Negotiating Fiscal Sustainability against Socio-Economic Development: A Model-Based Policy Analysis

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Abstract

Fiscal policy can be multidimensional in nature. On the one hand, it addresses socio-economic development, and on the other, it deals with ensuring fiscal sustainability. The ability of the government to design fiscal policies to achieve the twin goal of socio-economic development and fiscal sustainability requires understanding the social, economic and public debt impact of the fiscal policy. This can only be achieved by considering the complex relationships between the social sector, the economic sector and the public sector. Even though existing models and techniques offer insights about the impact of fiscal policy on socio-economic development and fiscal sustainability, they lack sufficient causal explanation of the dynamic impact of fiscal policy on socio-economic development and fiscal sustainability. This paper develops a causal socio-economic model to help analyze the impact of fiscal policy on socio-economic development and fiscal sustainability. Results from the policy analyses found that expansionary fiscal policy is the best policy to achieve socio-economic development. Contractionary fiscal policy is found to be the best policy for ensuring fiscal sustainability. We conclude that the balanced budget fiscal policy is the most workable fiscal policy for the government to achieve the twin goal of socio-economic development and fiscal sustainability.

Keywords: Fiscal Sustainability, Socio-economic development, Modeling and Simulation

1. Introduction

Over the past decade the emergence of the public debt crisis in many developing countries has been attributed to the growth of public spending (Tanzi and Blejer 1986). Guided by the economic models suggesting that growth can be stepped-up by increasing resources for investment, governments of developing countries have often resorted to borrowing to supplement revenue. The borrowed resource is often used for investment purposes and/or consumption smoothing (Campbell 1989). However, for a variety of reasons, including increased spending resulting from population growth, external shocks, bad economic management, low productivity, low competition in the world market, as well as output decline and slow recovery thereafter, government spending consistently exceed its revenue, hence causing continued borrowing (Lindauer and Velenchik 1992; Jha 2001; Ghatak and Sanchez-Fung 2007).

It is therefore not surprising that the economic program, i.e. structural adjustment program designed to deal with the public debt crisis in developing countries, had fiscal adjustment as a critical component. The aim of the fiscal adjustment is to reform the government expenditure management aimed at reducing total government expenditure and to correct the imbalances in government finances through tax reform aimed at improving the efficiency and effectiveness of the tax system and tax administration (Konadu-Agyemang 2001). However, due to the inability of government to increase tax revenue significantly, government expenditure was reduced to ensure fiscal balance. Empirical studies (Konadu-Agyemang 2001; SAPRIN 2002) have concluded that the social sector expenditure, i.e. education and health suffered most from the expenditure cut while in some countries the economic sector was not exempted from the cut in expenditure. Balancing the art of achieving socio-economic development and ensuring fiscal sustainability has been the dilemma of governments over the years. In most developing countries, these two goals appear to be in conflict because the only way to increase socio-economic development from beyond the current stage of development is to increase government expenditure. Increased expenditure will increase budget deficit and, consequently, public debt, defeating the goal of fiscal sustainability. The ability of the government to design fiscal policies to achieve the twin goal of socio-economic development and fiscal sustainability requires understanding the social, economic and public debt impact of the fiscal policy. This can only be achieved by taking into account the complex relationships between the social sector, the economic sector and the public finance sector.

Even though existing models and techniques offer insights about the impact of fiscal policy on socio-economic development and fiscal sustainability, they lack sufficient causal explanation of the dynamic impact of fiscal policy on socio-economic development and fiscal sustainability. This is the content-wise shortcoming we address in this paper.

Our contribution is as follows; first, we have developed a structure-behavior oriented model-based socio-economic framework that represent the complex interactions between the social, economic and public finance sectors based on an adaptation of system dynamics to the social, economic and public finance theories and an empirical observations. Second, we offer causal explanation for the dynamics observed in the social, economic and public finance sectors of the economy and their evolution over time. Lastly, we conduct a policy analysis from 2000 to 2080 to determine what socio-economic development and fiscal sustainability would be as a result of the four experimented fiscal policies[1].

The policy analysis demonstrates that; the expansionary fiscal policy is the best policy if one intends to increase and enhance socio-economic development; however, the down side of this policy is that it builds up high public debt that makes fiscal policy unsustainable. The simulation result concludes that contractionary fiscal policy is the best policy to significantly reduce the public debt burden in Ghana; but the trade-off for this policy is that it reduces socio-economic development. We find that the balanced budget fiscal policy is the second best policy to increase socio-economic development and reduce debt-GDP ratio. Lastly, the result of the combined fiscal policy[2] result demonstrates that the policy is the third best if one intends to increase socio-economic development and reducing debt-GDP ratio. We therefore recommend the balanced budget fiscal policy as the most workable fiscal policy for the

[1] The fiscal policies are; expansionary fiscal policy, contractionary fiscal policy, balanced budget fiscal policy and combined fiscal policy.

[2] This policy is a combination of expansionary fiscal policy in the medium term and contractionary fiscal policy in the long term. The combined policy ensures that government expenditure exceeds its revenue in the medium term to build human and physical capital to increase production and socio-economic development. When the foundation of the economy is perceived to be strong, government fiscal policy is changed to contractionary policy to ensure that previous deficit are financed by future surplus.

government of Ghana to pursue in its attempt of achieving the twin goal of socio-economic development and fiscal sustainability. Though contractionary fiscal policy reduces debt-GDP ratio much more significantly than the balanced budget fiscal policy does, the simple fact that it reduces socio-economic development do not make the policy the most desirable policy.

This paper is organized as follows. In section 2 we review the social and economic implications of public debt. Section 3 represents the methods for assessing fiscal sustainability and socio-economic development and also the assumptions of the system structure of the socio-economic model. Section 4 describes the socio-economic model in detail. Section 5 represents the validation of the model. Section 6 represents the base run behavior explanations. Section 7 represents the policy analysis and discussion. Section 8 represents the scenario analysis. Section 9 represents the conclusion.

2. Literature Review

This section reviews literature on social and economic implications of public debt in developing countries. The purpose of the literature review is: first and foremost to outline some of the empirical finding from studies in developing countries concerning the impact of public indebtedness on social and economic development. Second, we want to offer structure information to be imbedded in the model. Lastly, we want to refer the literature to structure documentation. We want to establish through validation if the behavior pattern from the model coincide with empirical findings.

2.1 Social and Economic Implications of Public Debt

According to (Mahdavi 2004), two main issues arise in relation to efforts aimed at containing the fiscal deficits. The first issue is the distribution of the deficit reduction between government expenditure cuts and higher taxes to increase revenues. Empirical evidence and findings from studies (Konadu-Agyemang 2001; SAPRIN 2002) indicates that, government expenditure is more likely to be reduced in times of deficit reduction than increases in taxes. This is because raising taxes may be perceived as a policy with distortionary effects (Mahdavi 2004). The second issue is the distribution of government expenditure cuts among various functional spending. Mahdavi argued that if spending cuts mainly fall on expenditure categories that affect current income and consumption levels of large segments of population, they will have adverse welfare (poverty) implications (Mahdavi 2004). This may result in a rise in the levels of public discontent and political instability. On the other hand, if the expenditure reduction is borne by sectors that maintain and enhance the economy's productive capacity, it may well endanger the long-term economic growth. This is particularly true in developing countries where the public sector is the main source of investment in infrastructure, education and health. During the structural adjustment program era, these concerns were expressed by many groups opposed to the structural adjustment program.

Various studies (Pattillo, Poirson et al. 2004; Lora and Olivera 2006) have concluded that high public debt severely constraints developing countries ability to provide social services such as education and health. A recent study by Lora and Olivera (2006) indicates that a higher debt ratio reduce social expenditure not just because interest payment on debt constrained social spending, but because high public debt is associated with cuts in total expenditure that affect the social sector. They established that debt displaces social expenditure mainly because it reduces the room (or the appetite) for further indebtedness. Mahdavi (2004) assess how the external debt burden may influence the composition of government spending and concluded that there is adverse effect of debt burden on capital expenditure, and on current expenditures other than wages and salaries. He explained that since a large part of social expenditure takes place in the form of wages and salaries paid to public servants in the education and health public sectors, this finding may suggest that social expenditure are shielded from the adverse effects of the debt burden (Mahdavi 2004).

Public debt has both social and economic consequences for every economy. However, there seems to be little agreement as to whether public debt affect social and economic sector of the economy negatively or positively. The debt overhang theory (Krugman 1988; Sachs 1989) concludes that high public debt negatively affect social and economic growth. On the other hand, debt irrelevance theory (Cordella, Ricci et al. 2005) concludes that the debt overhang argument holds for non-HIPC (countries who are not highly indebted), but that for HIPC (highly indebted countries) there is no evidence of the debt overhang argument.

A number of studies (Krassowski 1974; Sachs 1984; Krugman 1988; Olukoshi 1989; Sachs 1989; Sachs 2002; Pattillo, Poirson et al. 2004) have dealt with the public debt-economic growth relationship during the last two decades. Both theory and policy discussion indicate that the effect of public debt on economic growth could occur through both the main sources of growth, i.e. the capital accumulation channel and factor productivity growth channel. The capital accumulation channel argument is supported by the debt overhang theory which implies that when external debt grows large, investors lower their expectations of investment returns in anticipation of higher and progressively more distortionary taxes required to repay debt (Pattillo, Poirson et al. 2004). Consequently, new domestic and foreign investment is discouraged, which in turn, slows capital stock accumulation. In the highly indebted poor countries (HIPC), it is argued that investors hold back, given the uncertainties about what portion of the debt will actually be serviced with the countries own resources (Pattillo, Poirson et al. 2004). The factor productivity growth channel proponents argue that governments of indebted countries may be less willing to undertake difficult and costly reforms if it is perceived that the future benefit in terms of higher output will accrue partly to foreign creditors. They speculate that the poorer policy environment, in turn, is likely to affect the efficiency of investment and productivity. In addition, it is believed that uncertainties and instabilities related to debt overhang are likely to hinder incentives to improve technology or to use resources efficiently (Pattillo, Poirson et al. 2004).

According to the debt irrelevance theory, generous official assistance helped highly indebt poor countries (HIPCs) to service their debt, so that they never experience the crowding out of resources that preceded the emerging market debt crisis of the 1980s. Moreover, the debt irrelevance theory suggests that net official transfers to HIPCs have grown together with the debt stock from the 1970s, and that donors/creditors have continued to transfer to HIPCs resources in excess of those needed to service growing debt.

3. Methodology

3.1 Fiscal Sustainability

The definition of fiscal sustainability derives from the budget constraint of the public sector. Many authors (Buiter 1985; Blanchard, Chouraqui et al. 1990; Horne 1991; Ghatak and Sánchez-Fung 2007) have discussed the concept and meaning of fiscal policy sustainability. The idea of fiscal sustainability is intimately related to the public debt dynamics. According to Ghatak and Sánchez-Fung (2007), for a fiscal policy to be sustainable, every deficit should be financed by future surplus. To illustrate, let D_t be the stock of total public debt outstanding at the end of period; Ex_t the non-interest government expenditure, that is, government expenditure excluding total interest payments on the public debt; R_t the government revenue and grants; i the rate of interest on public debt and m is the debt maturity. Then, the budget constraint for the public sector can be written as:

$$dD_{t-1,t}/dt = (dt)Ex_t - (dt)R_t + (dt)iD_{t-1} + (dt)D_{t-1}/m \qquad (1)$$

Equation (1) shows that the change in public debt will be equal to the difference between non-interest government expenditures and government revenues and grants, plus total interest payment on public debt and repayment of principal. This budget constraint ignores public revenues arising from the creation of money. Equation (1) can be rewritten as:

$$D_t = (dt)pd_t + (dt)ds_t \qquad (2)$$

Here, pd_t is the primary deficit i.e. the difference between non-interest expenditure and government revenue and grants, and ds_t is debt servicing which consist of total interest payments and repayment of public debt. By iterating the government budget constraints forward, a fiscal policy is considered to be sustainable in infinity if the condition expressed in equation (3) holds:

$$D_t = -\sum_{t=1}^{T}\left((dt)pd_t + (dt)ds_t\right) \qquad (3)$$

Equation (3) is a condition for fiscal sustainability. It says that the value of future primary surpluses must be equal to the total public debt. Therefore, for the purpose of this study, a fiscal policy is said to be sustainable if the total budget surplus over time $\left[-\sum_{t=1}^{T}\left((dt)pd_t + (dt)ds_t\right)\right]$ is large enough to maintain or reduce total public debt over the time frame of the analysis.

According to the World Bank, fiscal policy is sustainable if debt-GDP ratio does not increase continuously and/or creates financing needs that cannot be adequately met by the supply of funds available to the public sector (Bank 2004). Blanchard (1990) defines sustainable fiscal policy as a policy that ensures that the ratio of debt to GDP converges back towards its initial level (Blanchard, Chouraqui et al. 1990). However, judgments about fiscal sustainability and particularly about excessive debt-GDP ratio are hard to make. Economic theory provides little guidance on this because it was generally believed (before the 1982 Latin American debt crises) that countries do not go broke. A common approach, therefore, is to rely on a simple rule that specifies, for example, that the debt ratio should not rise or exceed a specific limit (e.g. is the approach used by the World Bank and IMF for the highly indebted poor countries initiative).

For the purpose of this paper, a fiscal policy is perceived to be sustainable if;

1. The total budget surplus over time is large enough to reduce total public debt
2. Debt-GDP ratio decreases or remains constant as a result of the fiscal policy.

3.2 Socio-economic Development Index

Assessment of the development level in this study is based on the socio-economic development index (SEDI) proposed in this section. The SEDI consist of various indicators of education, health, social services and income. The SEDI is formulated to be as all-inclusive socio-economic indicator of development as practicable. The estimation of the SEDI is influenced by human development index (HDI)[3] from United Nations and socio-

[3] The human development index (HDI) is a composite index that measures the average achievements in a country in three basic dimensions of human development: a long and healthy life as measured by life expectancy at birth; knowledge, as measured by the adult literacy rate and the combined enrolment ratio for primary, secondary and tertiary schools; and a decent standard of living as measured by gross domestic product (GDP) per capita in purchasing power parity (PPP) US dollars

economic development index from the EU[4] (Mehrotra and Peltonen 2005). The SEDI estimation includes the following variables; primary school enrollment rate, secondary school enrollment rate, tertiary school enrollment rate, infant mortality, life expectancy, average access to basic health, per capita food availability, per capita community/social expenditure, unemployment rate and GNI per capita.

The SEDI is calculated by estimating the various components or index[5] of SEDI. However, each index consists of variables. Table 1 shows the SEDI indicators and its component variables.

SEDI Index (Variables)	***Values***		***Dimension Value***[6]		***Source of Value***
	Max	Min	Max	Min	
Education					
Primary enrollment rate (%)	1	0.2	1	0	HDE[7]
Secondary enrollment rate (%)	0.8	0.15	1	0	Author's Estimation
Tertiary enrollment rate (%)	0.6	0.05	1	0	Author's Estimation
Health					
Infant mortality	10	400	1	0	Author's Estimation
Life expectancy	85	20	1	0	HDE
Average access to health (%)	1	0.1	1	0	Author's Estimation
Per capita food availability	3	0.5	1	0	Author's Estimation
Social Services					
Per capital Com/Social exp.	400	10	1	0	Author's Estimation
Unemployment rate (%)	5	40	1	0	Author's Estimation
Income					
GNI per capita	40000	100	1	0	HDE

Table 1: Goalposts for Calculating Socio-Economic Development index (SEDI)

[4] The index consists of different indicators of health, infrastructure, environment and education taking into account the public/private sector nature of the variables and data limitations

[5] Index represents the main categories of the SEDI. As shown in table 1, the SEDI index are education, health, social services and income

[6] The estimated values are expressed as dimension values between 1 and 0.

