Cost of electricity supply	Millions of Nu. per GW	2.000	MFCC (2020)
pi	Household electricity price	Millions of Nu. per GW	1.568	MFCC (2020)
p	Firm electricity price	Millions of Nu. per GW	5.532	MFCC (2020)
m	Pension payment	Millions of Nu. per capita	0.047	MFCC (2020)

Incorporating the retirement ratio, ζ, in the fifth period of the model is an important element in the model simulation. However, the value assigned to the parameter does not significantly affect the model's outcome. Therefore, as a simplification, we assume the retirement ratio in the fifth period to be half. Out of ten years, an individual will work for five years. Upon setting all the parameters and variables, we calibrate the value for electricity to hours ratio, η.

4.4. Simulation results

We simulate and evaluate the Bhutanese economy at the steady state in two cases. Because the current government policy is such that the government sets the electricity price for individuals and firms, we consider the debt endogenized case as the base case. Next, we simulate the alternative case as the price endogenized case. We then compare the economic growth rate obtained in the simulation at the steady state with the base case. We assume that all the policy changes are initiated in the first period and are then permanent. Finally, we evaluate the effect of the policy changes on individuals' lifetime utility.

In the base case, the government resorts to issuing bonds to finance its deficit because the government fixes the electricity price and use it to fund the electricity supply and other public goods. More concretely, we endogenize public debt to keep the electricity price levied on firms by the government at the current rate. The results are summarized in Table 4.3. We observe that capital per capita at the steady state is about Nu. 628.653 million, and per capita income is about Nu. 1,860.771 million. Public debt reaches Nu. 913.632 million per capita at the steady state because the government issues bonds in the next period to finance the budget deficit. At the exogenously given electricity price, the electricity demanded by the firms is 13.827 GW.

Next, we simulate the price endogenized case and compare the results with the base case. We simulate the electricity price rather than the tax rates, which is widely simulated as the alternative fiscal policy, because hydropower revenue plays an important role in financing the development in addition to the taxes. Upon stimulation, we obtain that capital per capita amounts to Nu. 914.573 million, and per capita income is about Nu. 2,082.261 million. The electricity price decreases from the current rate of Nu. 5.5 million per GW to Nu. 4.540 million per GW. At this price, the electricity demanded by the firm amounts to 37.715 GW.

Overall, we observe that with the price endogenized case determining the electricity price, capital per capita increases by 45.48 percent, income per capita rises by 11.903 percent and electricity demand by firms increases by more than 100 percent. As government balances its budget through the public debt under the debt endogenized case, the level of debt increases at the steady state. The increase in debt crowds out capital for firms in the capital market, resulting in a lower capital level at the steady state under the base case. However, under the price endogenized case, public debt is kept constant, resulting in more capital in the market for the firms. Thus, we observe an increase in the level of capital at the steady state. Further, under the price endogenized case, the electricity price for firms falls, which leads to an increase in the demand for electricity by firms.

Table 4.3: Summary of results

Particulars	**Unit**	**Base case**	**Simulation**
		Debt endogenized	**Price endogenized**
Capital per capita [k]	Millions of Nu.	628.653	914.573
Income per capita [y]	Millions of Nu.	1,860.77	2,082.26
Firm electricity demand [$\hat{e}$]	GW	13.827	37.715
Lifetime utility [U]	In units of utility	125	131
Government debt per capita [d]	Millions of Nu.	913.632	0.344
Firm electricity price per GW [p]	Millions of Nu.	5.5	4.5

Finally, we compare the two cases to investigate which policy better serves individuals to maximize their lifetime utility. We then obtain consumption for different generations and lifetime utility at the steady state. The results obtained for the consumption and sub-utility level for individuals in different age groups under the base and simulated case are in Figure 4.1.A and B, respectively.

We compare individuals' consumption in each age group between the two cases in Figure 4.1.A. On the one hand, we obtain that consumption for younger age groups is lower under the debt endogenized case, compared to the price endogenized case by 31, 23, 13 and 2 percent for the first, second, third and fourth age groups, respectively. On the other hand, for the older fifth and sixth age groups, consumption in the debt endogenized case is higher than in the price endogenized case by 10 percent and 23 percent, respectively. This is because, in the debt endogenized case, the government issues bonds for financing its activities, primarily the electricity supply. The increase in debt under the debt endogenized case increases the interest rate and reduces the capital accumulation at the steady state, resulting in lower wages, as the wage is a function of capital.