[7] Human Development Estimate by the United Nations

The equation for representing the index is represented as;

$$Index_i = \frac{\sum_{i=1}^{n} E\,\text{var}_i}{n} \qquad (4)$$

Here, $Index_i$ is the estimated value for each category[8] of the SEDI, $E\,\text{var}_i$ is the estimated value of the variable and n is the number of variables under each category. $E\,\text{var}_i$ is calculated as:

$$E\,\text{var}_i = (\text{var}_i - \min_i)/(\max_i - \min_i) \qquad (5)$$

Here, var_i is the value of the variable i, $\min_i$ is the minimum value of variable i and $\max_i$ is the maximum value of the variable i. The socio-economic index at any time t is obtained by an arithmetic average of;

$$SEDI_t = \frac{\sum_{i=1}^{n} index_i}{n} \qquad (6)$$

Here, n is the number of variables. It is important to note that the calculation of the SEDI follows quite closely the human development index (HDI) of the United Nations (UN).

3.3 Model Boundary

Sterman (2000) defines model boundary as the separation between the system being modeled and the rest of the universe. The boundary is set to keep the model manageable without compromising its purpose. Table 2 shows the socio-economic model's boundary indicating the ignored, exogenous and endogenous variables respectively. A model is but a

[8] Education, health, social services and income

representation of reality. A representation carefully selected to serve a particular purpose. The purpose of this model is to develop a structure-behavior oriented model-based socio-economic framework that represents the complex interactions between the social, the economic and the public sector. The purpose of the model served as a guide to carefully select variables to be determined endogenously, exogenous and ignored in the model. The endogenous variables listed in table 2 are the variables defined by the feedback structure of the model. The exogenous variables affect the state development (behavior) of the model but are not affected by it. The exogenous variables are either constants or historical tables that are specified as input to the model. The ignored variables are completely omitted from the model.

Ignored Variables

- Politics
- International relations
- Monetary Sector

Exogenous Variables

- Price
- Interest Rate
- Inflation
- Exchange Rate
- Rest of the World

Endogenous Variables

Social

- Population
- Births
- Deaths
- Education
- Access to basic health

Production

- Agriculture
- Industry
- Services
- Investment
- Employment, human capital
- Households

Public Finance

- Government expenditure
- Government revenue
- Public debt

Table 2: Boundary diagram of the Socio-Economic Model

3.4 Simulation Methodology

3.4.1 Rationale

We selected the methodology of System Dynamics to create our socio-economic model. System Dynamics is an adequate methodology to capture the relevant system structure to explain the system's outcome behavior (Radzicki 1992; Sterman 2000; Wheat 2007). Fundamental is the idea that all socio-economic actions take place within "feedback loops". According to Forrester, "*the feedback loop is the closed path that connects an action to its effect on the surrounding conditions, and these resulting conditions in turn come back as information to influence further action*" (Forrester 1973). Two types of feedback loops are differentiated; the positive or reinforcing feedback loop (R), and the balancing or counteracting loop (C). A reinforcing loop represents a mechanism by which an action produces a result which causes more of the same action thus resulting in the reinforcement of a growth or decline of a system's state. A counteracting loop attempts to stabilize some current state at a desired level through an action of resistance; it reacts to any change and works as a dampening mechanism. The assumptions we represent by the system structure in our socio-economic model are explained in the following section. To portray these assumptions, we use causal loop diagram (Sterman 2000). A causal loop diagram is important tool in the SD modeling approach for representing the feedback loop structure of systems and for communicating the important feedbacks underlying the system.

3.4.2 Assumptions about Model System Structure

Figure 1 depicts the assumptions about the system structure of the socio-economic model. Forrester proposed that it is especially important to review, revise and document the structure of the model because structure is just as important as the assumed numerical initial and parameter values in determining the modes of behavior that a system can exhibit (Forrester 1973). The causal diagram in figure 1 helps to review, examine and observe the feedback structure of the socio-economic model. We have identified twelve reinforcing feedback loops and ten counteracting feedback loops.

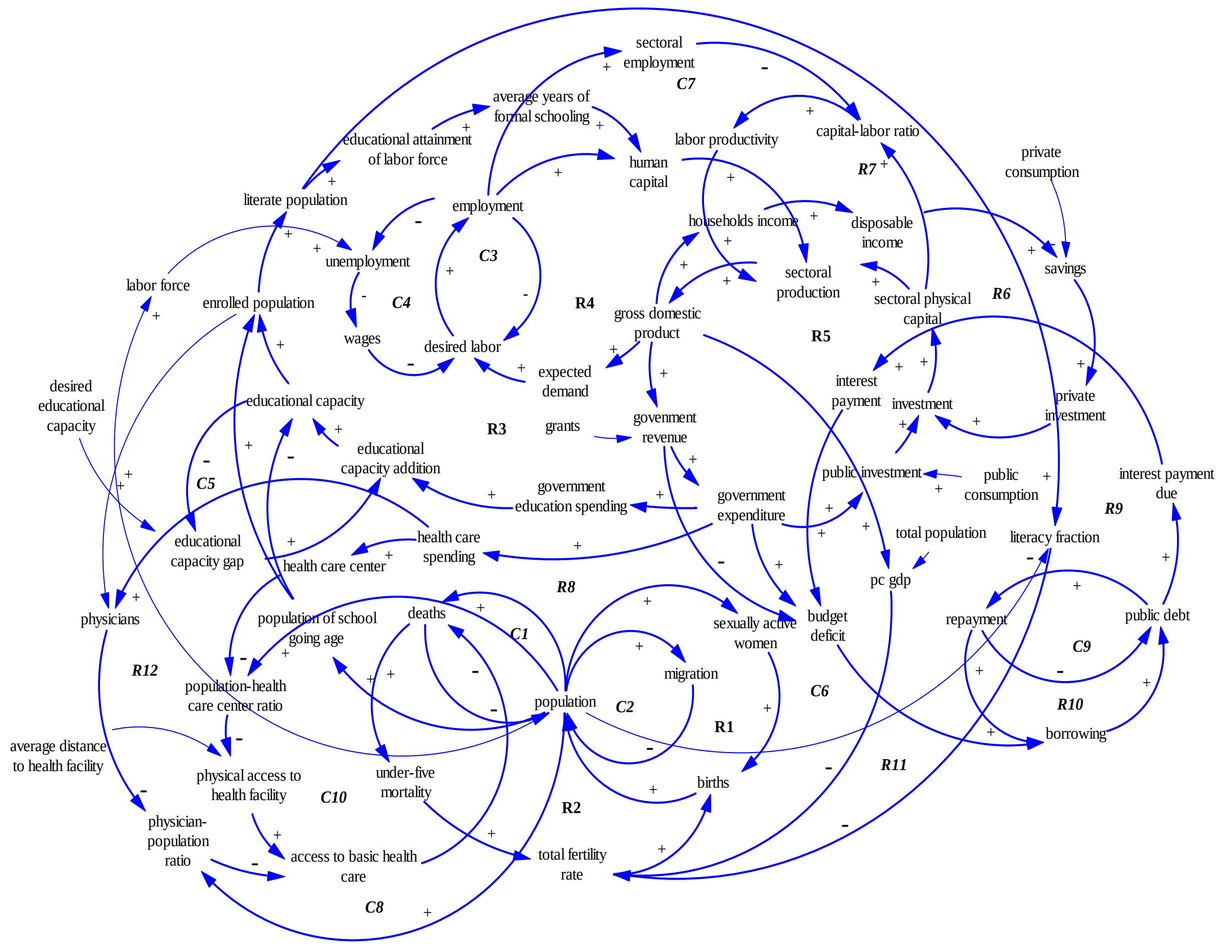

Figure 1: Complete Causal Structure of the Socio-economic Model interrelating the Social, Economic and Public Finance sectors of the economy

3.4.3 Social causal structure

The social causal structure consists of the demography, education and health. They are explained below:

Demography

The demographic causal structure consists of the following feedback loops; the births loop *(R1)*, the deaths loop *(C1)*, the migration loop *(C2)*, and the under-five mortality loop *(R2)*. These loops are explained below:

Births loop

Feedback loop *(R1)* represents the mechanism that generates addition to the population, causing population to grow. Loop *(R1)* includes births, population and sexually active women. According to *(R1),* births at any point in time depend on the population of sexually active women[9], and the total fertility rate of sexually active women. An increase in births causes an increase in population and, consequently, the population of sexually active women, which further create the condition for births to increase.

Deaths loop

Feedback loop *(C1)* represents one of the mechanisms responsible for population decrease. While births reinforce population growth as shown by *(R1),* deaths counteract such growth. Loop *(C1)* includes deaths and population. Loop *(C1)* represents the fact that a rise in population causes deaths to increase which, in turn, causes a decrease in the population the next time round.

Migration loop

The feedback loop *(C2)* represents second mechanism responsible for population decrease. Feedback loop *(C2)* includes migration and population. Counteracting feedback loop *(C2)* represents the fact that whereas a population increase positively affects migration an increase in migration in turn causes the population to decrease.

Under-five mortality loop

The feedback loop *(R2)* represents the mechanism through which under-five mortality affects the population dynamics. Loop *(R2)* includes under-five mortality, total fertility, births, population and deaths. As deaths increase, due to many factors, such as lack of access to basic health care, under-five mortality is expected to increase as well. Increase in the under-five mortality rate will increase the desired number of children to compensate the possibility of infant death consequently, total fertility rate increases. As the total fertility rate increases, birth and population is expected to increase which feeds back to increase death and under-five mortality rate.

Education

The education causal structure is governed by; the education loop *(R3),* the educational capacity loop *(C5),* and literacy loop *(R11)*. These loops are explained as follows;

[9] Female population between the ages of 15years-49years

Education loop

The education feedback structure is shown by the reinforcing loop *(R3)*. This loop represents the feedback process between government education spending, human capital and production. Loop *(R3)* includes educational expenditure, educational capacity addition, educational capacity, enrolled population, literate population, educational attainment of labor force, average years of formal schooling, human capital, sectoral production, gross domestic product, government revenue and government expenditure. Government finances expenditure by taxing income (GDP). Among other expenditures, a fraction of the tax revenue is spent on education. It is postulated that as education spending increases, educational capacity increases over time which increases the ability of the educational system to enroll more students. As the students eventually graduate with different educational attainments, labor force is made available to the economy for employment. The educational attainment of the labor force determines the quality of the labor force which is used to estimate the human capital. As human capital increases, we posit that GDP increases which, consequently, increases the tax revenue of government the next year round.

Educational capacity loop

Feedback loop *(C5)* represents the mechanism that makes sure that educational capacity does not exceed the desired capacity. This loop consists of educational capacity, educational capacity gap and educational capacity addition. Educational capacity is always compared to the desired capacity and the capacity gap is used to adjust educational capacity to ensure that we do not over or under capitalize education.

Literacy rate loop

Feedback loop *(R11)* represents the effect of literacy on the population dynamics. This loop includes literate population, literacy fraction, total fertility rate, births, population, population of school going age, educational capacity and enrolled population. As the literate population increases, the literacy fraction increases. Supported by demographic literature we hypothesize that an increase in literacy fraction will decrease the total fertility rate. Therefore, as the literacy fraction increases the birth rate and over time, the population decreases as well. In particular, the population within the school going age decreases. As a result, the educational capacity available is able to accommodate the population more effectively, which in turn, increases the literate population.

Health

Access to basic health care loops

Feedback loops *(R8, R12, C8 and C10)* represents the mechanism responsible for determining accessibility to health care. In the model, two factors determine access to basic health care. These factors are physical access to health facility, which is represented by loops *(R8 and C10)* and physician-population ratio, which is represented by loops *(R12 and C8)*. Loop *(R8)* includes health care spending, health care center, population-health care center ratio, physical access to health facility, access to basic health care, deaths, population, population of school going age, enrolled population, literate population, educational attainment of labor force, average years of formal schooling, human capital, sectoral production, gross domestic product, government revenue and government expenditure. This loop shows that as government expenditure increases due to GDP increase, it is expected that health care spending will increase. As health care spending increases, health care centers are expected to increase which in turn reduces the population per health center (i.e. population-health center ratio), consequently, access to basic health care increases. An increase in access to basic health care is postulated to decrease deaths and, thus, increase population which, consequently, will increase the labor force to yield more employment and thus increase production. As production increases, revenue to government is expected to increase which will, subsequently, increase health care spending the next year round. For *(R8)* to work, health care center growth must exceed population growth. If not, access to basic health care will decrease. This is represented by loop *(C10)*. Loop *(C10)* includes population, population-health care center ratio, physical access to basic health facility, access to basic health care and deaths. As population increases, all things being equal, the pressure on the existing health care centers increases, consequently, population-health care center ratio increases which in turn, decreases access to basic health care. As access to basic health care decreases over time, deaths are hypothesized to increase which will in turn decrease population.

Feedback loop *(R12)* includes health care spending, physicians, physician-population ratio, access to basic health care, deaths, population, population of school going age, enrolled population, literate population, educational attainment of labor force, average years of formal schooling, human capital, sectoral production, gross domestic product, government revenue and government expenditure. As government expenditure increases due to income (GDP) increase, it is assumed that health care spending will increase. As health care spending increases, more physicians are hired which increases the number of physicians. As physicians increase, physician-population ratio will decrease which will increase access to basic health care, over time, deaths is assumed to decrease as access to basic health care increases, which in turn increases population. Population increase will consequently increase the labor force to yield more employment and thus increase production. As production increases, revenue to government is expected to increase which will, subsequently, increase health spending the next year round. For *(R12)* to work, therefore, physicians' growth must exceed population growth; else, access to basic health care will decrease. This is represented by feedback loop *(C8)*. Loop *(C8)* includes population, physician-population ratio, access to basic health care and deaths. This loop implies that as population increase, physician-population ratio increases which consequently decrease access to basic health care. As access to basic health care decreases, over time deaths is expected to increase which will in turn, decrease population.

3.4.4 Economic causal structure

Employment loop

The feedback loops (R4, C3 and C4) represents the mechanism that generates employment. Loop *(R4)* includes gross domestic product, expected demand, desired labor, employment, human capital and sectoral production. The reinforcing loop *(R4)* represents how gross domestic product creates demand of goods and services which is produced by labor (employment). As employment increases, over time, human capital increases which in turn causes sectoral production and gross domestic product to increase. The counteracting feedback loop *(C3)* causes employment to increase as desired labor increases. Consequently, as employment increases, desired labor is expected to decrease the next year round, assuming desired labor remains constant. The counteracting feedback loop *(C4)* postulates that, if unemployment rises, wages will fall. As a result, desired labor will increase which will initiate the hiring of labor to increase employment over time. As employment increases eventually, unemployment decreases.

Public investment loop

The feedback loop *(R5)* represents how public investment creates physical capital that is used for production. Loop *(R5)* includes public investment, investment, sectoral physical capital, sectoral production, gross domestic product, government revenue and government expenditure. As public investment increases, investment goes up, which accumulates physical capital and consequently increase production. As production increases, government revenue is expected to increase which is used to finance all government expenditure. As a result government expenditure increases which in turn increase private investment the next time round.

Private investment loop

The feedback loop *(R6)* represents the mechanism that creates private investment. Loop *(R6)* includes gross domestic product, household income, disposable income, savings, private investment, sectoral physical capital and sectoral production. As households' income increases as a result of increased income from production (GDP), disposable income increases. As disposable income increases, it is expected that savings will rise, which in turn will increase private investment with a delay and, consequently, investment. In reality, rise in investment increases physical capital accumulation. As a result, GDP increases.

Labor Productivity loop

The feedback loop structure of labor productivity is governed by the reinforcing loop *(R7)* and the counteracting feedback loop *(C7)*. Loop *(R7)* includes sectoral physical capital, capital-labor ratio, labor productivity, sectoral production, gross domestic product, government revenue, government expenditure, public investment and investment. The reinforcing loop *(R7)* represents how an increase in physical capital, relative to employment, causes capital-labor ratio to increase, which feeds back to increase labor productivity, production and thus physical capital accumulation. The counteracting feedback *(C7)* includes employment, sectoral employment, capital-labor ratio, labor productivity, sectoral production, gross domestic product, expected demand and desired labor. Loop *(C7)* represents how an increase in employment relative to physical capital causes capital-labor ratio to decrease, consequently, causing labor productivity to fall. As labor productivity decline, production decreases which feed back to dampening the increase in employment.

3.4.5 Public debt causal structure

The accumulation of public debt is embodied in the reinforcing feedback loops *(R9, R10, and C9)*. Government finances its spending in part by taxing income (GDP); and finances any gap remaining, as is the case in developing countries', by raising public debt through borrowing. The feedback loops (*R9)* and (*R10)* represents the *debt trap phenomenon (Saeed 1993)* which represents the basic mechanism responsible for debt accumulation in developing countries. The reinforcing loop (*R9)* includes the following variables: Budget deficit, borrowing, public debt, interest payments due and interest payments. As the budget deficit increases due to government excess spending over revenue and grants, the deficit is financed through borrowing. As borrowing increases, public debt accumulates, - consequently the interest payments build-up. As interest payments increases, so does the budget deficit due to increased spending. The deficit must, in part, be financed by additional borrowing which in turn increase public debt the next time round. The reinforcing loop (*R9)* illustrates the deep-seated structure of the debt accumulation process. The reinforcing loop (*R10)* includes public debt repayment and borrowing. As public debt increases, repayment increases over time. Due to pervasive deficit spending by government, repayment increase causes the need to borrow to finance repayment, which in turn increases public debt the next year round. The public debt growth is contained by the counteracting feedback loop (*C9)* striving to reduce the public debt stock and other measures such as debt relief and interest relief that are not represented in the feedback loop structure of this model. Loop (*C9)* includes public debt and repayment. As public debt increases, repayment increases which then decreases public debt the next time round.

4. Description of Stock and Flow Structure of the Modules

4.1 Population Module

Since population size, composition and growth have a major influence on socio-economic development, a long-term socio-economic model requires a population module that generates these outputs. The significant importance of population in a country's economic growth makes its presence in such model essential and fundamental not the least, because population provides one of the two major inputs to economic production, i.e. labor and the other one being technology. The population module represents the total population and population age-distribution disaggregated by sex. The conceptual framework of the population module is based on the demographic transition theory (Thompson 1928) and empirical observations which suggest that births, deaths and net migration are the three determinants of changes in the size of population over time. The stock and flow structure of the population module is shown in figure 3 below.

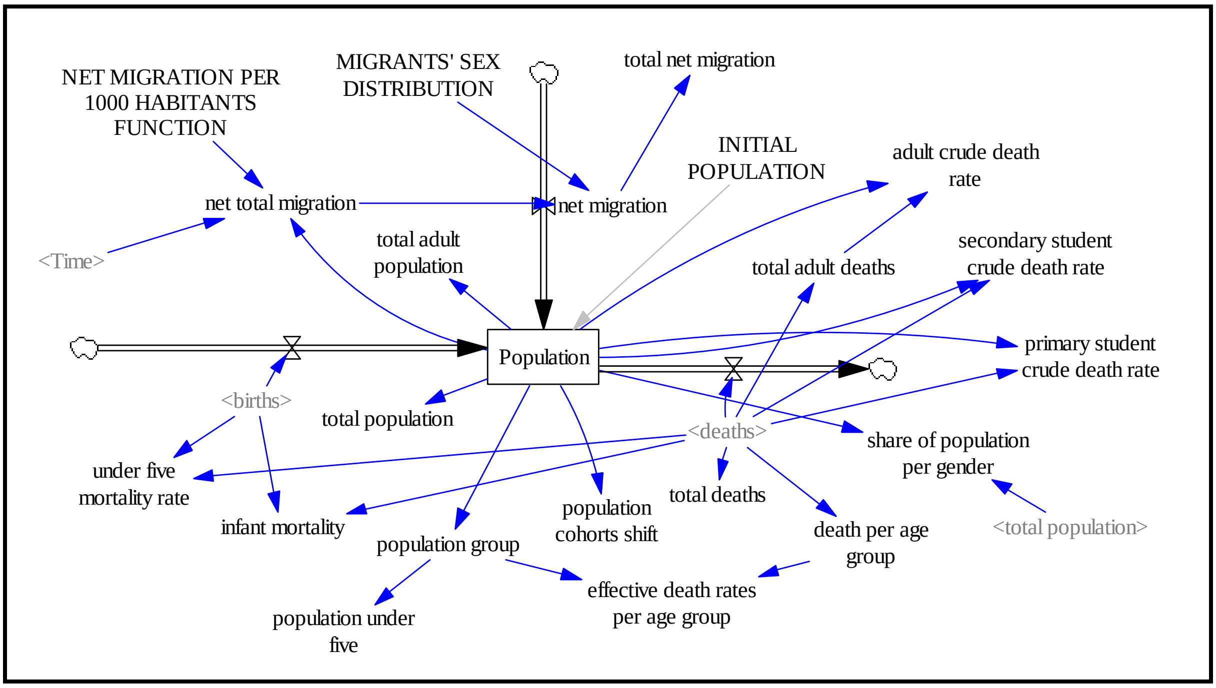

Figure 3: The stock and flow structure of the population module

The population stock is disaggregated into male and female genders and 82 age cohorts. i.e. (new born, age 0 to 79, 80+) for each gender. The ageing process is conceptually straightforward, as illustrated in Figure 2. Babies born (births) is moved to a stock called new born, which is immediately moved to age 0-1 cohort. At the end of each year, the surviving population in each age cohort is moved to the next age cohort, except for the last age cohort (age 80+). The population in the last age cohort remains in the cohort until they die.

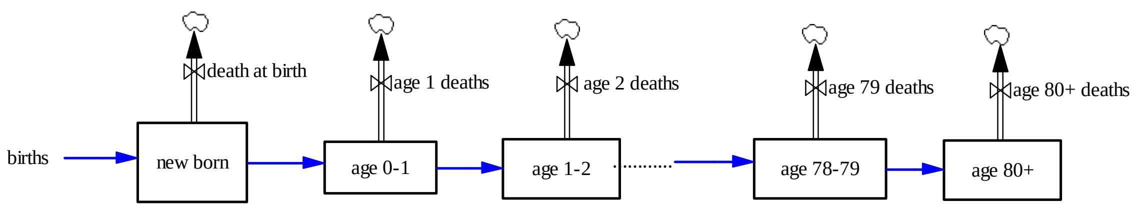

Figure 2: Ageing process in the population module

In the population module, the equation that shifts the population from one cohort to the other at the end of each year (minus deaths) is:

Population cohort shift [sex] = SHIFT IF TRUE (population [sex, new born], MODULO (time, 1) <time step/2, age 80 and over, 1, 0)

When the condition MODULO (time, 1) <time step/2 is true (when time reaches the end of each year), the subscripted variable population shifts from one age cohort to the next. The second to last parameter of the equation causes the function to add (not replace) the age 79 cohort to the last cohort age 80+. The last parameter of the function (0) is used to replace the first age cohort, i.e. to set the first cohort to zero at the end of each year to store new births the next year.

We initialize the population stock by estimating the population for each age (age 0- 80+) using the 5 year age group population data of the World Population Prospects provided by United Nations (UNDP 2002). We postulate a diminishing stock variable for the population ageing process where a given population declines as it moves from one age cohort to the other due to deaths. Therefore, the formula for disaggregating the 5 year age group population data to initialize the model is as follows; using age 0-4 as an example:

$$AGE_0 = X_{0-4} + 2*\left(X_{0-4} - X_{5-9}\right)/5 \qquad (7)$$

$$AGE_1 = X_{0-4} + \left(X_{0-4} - X_{5-9}\right)/5 \qquad (8)$$

$$AGE_2 = X_{0-4} = P_{0-4}/5 \qquad (9)$$

$$AGE_3 = X_{0-4} - \left(X_{0-4} - X_{5-9}\right)/5 \qquad (10)$$

$$AGE_4 = X_{0-4} - 2*\left(X_{0-4} - X_{5-9}\right)/5 \qquad (11)$$

Here, X_{0-4} is the mean population of age group (age 0-4), X_{5-9} is the mean population of age group (age 5-9) and P_{0-4} is the sum of the population age group (age 0-4).

Equation (7) to (11) illustrates the estimation of initial population into the age 1-4 cohort. The approach and sequence is followed for the successive age groups to disaggregate the population into each age cohort to initialize the population module.

4.2 Births Module

The study of population dynamics must begin with fertility (McFalls 2003). The determinants of fertility have engaged the interest of economists for sometime. Adam Smith noted that families were larger in settings where labor was scarce and child labor was especially valuable to parents (Smith 1776). However, Malthus viewed fertility not as an individual choice but as an outcome of social institutions. Malthus assumed with some justification that fertility is determined primarily by two variables, age at marriage and the frequency of coition during marriage (Malthus 1798). According to Becker, the development and spread of knowledge about contraceptive during the last century greatly widened the scope of family size decision-making, for it has separated the decision to control births from the decision to engage in coition (Becker 1960). However, such a widening of the scope of decision-making has increased the importance of other factors. In every society a variety of cultural, economic and health factors interfere with the process of human reproduction (McFalls 2003). Demographic literature has identified countless factors that affect births. Any population model that tries to account for each factor soon becomes hopelessly confusing (Meadows, Randers et al. 1972). To avoid confusion without compromising the fundamental objective of the model, we assume that births depend on three variables namely, the number of sexually active women, the total fertility rate and age specific fertility distribution. The choice of these variables is consistent with the proposed factors by Malthus (Malthus 1798) incorporating Becker's approach to fertility rate estimation (Becker 1960). These causal variables were found in a review of literature on fertility see (Smith 1776; Malthus 1798; Kamerschen 1972; McFalls 2003; Schultz 2007). The structure of the birth module is as shown in figure 5:

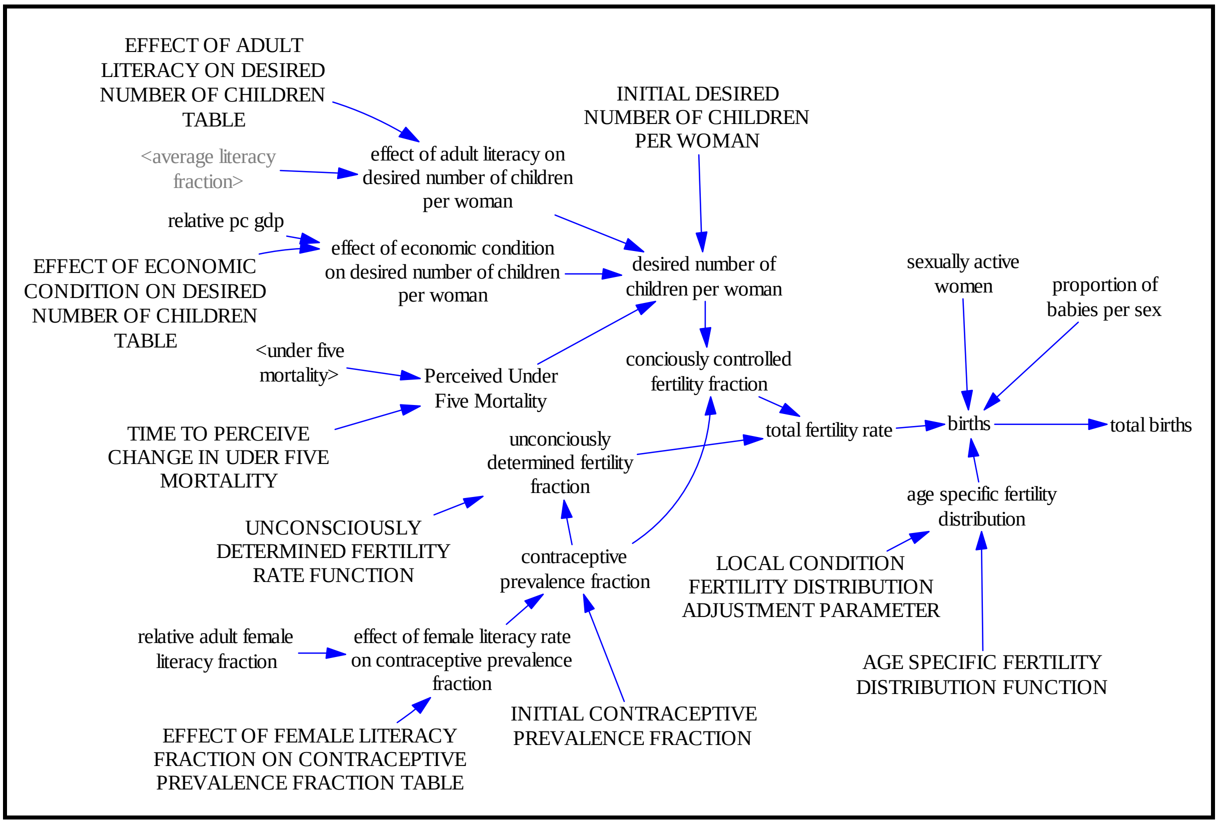

Figure 5: The Structure of Birth Module

(i) Sexually active women

This is the female population between the age cohorts 15-49 years. It is assumed that females between these age cohorts are the womb of the nation. As the female population in the 15-49 years increases, births are more likely to increase.

(ii) Total Fertility Rate

In the births module, the total fertility rate is positively influenced by the desired number of children and negatively affected by the contraceptive prevalence fraction. Leaving the contraceptive prevalence fraction for later discussion, consider the desired number of children: It is suggested that income (GDP), education and perceived under-five mortality are the determinants of desired number of children. It is assumed that human nature no longer guarantees that a growth in income appreciably above the subsistence level results in a large inadvertent increase in fertility (Becker 1960). In other words we stipulate a negative relationship between income and desired number of children. Moreover, we postulate that, as literacy rate increases and women increasingly become active economically, the desired number of children will decrease over time. Lastly, we assume that a decline in under-five mortality would induce a corresponding decline in desired number of children. Considering the contraceptive prevalence fraction, the growth of knowledge about contraception has greatly widened the scope of decision-making concerning family sizes. We would expect this to have reduced the relative fertility rate among users. We assume a positive causal relationship between relative adult literacy and contraception use. A rise in literacy rate is postulated to increase contraception use which subsequently reduces fertility. Consciously controlled fertility fraction is defined as desired number of children per woman by contraceptive prevalence fraction. On the other hand, unconsciously determined fertility fraction is determined by unconsciously determined fertility fraction by the fraction of adult population not using contraception (1-contraceptive prevalence fraction). Thus, total fertility rate is defined as consciously controlled fertility fraction plus unconsciously determined fertility fraction. Therefore, births are determined by total fertility rate, sexually active women, age specific fertility distribution. Births are disaggregated by proportion of babies per sex. The age specific fertility distribution function used in the model is shown in figure 4.