Thus, the consumption of the young is higher in the price endogenized case but higher for the old in the debt endogenized case.

As for the sub-utility derived from individual consumption in each age group, we can see from Figure 4.1.B that individuals receive higher utility from consumption when young than the one when old in both cases. While both cases exhibit similar trends, it is worth noting that the sub-utility differences in the younger age groups are more significant than in older age groups. Comparing the debt and price endogenized case, we can see that sub-utilities are higher for the latter from the first to fourth age groups, whereas they are higher for the former for the fifth and sixth age groups. This is because, under the debt endogenized case, the wage reduces due to a reduction in capital accumulation – resulting in lower income for young periods and thus lower utility, while the interest rate increases due to an increase in the debt level – resulting in higher income for older periods.

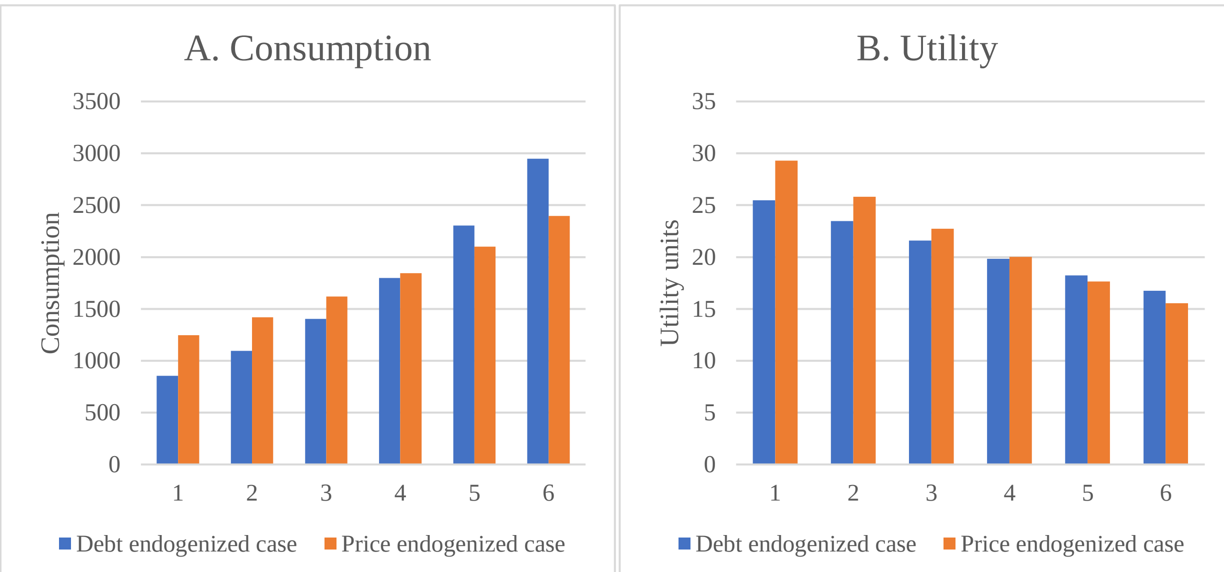

Figure 4.1: Utility and consumption level for different generations

Finally, by aggregating the sub-utility of individuals during their lifecycle, we obtain their lifetime utility. The utility level under the price endogenized case is 131, which is higher than the debt endogenized case of 125 (see Table 4.3). As shown in Figure 4.1, this difference is because of the crowding-out effect in the capital market, the capital per capita under the debt endogenized case. In addition, the interest rate increases following this crowding-out effect, which increases the returns from saving in older periods. However, because capital decreases, the present value of expected lifetime income declines compared to the price endogenized case. Therefore, lifetime utility is lower in the debt endogenized case than in the price endogenized case.

Although intragenerational consumption and the utility level depend on the policy type, our model suggests that it is better to adopt the price endogenized case to maximize individuals' lifetime utility.