(iii) Age Specific Fertility

Figure 4 shows the fertility distribution by age. In the model this is taken as exogenous variable based on data from Ghana population data analysis report (Ghana Statistical Service 2005).

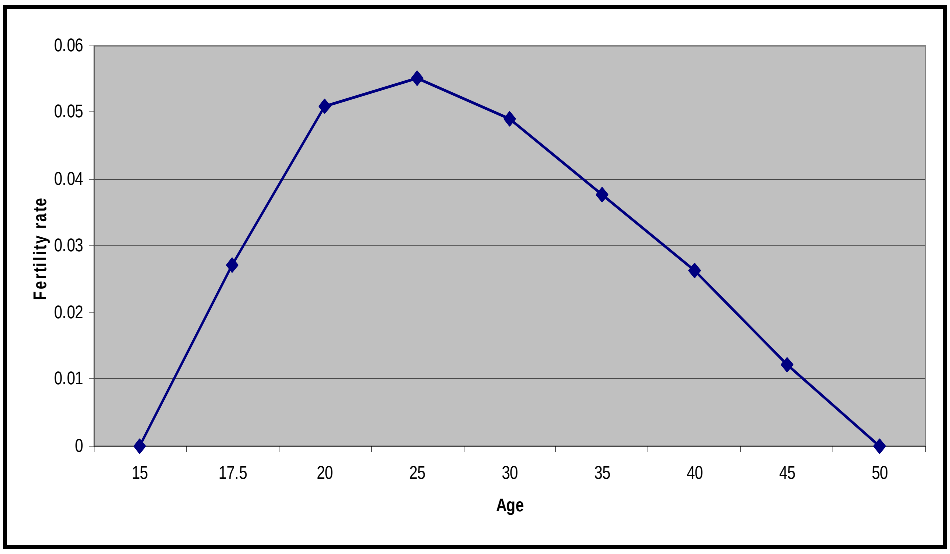

Figure 4: Age Specific Fertility rate

4.3 Deaths Module

In recent history, there has been a substantial decline in mortality in the poorer countries of the world. One manifestation of this mortality decline has been labeled the population explosion, in that the large increase in the numbers of people has been associated with drops in deaths, rather than increases in fertility. Extensive research review shows two main arguments about the causes of mortality decline. Increasing success in the application of communicable disease control technologies through public activities is argued to be the main reason for the decline in mortality. On the other hand, Krishnan (1975), indicated that the decline in mortality had been the result of general economic improvement, particularly in the elimination of famines and improved nutrition available to the people of the less developed countries (Grosse and Perry 1982). The relationship between social and economic well-being and health status has long been recognized, but it has been argued that the association between economic levels and health status has weakened in recent decade. The structure of the death module is as shown in figure 7.

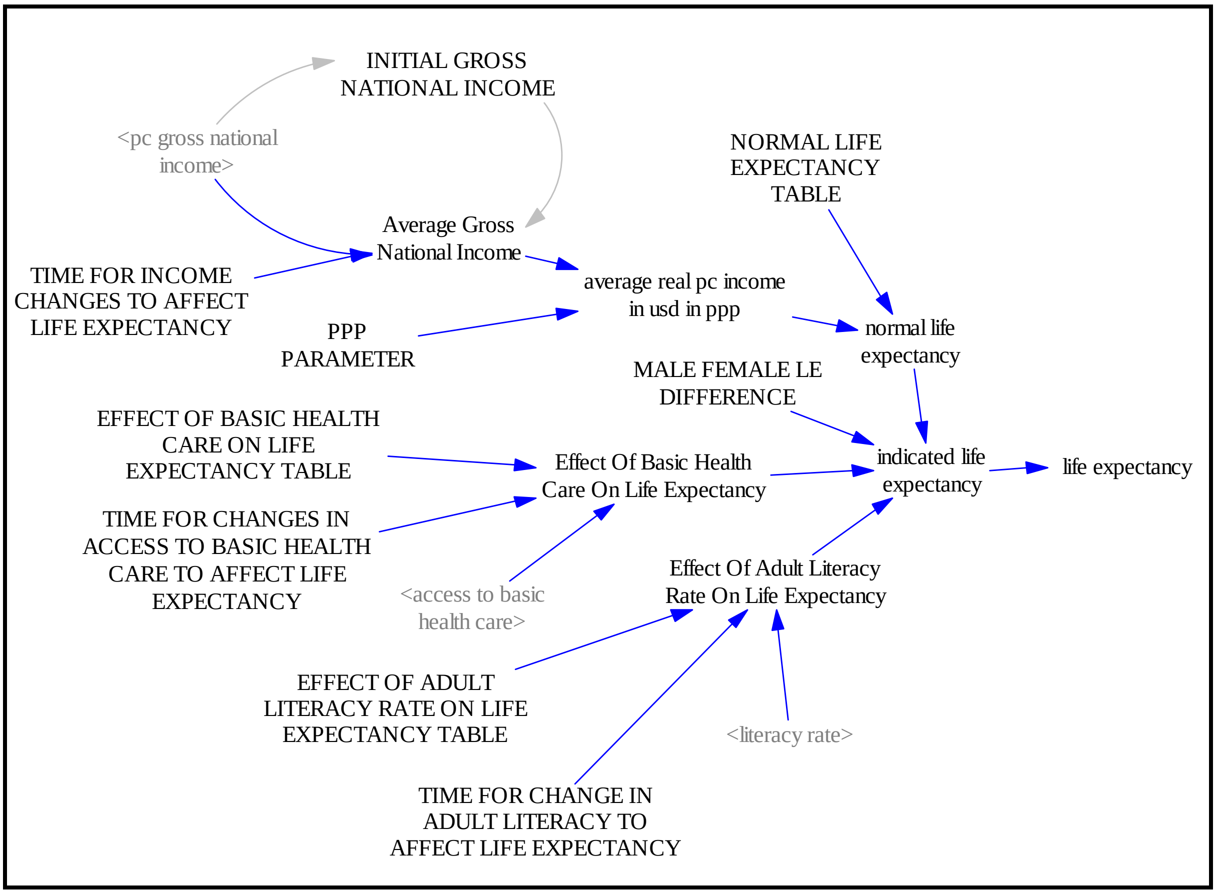

Figure 7: The Structure of Death Module

In the model income, health and literacy rate are the three main factors determining deaths through life expectancy. We postulate a positive relationship between income and life expectancy. However, it is important to note that this relationship is nonlinear, where, at a certain level of income, the effect is flattened (see figure 6). Access to basic health care is the proxy for health. We assume a positive causal relationship between access to basic health care and life expectancy. As the percentage of the population with access to health care increases, it is expected that life expectancy will increase which will subsequently reduce mortality. Lastly, the literacy rate is believed to contribute to increase life expectancy. As the population becomes more literate, their way of life and level of awareness about health issues increases. This directly or indirectly affects life expectancy positively. Figure 6 shows the postulated relationship between income and life expectancy.

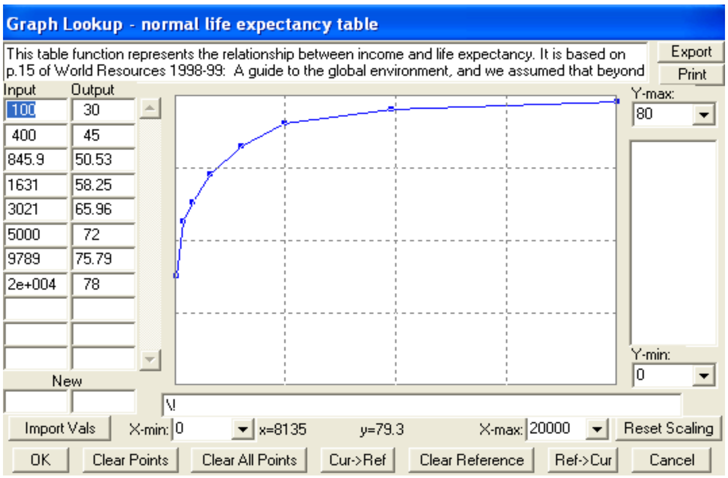

Figure 6: Income and Life Expectancy

4.4 Education Module

The history of education in Ghana indicates that government efforts in education lagged behind the missions (religious groups), and between 1847 and 1923, there was no colonial education policy per se (Finlay 1971). After independence, the education system grew and access to education was a response to African aspirations, their desire for parity with European elites, and their recognition of where mobility opportunities resided (Foster 1965). As primary education expanded, the concomitant effect was increased pressure for development of secondary schools, partly because it was the logical extension of existing education and would meet employment needs and opportunities (Finlay 1971). The stock and flow structure of the educational module is as shown figure 8.

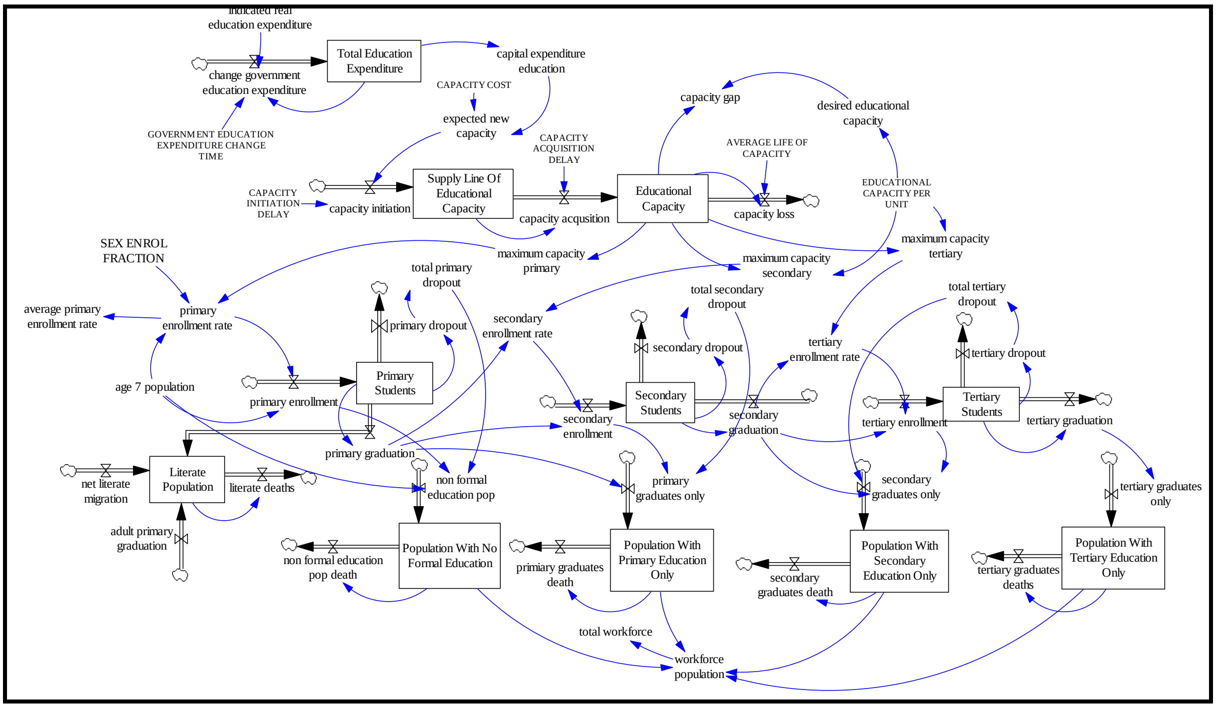

Figure 8: Stock and Flow Structure of Education Module

The education module models the educational capacity, the education system and the recruitment of labor. Leaving the educational system and the recruitment of labor for later discussion, consider the educational capacity: The input to the educational capacity sector is the total education expenditure which comprises of public and private education expenditure. Total education expenditure is used to finance capital and recurrent education expenditure. The capital expenditure finances capital spending that creates educational capacity to support the education system at each level. The allocation of capital spending to primary, secondary and tertiary levels of education is based on a decision variable “educational capital expenditure function”. This decision variable reflects government education priorities. We used subscripts to disaggregate educational capacity into the three educational levels identified in the model, i.e. primary, secondary and tertiary.

Considering the educational system, this sector of the module models the process of students going through schooling from the primary to the secondary and to the tertiary level. Students are disaggregated by both stage and gender with subscripts. The primary education has six stages, each stage is assumed to last for one year, while secondary education has six stages, comprising of junior secondary, i.e. three stages, and senior secondary, i.e. three stages, with each stage duration of one year. Moreover, tertiary education is assumed to comprise of four stages with each stage lasting for a year. The output of each stage and level of education serves as an input to the subsequent stage and level. We assume age seven as the age for starting primary school. The main input to the educational system sector is the age 7 population. The stock of student at each level of education is increased by enrollment and decreased by graduation and dropouts. The following equations are used to represent student population at each level. The equation representing the primary students is:

$$S_t^{pe} = S_{t-1}^{pe} + \left(e_t^{pe} - g_t^{pe}\right) - \left(S_{t-1}^{pe} * dr_t^{pe}\right) \qquad (12)$$

Where, S_{t-1}^{pe} are the previous year primary students, e_t^{pe} is the primary enrollment, g_t^{pe} is the primary graduation and dr_t^{pe} is the primary dropout fraction. The equation representing the secondary students is:

$$S_t^{se} = S_{t-1}^{se} + \left(e_t^{se} - g_t^{se}\right) - \left(S_{t-1}^{se} * dr_t^{se}\right) \qquad (13)$$

Here, S_{t-1}^{se} are the previous year secondary students, e_t^{se} is the secondary enrollment, g_t^{se} is the secondary graduation and dr_t^{se} is the secondary dropout fraction. The equation representing the tertiary students is:

$$S_t^{te} = S_{t-1}^{te} + \left(e_t^{te} - g_t^{te}\right) - \left(S_{t-1}^{te} * dr_t^{te}\right) \qquad (14)$$

Here, S_{t-1}^{te} are the previous year tertiary students, e_t^{te} is the tertiary enrollment, g_t^{te} is the tertiary graduation, and dr_t^{te} is the tertiary dropout fraction.

Considering the recruitment of labor, the model account for the population disaggregated by levels of education. This is important for the labor recruitment process, because the educational attainment of the labor force is differentiated. In the model, the following equations are used to represent the population with different levels of education. The equation representing the population with no formal education is:

$$P_t^{nf} = P_{t-1}^{nf} + \left(p_t^{7} - e_t^{pe}\right) + d^{pe} - \left(P_{t-1}^{nf} * r_t^{nf}\right) \tag{15}$$

Here, P_{t-1}^{nf} is the previous year population with no formal education, p_t^{7} is the age 7 population, e_t^{pe} is the primary enrollment, d^{pe} is the primary dropout and r_t^{nf} is the death fraction of the population with no formal education. The equation for representing the population with primary education is:

$$P_t^{pe} = P_{t-1}^{pe} + \left(g_t^{pe} - e_t^{se}\right) + d^{se} - \left(P_{t-1}^{pe} * r_t^{pe}\right) \tag{16}$$

Where, P_{t-1}^{pe} is the previous year population with primary education only, g_t^{pe} is the primary graduation, e_t^{se} is the secondary enrollment, d^{se} is the secondary dropout and r_t^{pe} is the death fraction of the population with primary education only. The equation representing the population with secondary education is:

$$P_t^{se} = P_{t-1}^{se} + \left(g_t^{se} - e_t^{te}\right) + d^{te} - \left(P_{t-1}^{se} * r_t^{se}\right) \tag{17}$$

Here, P_{t-1}^{se} is the previous year population with secondary education, g_t^{se} is the secondary graduation, e_t^{te} is the tertiary enrollment, d^{te} is the tertiary dropout and r_t^{se} is the death fraction of the population with secondary education. The equation representing the population with tertiary education is:

$$P_t^{te} = P_{t-1}^{te} + g_t^{te} - \left(P_{t-1}^{te} * r_t^{te}\right) \tag{18}$$

Here, P_{t-1}^{te} is the previous year population with tertiary education, g_t^{te} is the tertiary graduation, and r_t^{te} is the death fraction of the population with tertiary education.

We assume age 18 to 60 years as the working age. Therefore the total workforce in the model consist of the total workforce with no formal education, 18 years to 60 years, total workforce with primary education, 18 years to 60 years, total workforce with secondary education, 18 years to 60 years and total workforce with tertiary education, 18 years to 60 years. The equation representing the total workforce is;

$$L_t = l_t^{nf} + l_t^{pe} + l_t^{se} + l_t^{te} \qquad (19)$$

Where L_t is the total workforce, l_t^{nf} is the workforce with no formal education, l_t^{pe} is the workforce with primary education only, l_t^{se} is the workforce with secondary education, l_t^{te} is the workforce with tertiary education. The workforce with no formal education is represented by equation (20) as:

$$l_t^{nf} = \sum_{t=1}^{n} age18 \leq P^{nf}{}_t \leq age60 \qquad (20)$$

Equation (21) represents the workforce with primary education only as:

$$l_t^{pe} = \sum_{t=1}^{n} age18 \leq P^{pe}{}_t \leq age60 \qquad (21)$$

Representation of the workforce with secondary education is as shown in equation (22):

$$l_t^{se} = \sum_{t=1}^{n} age18 \leq P^{se}{}_t \leq age60 \qquad (22)$$

The workforce with tertiary education is represented by equation (23) as follows:

$$l_t^{te} = \sum_{t=1}^{n} age18 \le P^{te}{}_t \le age60 \qquad (23)$$

4.5 Access to Basic Health Care Module

The stock and flow structure of access to health care module is as shown in figure 9.

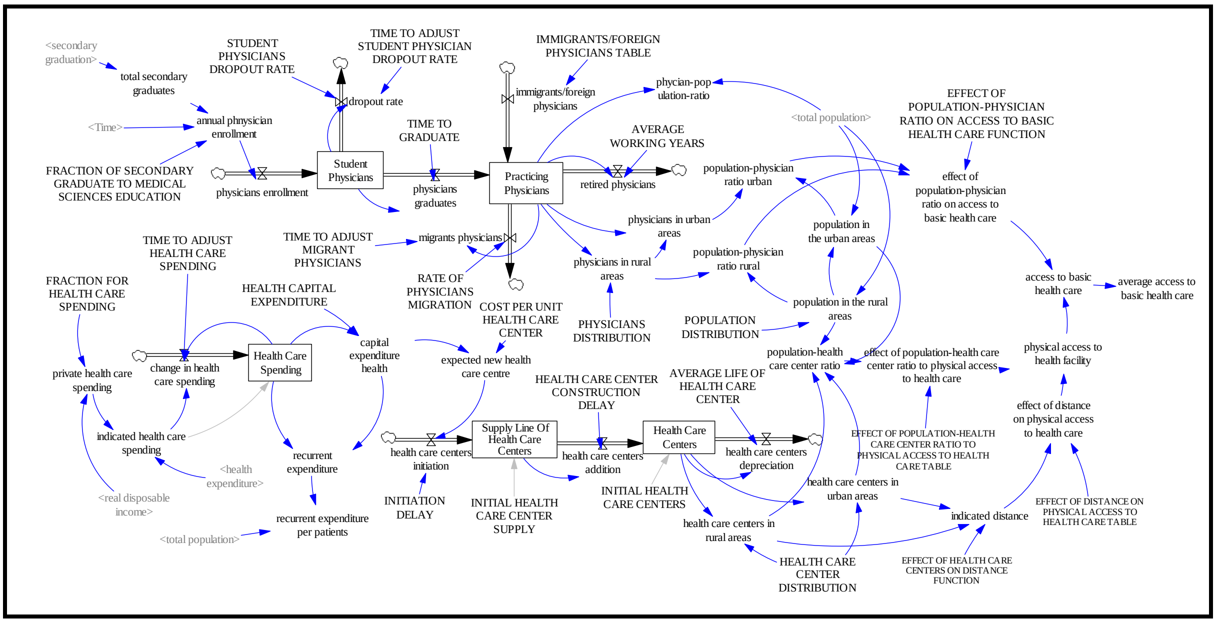

Figure 9: Stock and Flow Structure of Access to Basic Health Care Module

The access to basic health care module represents health capacity. It includes the population of physicians and the process of student's physicians going through schooling and eventually becoming practicing physicians to contribute to health care delivery. The model also accounts for the distribution of health capacity and practicing physicians within the urban and rural parts of the country and its effects on health care access. In the module, we assume that capital expenditure on health contribute to the creation of health capacity. Therefore, as capital health expenditure increases it's presupposed that health capacity will increase. It has been established that in most developing countries, including Ghana, the per capita social services is more skewed towards the urban areas compared to the rural areas. We therefore assume that a higher proportion of health centre's will be located in the urban areas resulting, in lower population-health centre ratio in the urban areas than, what we find in the rural areas.

In the module, we assume a fraction of the students going to the university to enroll into medical school and become student physicians. Based on the medical school educational structure in Ghana, we assume 6 years delay from enrollment to medical school to becoming a practicing physician. The population of student's physicians increases by enrollment and decreases by graduation or dropout rate. The population of practicing physicians increases by graduates from the medical school, and immigration of physicians whereas retirement and out-migration decreases the population of practicing physicians. It has been established in Ghana that there are more physicians per capita in the urban areas as compared to the rural areas. The model incorporates this vital information by assigning a higher proportion of practicing physicians per capita to the urban area. Access to basic health care depends on physical access to health facility and effect of population-physician ratio on access to basic health. Physical access to health facility is determined by population-health centre ratio and average distance to access health centre. It is estimated that the rural population travels an average distance of 10km to access a health facility which causes their physical access to health services to be low compared to the urban population with an average distance of 2km. Moreover, it is hypothesized that, as the population to health centre ratio, increases, access to health decreases due to the inability of the limited facility to take proper care of such a larger population.

4.6 Government Revenue/Expenditure Module

The structure of the government expenditure and revenue module is as shown in figure 10 below:

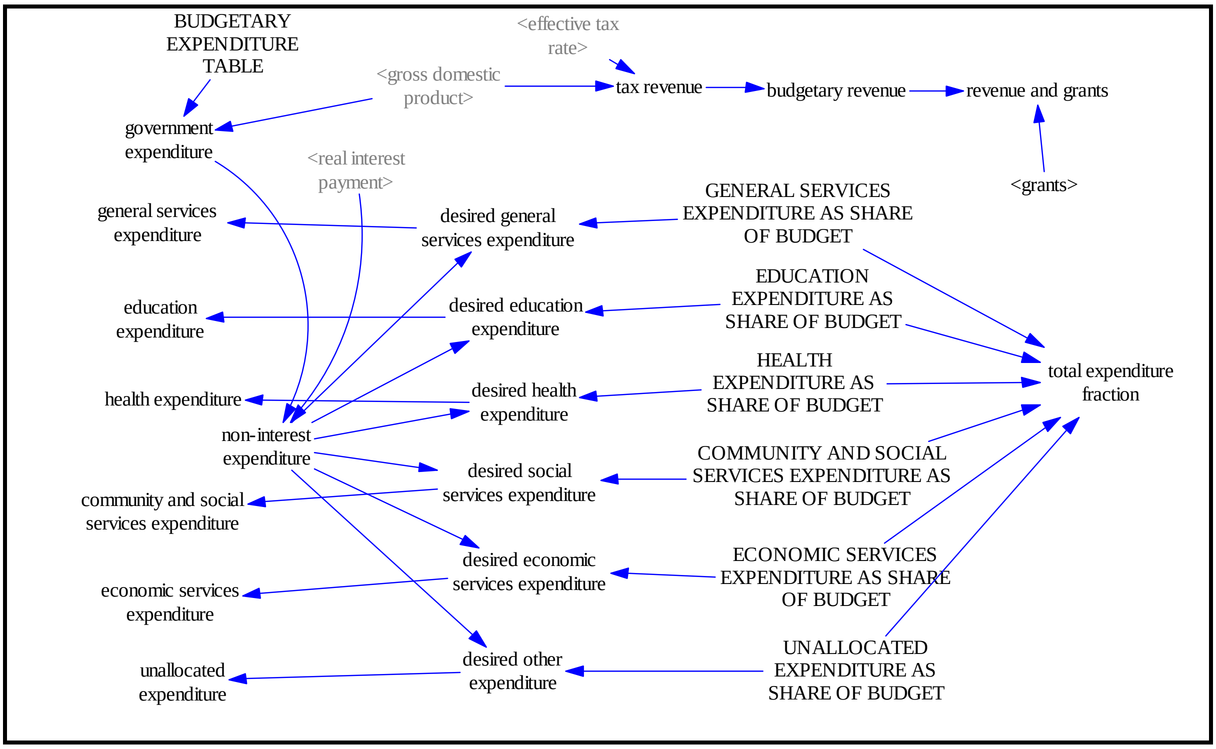

Figure 10: Structure of the Government Expenditure and Revenue Module

This module represents government expenditure and revenue accounting identities underlying the government fiscal policy. Government expenditure is defined as the budgetary expenditure fraction of gross domestic product. Budgetary expenditure fraction is a decision variable, where the government decides on the total expenditure for each fiscal year. The total budgetary expenditure fraction is estimated exogenously from historical data by computing the ratio of government expenditure as a fraction of GDP. Non-interest expenditure is the difference between government expenditure and real interest payments. The total government expenditure consists of six functional expenditures. The functional expenditures are; general services, education, health, community/social services, economic services and unallocated expenditure. The functional expenditure share of non-interest expenditure is estimated from historical data. The allocation of the functional expenditure is taken as a decision variable where government based on the expenditure priorities decides the fraction of non-interest expenditure to be spent on each area. Public investment is captured in the functional expenditure by the share of government expenditure for economic services. In the government expenditure accounting, for instance, desired general services expenditure is the actual government expenditure on general services and general services expenditure is the actual expenditure. It is hypothesized in the government expenditure accounting that desired expenditure equals the real expenditure.

Considering government revenues the tax revenue is estimated as a function of the effective tax rate and gross domestic product. The effective tax rate is the actual tax fraction of income (GDP) actually collected by the tax authorities, estimated from historical data. Grants are exogenous variable from historical data. Revenues and grants is the sum of tax revenues and grants.

4.7 Public Debt Module

The conceptual framework of the public debt module is a SD-based adaptation of the government budget constraint literature (Christ 1968 ; Blinder and Solow 1973). This literature sets out that the fiscal deficit must equal the sum of domestic borrowing, foreign borrowing and seignorage and considers the impact of deficit financing on output (Islam and Wetzel 1991). Guided by the economic models suggesting that growth can be stepped-up by increasing resources for investment, governments of developing countries have often resorted to borrowing to supplement revenue. The borrowed resource is often used for investment purposes and/or consumption smoothing (Campbell 1989). However, due to various reasons, including increased spending resulting from population growth, external shocks, bad economic management, as well as output decline and its slow recovery thereafter, government spending consistently exceed its revenue, hence causing a continued borrowing (Lindauer and Velenchik 1992; Jha 2001; Ghatak and Sanchez-Fung 2007). As a consequence, debt accumulates causing a heavy debt burden.

The public debt model demonstrates transparently the mechanisms that generate debt. Public debt disaggregates into domestic and foreign sources. Subscripts[10] are used to separate domestic debt from foreign debt. Principal relief and interest relief in the model are only applicable to foreign debt, and are represented by exogenous variables generated from historical data.

[10] The following variables: (borrowing, borrowing fraction, public debt, total public debt, repayment, debt maturity, interest payments due, interest payments, obligatory interest rate, interest rate, interest addition, accrued interest, interest subtraction) in the public debt model as shown in figure 1a are subscript variables separated into domestic and foreign.

We assume that government finances its budget deficit by borrowing from domestic and foreign sources and depict it as a result of a government budget constraint:

$$pd_t + i_t^{\,d} D^d{}_{t-1} + i_t^{\,f} D^f{}_{t-1} + {D^d{}_{t-1}}/{m^d} + {D^f{}_{t-1}}/{m^f} = Bd_t = gB_t^{\,d} + gB_t^{\,f} \qquad (21)$$

Where pd_t is primary deficit, $i_t^{\,d}$ is the domestic interest rate, $D^d{}_{t-1}$ is the domestic public debt of the previous year, $i_t^{\,f}$ is foreign interest rate, $D^f{}_{t-1}$ is the foreign public debt of previous year, m^d is the domestic debt maturity, , m^f is the foreign debt maturity, Bd_t is the budget deficit, $gB_t^{\,d}$ is the domestic borrowing and $gB_t^{\,f}$ is the foreign borrowing.

We express the stock of total public debt (D_t) from the government budget constraint equation and the public debt model in figure 14 as follows:

$$D_t = D^d{}_t + D^f{}_t \qquad (22)$$

$$D^d{}_t = \left[D^d{}_{t-1} + (dt)gB_t^{\,d} - (dt)\left({D^d{}_{t-1}}/{m^d}\right)\right] + \left[AI^d{}_{t-1} + (dt)Ia^d{}_t + (dt)Ui^d{}_t - (dt)Is^d{}_t\right] \qquad (23)$$

$$D^f{}_t = \left[D^f{}_{t-1} + (dt)gB_t^{\,f} - (dt)\left({D^f{}_{t-1}}/{m^f}\right)\right] + \left[AI^f{}_{t-1} + (dt)Ia^f{}_t + (dt)Ui^f{}_t - (dt)Is^f{}_t\right] + \left[D^f{}_t(f_t - f_{t-1})\right] - \left[(dt)rD^f{}_{t-1}\right] \qquad (24)$$

Here $AI^d{}_{t-1}$ is domestic accrued interest obligation of the previous year, $(dt)Ia^d{}_t$ is the domestic interest obligation accrual, $(dt)Ui^d{}_t$ is the domestic unpaid interest payments, $(dt)Is^d{}_t$ is domestic interest obligation elimination, $AI^f{}_{t-1}$ is the foreign accrued interest obligation of the previous year, $(dt)Ia^f{}_t$ is foreign interest obligation accrual, $(dt)Ui^f{}_t$ is foreign unpaid interest payments, $(dt)Is^f{}_t$ is foreign interest obligation elimination, f_t is the current average exchange rate per year, f_{t-1} is average exchange rate of the previous year and $(dt)rD^f{}_{t-1}$ is the foreign public debt forgiven per year.