4.5. Conclusion

This chapter simulates Bhutan's macroeconomy using a six-period OLG model incorporating electricity. Similar to the results obtained in Chapter 3, we emphasize the role of electricity because hydropower is important to Bhutan's economy and will remain so in the near future. We analyze the effect of debt endogenized and price endogenized cases on long-run economic growth and the effect of these policies on individuals' consumption and lifetime utility. The salient feature of this chapter is that it has a broader lifecycle analysis, and electricity consumption enables individuals to devote more time to income-generating activities.

When we simulate the price endogenized case, the capital and income per capita increase by 45.48 and 11.903 percent, respectively, compared to the base case. This is because, under the base case, the increase in debt causes a crowding-out effect in the capital market, resulting in a lower level of capital. Moreover, the electricity price under the price endogenized case decreases from an initial level of Nu. 5.5 million to Nu. 4.540 million per GW. The lower electricity price in the price endogenized case is caused by higher electricity demand (37.715 GW per capita) compared to debt endogenized case (13.827 GW per capita).

Similarly, individuals' lifetime utility is higher under the price endogenized case. The lifetime utility under the price endogenized case is 131, and the debt endogenized case is 125. The higher utility from the first to the fourth period under the price endogenized case is because of the higher capital and income per capita, resulting in higher utility. Only for the fifth and sixth periods the utility is higher for the debt endogenized case because of the increased income on their savings during the period. Overall, our model indicates that the price endogenized is preferable to the debt endogenized case.

This chapter is subject to some limitations. One is the availability of detailed data on electricity and its usage. Second is the inability of the model to reflect that Bhutan's debt is classified into various categories where a significant proportion of hydropower debt is regarded as de facto FDI.

Finally, it should be noted that the electricity price obtained under the price endogenized case is not the marginal cost or price determined in the market just for electricity. In fact, the price is higher than the marginal cost, in our analyses. Instead, it is the price that is required to balance the government's budget, which includes costs over and above the marginal cost of supplying electricity.

Despite these limitations, this chapter provides an important policy implication. Endogenizing the electricity price is critical for maintaining a sound fiscal position and raising the welfare of the Bhutanese people.

Chapter 5: Conclusion

This dissertation began by evaluating Bhutan's developmental progress and its characteristics. We highlighted the primary source that fuels Bhutan's economic growth since the opening of Bhutan's economy to the outside world in the 1960s. While Bhutan's economic growth sources are not limited to human capital and hydropower, these two are the primary and consistent sources that fueled Bhutan's economic growth. Bhutan is scheduled to graduate from LDC to MIC by 2023, and its topography and economic circumstances make it such that the government's intervention in the market is crucial for the country's sustainable development. More challenges await Bhutan's sustainable economic development in the future, as low productivity and economic vulnerabilities are still a major issue that has not been adequately addressed. Thus, we see that the role of human capital and hydropower to fuel Bhutan's economy will intensify further. In this regard, we investigate Bhutan's economy fueled by human capital and hydropower to see how changes in the respective policy could affect economic growth by stimulating the economy using the overlapping generations model.

First, in Chapter 2, we simulated Bhutan's economy using the two-period overlapping generations model with endogenous growth fueled with human capital accumulation through education subsidy. We evaluate the effect of education subsidies, with different financing modalities, on human capital accumulation along the transition and steady growth path after considering the current macroeconomic conditions. We extend the current central school program to cover all students in Bhutan, which results in an increase in the education subsidy from the current level of 60 percent to 70 percent. We find that increasing the education subsidy financed through taxes is preferable from an economic growth perspective than when financed through debt. The economic growth rate is higher under the debt financing case from the second to the fourth period, that is, 12.456, 3.002, and 0.432 percentage points per 30 years, respectively. However, after the fourth period, economic growth is higher in the tax financing case by 0.660 percentage points per 30 years, on average, during the transition period and by 0.853 percentage points per 30 years, at the steady growth path. This results from a crowding-out effect caused by government debt in the capital market.