Equation (22) demonstrates that total public debt consists of domestic public debt and foreign public debt. Equation (23) defines the domestic public debt, where the first term of the equation represents the integration of domestic borrowing and domestic repayment into the domestic public debt. The second term characterizes the integration of domestic interest obligation accrual, domestic unpaid interest payments and domestic interest obligation elimination into the domestic accrued interest obligation. In equation (24), the first term of the equation represents the integration of foreign borrowing and foreign repayment into foreign public debt. The second term represents the integration of foreign interest obligation accrual, foreign unpaid interest payments and foreign interest obligation elimination into foreign accrued interest obligation. The third term represents the foreign debt adjustment[11], where the change in exchange rate is multiplied by the foreign debt. The last term represents debt relief.

The public debt model adopted the 'co-flow structure' (Sterman 2000) to account for 'accrued interest obligation'. As government borrows, it attracts an interest obligation, which is referred to as 'interest obligation accrual' (see figure 12). The 'interest obligation accrual' is stored into a stock of 'accrued interest obligation'. 'Accrued interest obligation' represent the total obligatory interest to be serviced per year. On the other hand, when repayment on debt is made, it decreases 'accrued interest obligation' through 'interest obligation elimination'. In sum, the co-flow structure helps us to keep track of 'accrued interest obligation' as an attributes of public debt.

Obligatory interest rate is estimated as accrued interest obligation divided by public debt. Assuming that government is able to service all interest payment due, where interest payments due equals' interest payment. In that situation, 'obligatory interest rate' (as is being referred to in this model) would be known as 'average interest rate'. However, in the model, we postulate that depending on government debt burden (measured by debt-GDP-ratio), interest payments due can be rescheduled for future payment. The addition of unpaid interest payments to the stock of accrued interest obligation create imbalance between public debt and accrued interest obligation, therefore, the average interest rate on public debt is referred to as 'obligatory interest rate'.

Unpaid interest is the difference between interest payments due and interest payment. The model separates interest payments due from interest payments because when government debt burden is high, deficit spending is reduced by rescheduling interest payments which inadvertently reduces borrowing. Interest payments due is estimated as public debt multiplied

[11] Foreign debt adjustment is the foreign debt incurred due to changes in exchange rate.

by obligatory interest rate. Interest payments are estimated as interest payment due multiplied by effect of debt-GDP-ratio on interest payments. The non-linear function of the effect of debt-GDP-ratio on interest payment is as shown in figure 11 below. According to figure 11, as debt-GDP-ratio increases, governments' ability to service interest payments is reduced; as a result a fraction of the interest payments due is actually paid.

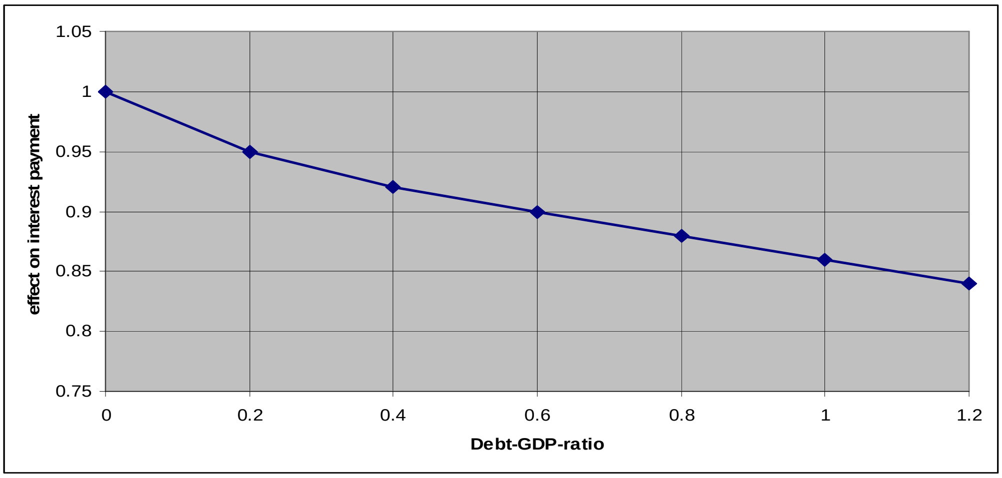

Figure 11: Non-Linear effect of Debt-GDP-Ratio on Interest Payment

The foreign debt adjustment is most often unaccounted for in many studies such as (Simonsen 1985; Meijdam and Stratum 1989; Saeed 1993; Senhadji 1997; Helbling, Mody et al. 2004). In many developing countries, foreign debt adjustment is a significant debt component that is often not recognized. The foreign debt adjustment in the public debt module captures the debt incurred due to exchange rate changes. The adoption of a Structural Adjustment policy of currency exchange liberalization and the resulting devaluation, as well as currency devaluation policies significantly increased the exchange rate in many developing nations, Ghana included, in the 1980s after many years of a fixed exchange rate policy regime (Islam and Wetzel 1991; Konadu-Agyemang 2001). Since foreign loans are contracted in foreign currency, the sudden increase in the exchange rate following the liberalization of the exchange market significantly increased the foreign debt in local currency equivalence. This is captured in the model to account for the exchange rate effect on foreign debt accumulation. As the exchange rate increases[12], *ceteris paribus* foreign debt is increased by the debt incurred from the exchange rate increase (foreign debt adjustment). It is

[12] Exchange rate is the current market price of 1 US dollar to 1 Cedi (Ghanaian currency). An increase in exchange rate is when more cedi is needed to exchange for 1 US dollar. That is to say that the local currency (cedi) has depreciated or the US dollar has appreciated.

important to note that foreign debt adjustment arises only when the exchange rate changes. In cases where exchange rate remains stable, there is no foreign debt adjustment. The stock and flow structure of the public debt module is as shown in figure 12.

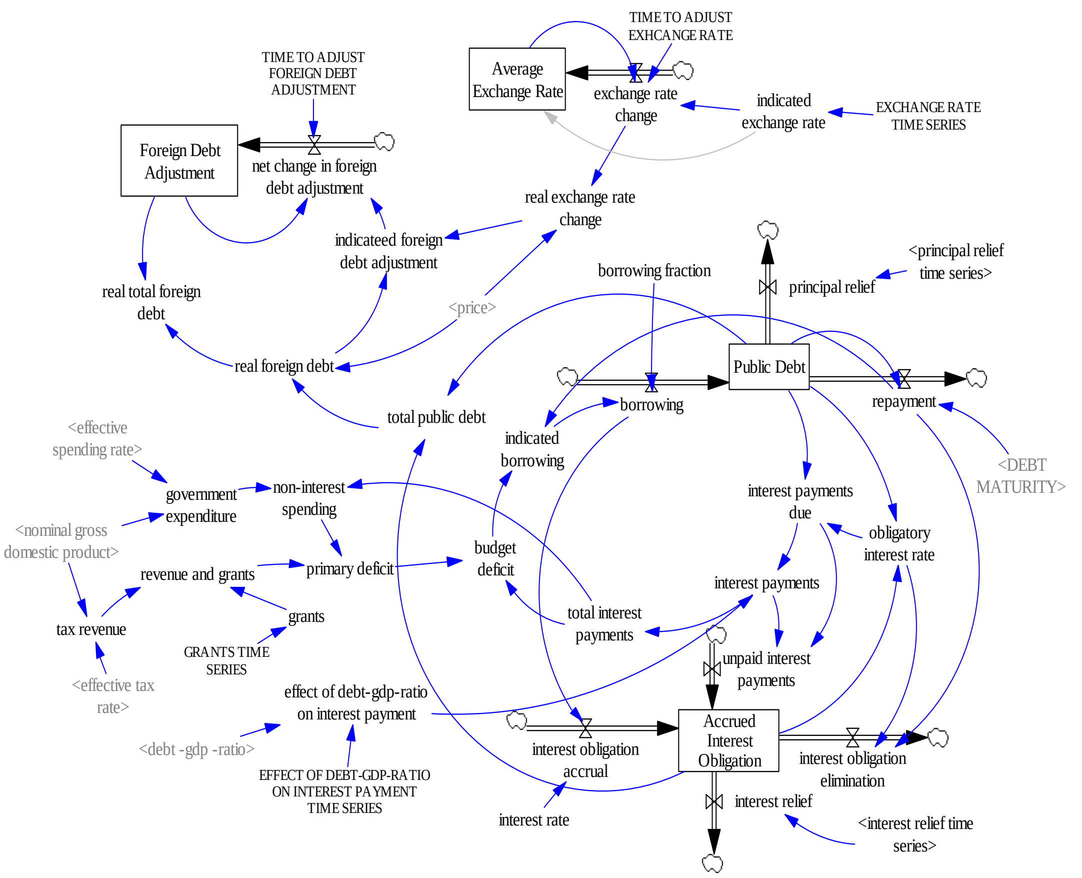

Figure 12: Stock and Flow Structure of Public Debt

4.8 Households Module

In the household module, real total household income is calculated as the sum of income (GDP) and total net transfers. In other words, real total household income equals the sum of income from production, private transfers, private income and interest payment from domestic loans. Private transfer and private income are exogenous variables from historical data. Disposable income to households is the sum of after-tax income. It is assumed in the model that, the household use their disposable income for consumption and or savings. The consumption decision of households in the model assumes that households will spread existing resources to achieve a smooth consumption profile and the excess resources will go for savings. We speculate that as disposable income rises, consumption as well as savings increases. Over time, savings are used for investment which builds-up capital for production whereas; increased consumption can move aggregate demand upward consequently leading to more production to meet demand for goods and services. The structure of the household module is as shown in figure 13.

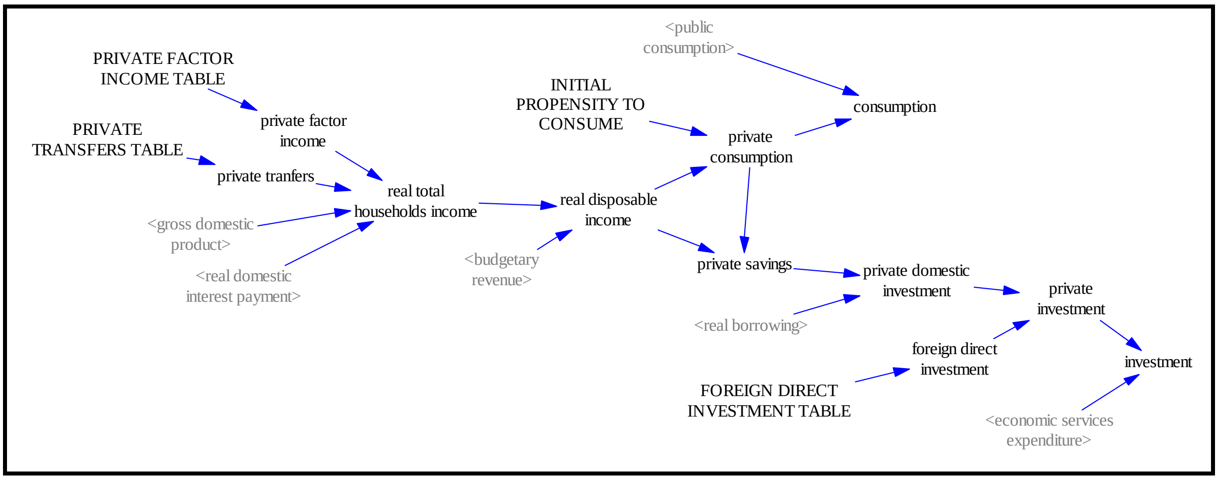

Figure 13: Structure of Household Module

4.9 Land Module

The land module represents the urban land, agricultural land in use and other land[13] and account for the factors responsible for the changes in these categories of land. In the model, urban land increases as agricultural land and other land are converted for urban land use due to population increase in urban areas. In the model we assume a per capita space for each person in the urban area. Therefore, desired urban land is defined as urban population by per capita space. Agricultural land increases as more other land is transformed into agricultural land and decreases as agricultural land is moved to other land due to land fertility decline and transformation of agricultural land to urban land due to urbanization. Desired agricultural land is calculated as indicated per capita land for agriculture by rural population. Here, desired agricultural land is the land desired by farmers to support their livelihood. It is assumed that agricultural activities occur only in the rural areas. Indicated per capita land is defined as normal per capita land for agriculture and effect of fertilizer use on agricultural land expansion. It is postulated that as fertilizer use decreases due to increase in fertilizer prices, per capita land for agriculture increases due to reduction in land fertility. Therefore,

[13] Land other than for agriculture and urban land use

for a farmer to achieve the production targets, land size must be increased. The stock and flow structure of the land module is as shown in figure 14.

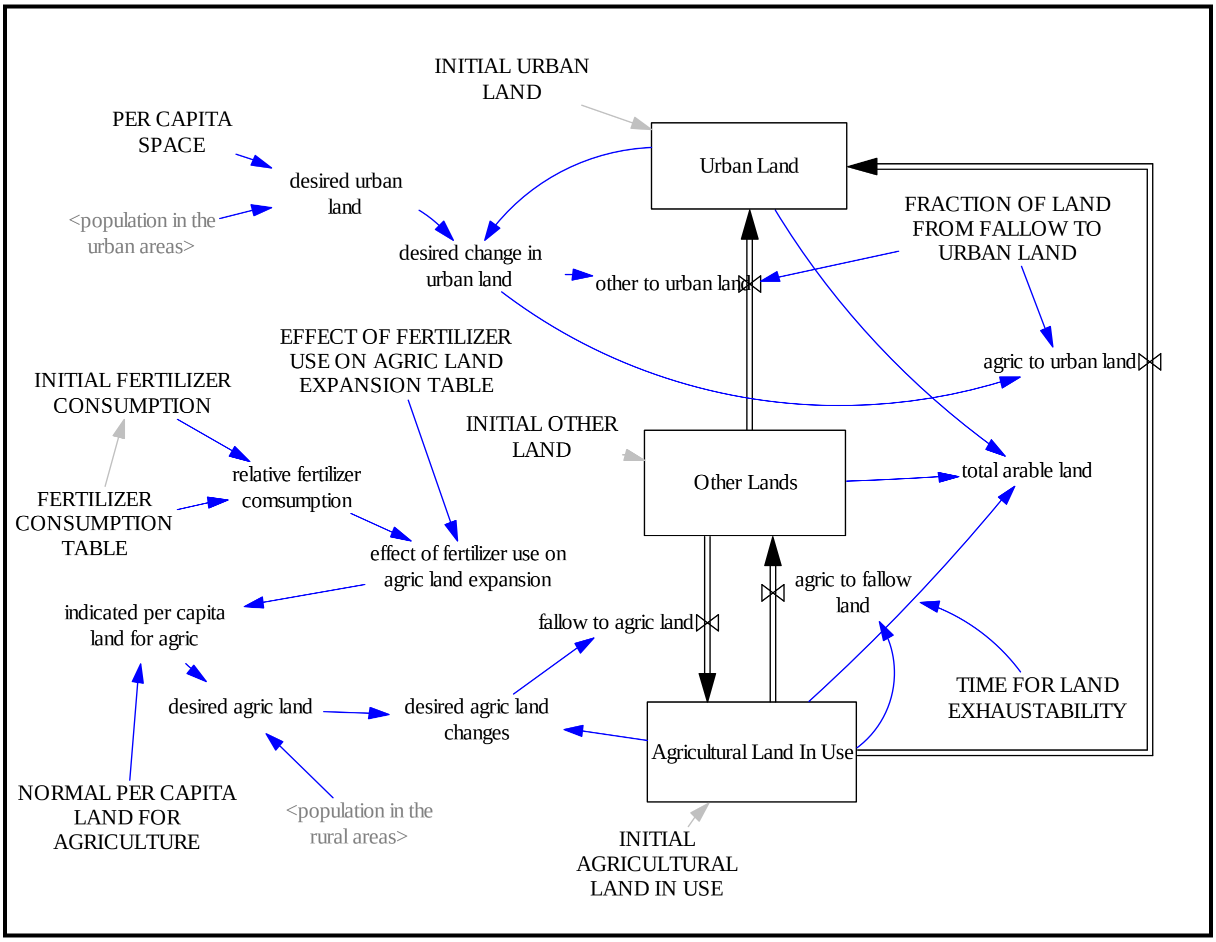

Figure 14: Stock and Flow Structure of Land Module

4.10 Employment Module

The stock and flows structure of the employment module is shown in figure 16.

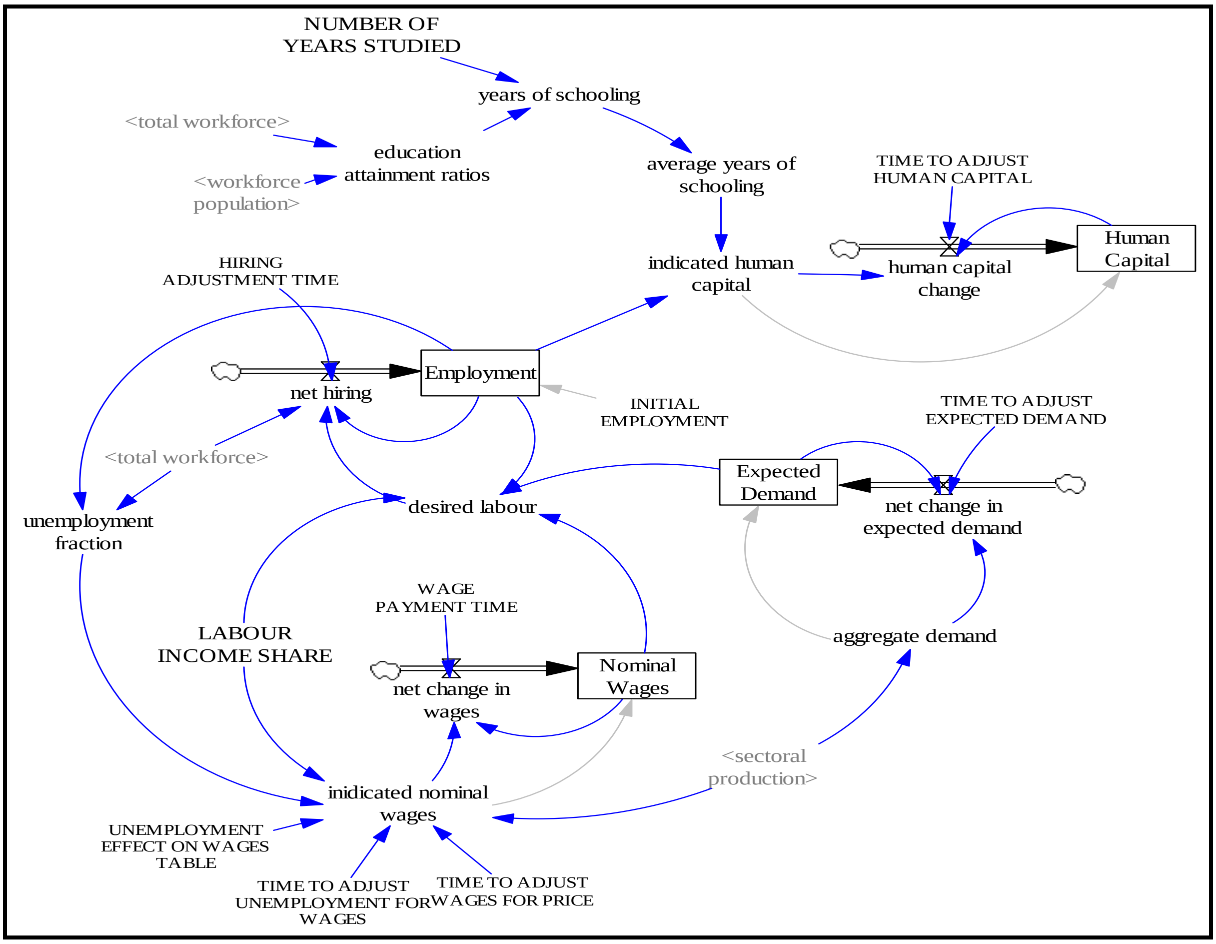

Figure 16: Stock and Flow Structure of Employment Module

Neoclassical economics postulate that employment depends on both the supply of and demand for labor. Demand for labor is represented in the model by a variable called “desired labor”. As desired labor changes, employment adjusts through net hiring. Desired labor depends positively on expected aggregate demand for goods and services and negatively on wages. Net hiring is the difference between desired labor and employment divided by the hiring adjustment time. The total workforce is defined as the working age population (age 18-60 years). Wages is the income share of labor (income is taken to be equal to GDP). In the model, wages is formulated by exponential smoothing. Indicated wages are the negotiated wages. The real wages adjusts to their indicated values with a delay (wages payment time). This adjustment time determines how rapidly wages respond to the result of negotiations. In the model, wages payment time is monthly, adjustment can take place at a minimum of 0.08

years. Indicated (negotiated) wages is a function of gross domestic product and labor income share adjusted by the unemployment effect on wages. The equation for representing employment is as follows;

$$Ep_t = Ep_{t-1} + (dt)nh_t \qquad (25)$$

Where Ep_t is current employment, Ep_{t-1} is previous year employment, nh_t is net hiring. Net hiring is represented by equation (34) as;

$$nh_t = If\left[wf_t > Ep_t, (dL_t - Ep_t)/\Phi, 0\right] \qquad (26)$$

Here wf_t is total workforce, dL_t is desired labor, and Φ is time delay to adjust net hiring. Equation (35) represents the desired labor as;

$$dL_t = {}^{xd_t(1-\alpha)}\!\Big/_{Nw_t / Ep_t} \qquad (27)$$

Here, xd_t is expected demand, $(1-\alpha)$ is labor income share, and Nw_t is nominal wage.

The supply of labor is referred to as total workforce. The unemployment fraction is the unemployment relative to the total workforce. Assume that the unemployment fraction increases unexpectedly. This will push wages downwards, thus keeping wages lower than when the economy is in equilibrium, i.e. normal. The effect of the unemployment fraction on wages is represented by the nonlinear function portrayed in figure 15. Figure 15 shows that, as the unemployment fraction increases, wages are adjusted downwards because the unemployed labor would rather work for less wages than being unemployed. We assume that, decreasing wages will stimulate demand for labor causing an increase in employment.

Figure 15: Non-linear effect of unemployment fraction on wages

The employment module postulates that employment opportunities are filled by workforce with the highest educational attainment respectively. In other words, it is assumed that workforce with tertiary education attainment is the first category of workforce to be employed, followed by workforce with secondary education attainment, primary education attainment and lastly, non formal education respectively. The acquisition of human capital is represented by an exponential smoothing. The real human capital adjusts to its indicated value with a delay (time to adjust human capital). Indicated human capital is a function of average years of schooling and employment. The representation of human capital in the model is based on Loening's human capital estimation method (Loening 2005). The equation representing human capital is as shown below:

$$hc_t = hc_{t-1} + (dt)chc_{t-1} \quad (28)$$

Here, hc is the human capital and chc is the change in human capital. The change in human capital is calculated in the model as:

$$chc_t = (ihc_{t-1} - hc_{t-1}) / thc \quad (29)$$

Here, ihc_{t-1} is the previous year indicated human capital and thc is the time to adjust human capital. The indicated human capital is calculated in the model as:

$$ihc_t = Ep_{t-1} * ays_{t-1} \quad (30)$$

Here, Ep_{t-1} is previous year employment and ays_{t-1} are the previous year average years of schooling. The average years of schooling is defined as:

$$ays_t = SUM\left(ear_{t-1} * nys\right) \qquad (31)$$

Here, ear_{t-1} is the previous year education attainment ratio and nys is the number of years of studies. The educational attainment ratio measures the level of education among the workforce.

4.11 Agriculture Module

Agricultural production in developing countries has virtually been dominated by small-scale farmers who are known to produce up to 90% of food consumed in some countries in Africa (Lambert 1989; IFAD 1993). In Africa, it is estimated that small-scale farmers make up at least 73% of the farming population (Garrison 1990; IFAD 1993; Odulaja and Kiros 1996) and it is expected to be about 90% in Ghana. The stock and flow structure of the agricultural sector is as shown in figure 17.

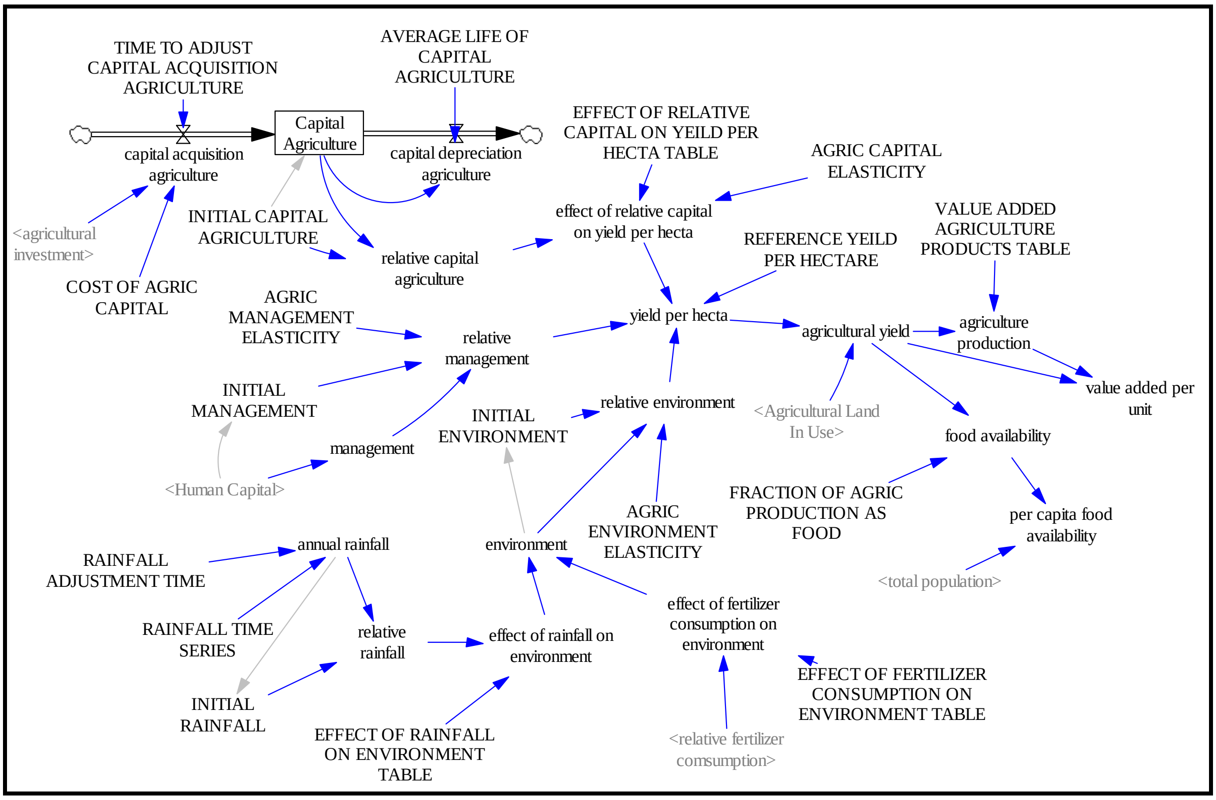

Figure 17: Stock and Flow Structure of Agricultural Module

The agricultural production function in the module reflects the characteristics described. The production function used in the agricultural module is based on the agricultural production function by Odulaja and Kiros (1996)[14] with modification. The modification here is that, we introduce a fourth factor of production, i.e. capital, which represents investment in agricultural research and extension services [15]. In most developing countries in Africa, agricultural activities are small-scale, which make little use of agricultural machinery. However, government investment in agriculture through agricultural research departments to produce high-breed seeds, to come out with best farming practices and advice farmers on cropping pattern is considered here as the capital in the agriculture model. In the module, agricultural production ($Y^a{}_t$) is calculated as a function of yield per hectare (yh_t) and land area cultivated (cl_t).

$$Y^a{}_t = yh_t * cl_t \qquad (32)$$

Where yield per hectare (yh) is portrayed as a function of reference yield per hectare (ry), relative environmental effect (en), relative management effect (rm), relative capital effect (K^a) represented as;

$$yh_t = ry * en * rm * K^a \qquad (33)$$

In the module, we define relative environment effect ($_e\, en$) as;

$$en = \left[\left(rf_t / rf_{t-1} \right) * \left(ft_t / ft_{t-1} \right)\right]^{\beta} \qquad (34)$$

Here, rf_t is average annual rainfall, and rf_{t-1} is the initial average annual rainfall, ft_t is the current fertilizer consumption, ft_{t-1} is the initial fertilizer consumption and β is the agric environment elasticity.

Relative management effect (rm) is portrayed in the module as;

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[14] . $Y = f(L)g(E)h(M)$. Where L is land size, E is environmental effects and M is management effects and f, g, h are functions relating to L, E and M respectively.

[15] Is the application of scientific research and new knowledge to agricultural practices through farmer education

$$rm = \left({hc^a}_t \big/ {hc^a}_{t-1} \right)^{\delta} \qquad (35)$$

Here, ${hc^a}_t$ is the current human capital in agricultural sector, and ${hc^a}_{t-1}$ is the initial human capital in agricultural sector, and δ is the agric management elasticity.

Lastly, relative capital is portrayed as;

$$K^a = \left(Va_t \big/ Va_{t-1} \right)^{\varepsilon} \qquad (36)$$

Here Va_t is the current agricultural capital, i.e. investment in agricultural research and agricultural extension staff, Va_{t-1} is the initial agricultural capital and ε is agric capital elasticity.

In the agricultural module, agricultural production is driven by the increase in availability of the production factors i.e. land, environment, management and capital. Agricultural value added is the price of agricultural products and agricultural production is calculated as agricultural yield by value added to agriculture.

4.12 Industry Module

The stock and flow structure of the industrial module is as shown in figure 18.