The results obtained in Chapter 2 provide insights and a better understanding of appropriate developmental policy for Bhutan's economy fueled with human capital. Since Bhutan is a low-income country, it has access to concessional borrowings with zero or very low-interest rate on government bonds. Furthermore, the modern taxation administration and laws are outdated and cost of tax collection is relatively high. Thus, as indicated by our results, in the short-run, it is acknowledgeable that Bhutan borrows to finance the extension of the central school program and achieve higher economic growth compared to the program being financed by taxes. However, in the long run, since tax financing brings about higher economic growth, the government should finance such programs through taxes rather than government bonds. From this standpoint, taxation policies and administration should be modernized to improve the efficiency of the tax collection system. While human capital accumulation through education subsidy remains important for Bhutan in the long run, hydropower also plays a significant role in shaping the Bhutanese economy. Thus, we calibrated and simulated Bhutan's economy in the next two chapters by incorporating electricity into the model.

Second, in Chapter 3, we incorporate electricity in the individuals, firms and government's behavior and simulate Bhutan's macroeconomy in a two-period OLG model. We first calibrate the debt endogenized case as the base case, and obtain the transition and steady-state values. Next, we simulate the price endogenized case as the alternative policy choice and obtain the transition and steady-state values. Comparing the base case with the simulated case shows that the debt endogenized case is preferable to the price endogenized case. That is because of the following three reasons. First, the capital accumulation is higher for the debt endogenized case by 1.10 percent on average during the transition and 1.27 percent at the steady state, although the difference is negligible. Second, electricity demand is higher for the debt endogenized case by 19.99 percent on average during the transition and 21.70 percent on average at the steady state. Finally, the level of lifetime utility is also greater debt endogenized case by 3.33 percent on average during the transition and 3.65 percent on average at the steady state.

The numerical analysis shows that the existing electricity policy is preferable. That is mainly because, as stated before, the debt or the electricity price, when endogenized, reflects the government's financing needs, including expenditure over and above the marginal cost of hydropower construction. As a result, the electricity price increases under the price endogenized case, leading to lower electricity demand and capital accumulation. Although such cases look hypothetical, hydropower revenue serves as revenue for the government in Bhutan, making the case in our model pragmatic. Based on the result of numerical analysis, it is important to consider that hydropower revenue should not be viewed as a tool to balance the government budget. While the result gives insight into the hydropower policy for Bhutan, we also acknowledge that it does not adequately capture the lifecycle of individuals. In this regard, in the next chapter, we construct a six-period OLG model incorporating the salient features from this chapter.

In Chapter 4, we simulated Bhutan's macroeconomy using a six-period OLG model incorporating electricity. Similar to Chapter 3, we analyze the effect of the debt endogenized and price endogenized cases but only on long-run economic growth and the effect of these policies on individuals' consumption and lifetime utility. The salient feature of this chapter is that it has a broader lifecycle analysis, and electricity consumption enables individuals to devote more time to income-generating activities. Upon simulation, we find that the price endogenized case has higher capital and income per capita by 45.48 and 11.903 percent, respectively, compared to the base case. This is because, under the base case, the increase in debt causes a crowding-out effect in the capital market, resulting in a lower level of capital. Similarly, individuals' lifetime utility is higher under the price endogenized case. The lifetime utility under the price endogenized case is 131 and the debt endogenized case is 125. Overall, our model indicates that the price endogenized is preferable to the debt endogenized case.

We can see that Chapters 3 and 4 provide different results even though similar framework is utilized: the former favors the debt endogenized case, while the latter favors the price endogenized case. One of the main reasons for the difference is due to having more lifecycles in Chapter 4. In the six-period OLG model of Chapter 4, the impact of debt issued by the government along with the interest rates, amplifies the crowding-out effect in the case of debt endogenized case, resulting in favorable results for the price endogenized case. However, it is also worth noting that, due to computational complexities, the analysis in Chapter 4 using the six-period OLG model is limited only at the steady state. Thus, it provides a scope for further analysis in Chapter 4 in the future to evaluate the economy during the transition.

Finally, the analyses in this dissertation are subject to some limitations. One is the availability of detailed data on electricity and its usage. Second is the inability of the model to reflect that Bhutan's debt is classified into various categories where a significant proportion of hydropower debt is regarded as de facto FDI. Despite these limitations, the analyses in this dissertation provide an important policy implication. It can serve as an additional tool for the practitioners while deciding on drafting the detailed project report (DPR), negotiating loans for new hydropower projects, and negotiating electricity prices for the existing hydropower stations.

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