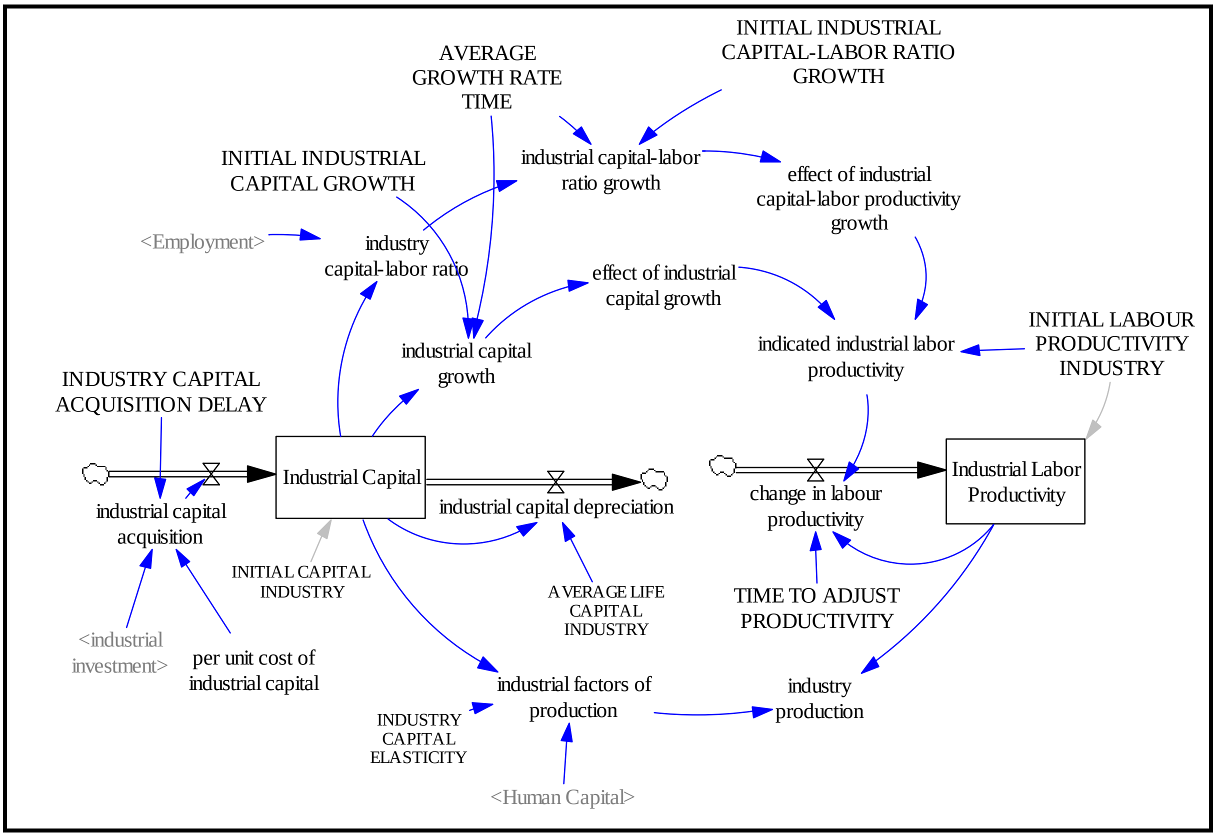

Figure 18: Stock and Flow Structure of Industrial Module

The industry module employs a Cobb-Douglas production function to represent industrial production. Industrial capital is accumulated through industrial capital acquisition and industrial capital depreciation. Industrial capital acquisition is defined by industrial investment divided by per unit cost of industrial capital. Industrial capital depreciation is based on the perpetual inventory method with a common geometric depreciation rate of 4% (Collins and Bosworth 1996). This gives an average life of industrial capital of 25 years. Industrial human capital represents the human capital accumulation in the industrial sector of the economy. Industrial production is represented as;

$$Y^i_t = \left(K^i_{t-1}\right)^{\mu i} * \left(hc^i_{t-1}\right)^{1-\mu i} * lp^i_{t-1} \qquad (37)$$

Here, Y^i_t is the industrial production, K^i_{t-1} is the industrial capital, hc^i_{t-1} is the human capital in the industrial sector, lp^i_{t-1} is the industrial labor productivity and μi is the industrial physical capital elasticity.

Labor productivity calculation in the module is based on the labor productivity function (Sargent and Rodriguez 2000). In the industrial module, we define labor productivity as;

$$lp^{i}{}_{t} = lp^{i}{}_{t-1+}(dt)clp_{t-1} \qquad (38)$$

Here, $lp^{i}{}_{t}$ is the industrial labor productivity, clp_{t-1} is the change in industrial labor productivity. Change in the industrial labor productivity is the difference between indicated labor productivity and labor productivity adjusted by time. Indicated labor productivity is a function of initial industrial labor productivity, effect of industrial labor-capital ratio growth and effect of industrial capital growth.

4.13 Service Module

The stock and flow structure of the service module is as shown in figure 19.

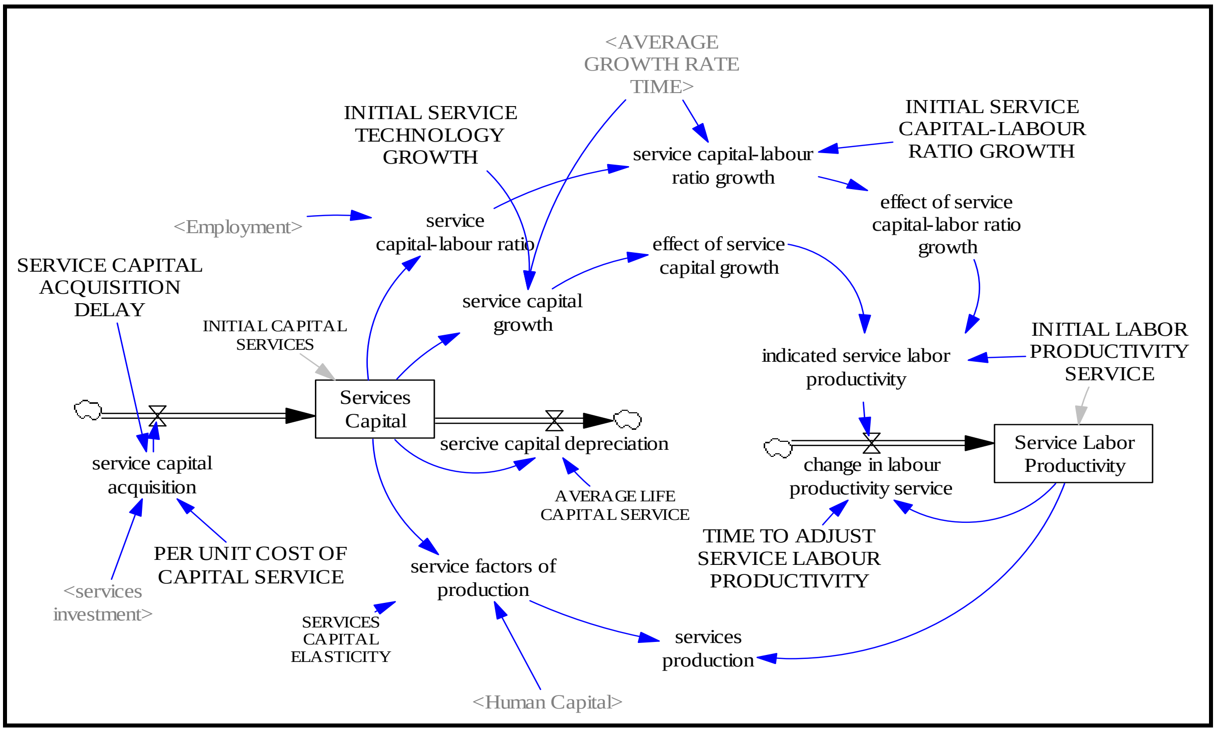

Figure 19: Stock and Flow Structure of Service Module

The service module like the industrial module uses the Cobb-Douglas production function to estimate the service production. Service capital accumulates through service capital acquisition and service capital depreciation. Service capital acquisition is the delayed capital acquisition which is service investment divided by per unit cost of capital service. Service capital depreciation follows the perpetual inventory estimation of capital with 6.67%

depreciation rate which translates to 15 years of service capital life. Service labor productivity follows the definition of Sargent and Rodriguez (2000) as explained in the industrial sector. The service production is defined as;

$$Y^s{}_t = \left(K^s{}_{t-1}\right)^{\mu s} * \left(hc^s{}_{t-1}\right)^{1-\mu s} * lp^s{}_{t-1} \qquad (39)$$

Here $Y^s{}_t$ is the service production, $K^s{}_{t-1}$ is the service capital, $hc^s{}_{t-1}$ is the human capital in the service sector, $lp^s{}_{t-1}$ is the service labor productivity and μs is the service physical capital elasticity.

4.14 Investment/Aggregate Production Module

The investment module simply represents how agricultural, industrial and service investments are calculated. In the model, investments are apportioned to the three sectors of the economy (agriculture, industry and services) by a decision variable, investment share. We assume that 10 percent of investment goes to the agricultural sector, 40 percent to the industrial sector and 50 percent to the service sector. Investment to the various sectors is portrayed as investment multiplied by investment share. Gross domestic product is the sum of industrial production, service production and agricultural production. The sector GDP ratio accounts for the ratio of each sector of production to the total production. The structure of investment and production is shown in figure 20.

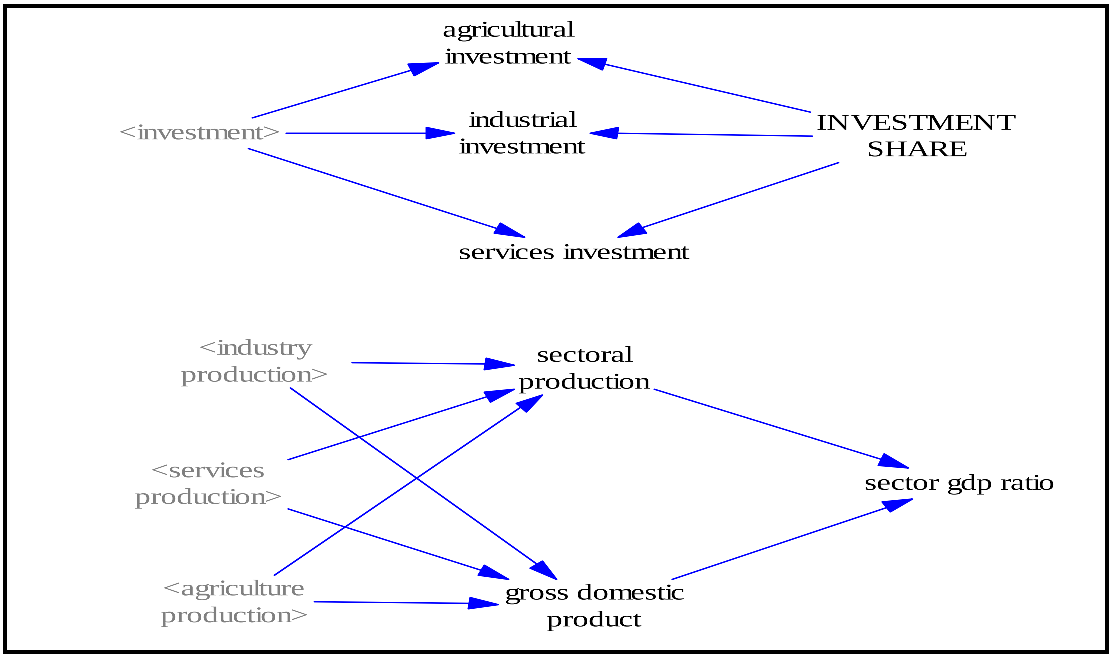

Figure 20: Structure of Investment and Aggregate Production Module

5. Validation

Validation of the model is an integral part of our model development (Forrester and Senge 1980; Sterman 1984; Barlas 1996; Sterman 2000; Schwaninger and Grosser 2008). First, the model is firmly grounded in empirical research on economic growth (Smith 1776; Solow 1956; Romer 1990; Stern 1991; Solow 1994; Ranis, Stewart et al. 2000), demographic transition theory (Thompson 1928), SD-based adaptation of the government budget constraint literature (Christ 1968 ; Blinder and Solow 1973) and the debt trap theory (Saeed 1993). Second, the validation of the parameter values utilized draw on variety of data sources such as; quarterly digest of statistics from Ghana Statistical Service, world development indicators from the World Bank, international financial statistics from IMF, world population prospects from UNDP, demographic and health surveys in Ghana and expert opinions from interviews. Third, the model has been extensively analyzed using structure-oriented behavior test (e.g., extreme condition test, boundary adequacy test and verification test). Finally, in the behavior reproduction tests we compared the simulation output with several historical times series (e.g., total population, life expectancy (female), life expectancy (male), under-five mortality, government expenditure, gross domestic product, household income, disposable income, foreign debt and domestic debt). The result from the behavior reproduction tests (Theil inequality) is presented as follows:

5.1 Behavior reproduction test

In a behavior reproduction tests we compare the simulation output with several historical times series. Summary statistics of historical fit (Sterman 1984) has become a standard validity test for system dynamics models (Oliva 1998). The summary statistics proposed by Sterman (2000), apply mean-square-error (MSE) to the measurement and interpretation of forecast errors by comparing the model output to historical data. The MSE is defined as:

$$\frac{1}{n}\sum_{t=1}^{n}\left(S_t - A_t\right)^2 \qquad (40)$$

Where n is the number of observations, t is time, S_t is the simulated value at time t, and A_t is the historical value at time t.

Failure to fit the historical data with simulated value may be caused by a poor model or by a large degree of randomness in the historical data (Sterman 1984). Sterman employs the Theil statistics (Theil 1966) to decompose the MSE. The 'inequality proportions' (Theil statistics) derived from the MSE are:

$$U^{M} = \frac{(\bar{S} - \bar{A})^2}{\frac{1}{n}\sum (S_t - A_t)^2} \qquad (41)$$

Here, U^M is the fraction of MSE due to bias, $\bar{S}$ is the mean of the simulated values and $\bar{A}$ is the mean of the historical values.

$$U^{S} = \frac{(S_S - S_A)^2}{\frac{1}{n}\sum (S_t - A_t)^2} \qquad (42)$$

Here, U^S is the fraction of MSE due to unequal variance, S_S is the standard deviation of simulated values and S_A is the standard deviation of historical values.

$$U^{C} = \frac{2(1 - r)\ S_S S_A}{\frac{1}{n}\sum (S_t - A_t)^2} \qquad (43)$$

Here, U^C is the fraction of MSE due to unequal covariance and r is the correlation coefficient.

$U^M + U^S + U^C = 1$. Table 3 present the error decomposition of the socio-economic model.

Variable	RMSE	Inequality Statistics			R^2
		U^M	U^S	U^C	
Total population	0.018	0.013	0.320	0.667	0.998
Life expectancy (female)	0.020	0.192	0.760	0.048	0.998
Life expectancy (male)	0.025	0.437	0.537	0.026	0.998
Under-five mortality	0.190	0.573	0.332	0.096	0.952
Government expenditure	0.433	0.352	0.056	0.591	0.759
Gross domestic product	0.115	0.167	0.167	0.666	0.849
Household income	0.119	0.185	0.298	0.517	0.871
Disposable income	0.122	0.172	0.230	0.598	0.827
Foreign debt	0.800	0.128	0.043	0.829	0.773
Domestic debt	0.286	0.407	0.158	0.435	0.856

Table 3: Error Decomposition (Theil Inequality)

Table 3 demonstrates that the model reproduces these variables with a high accuracy ranging from $r^2 = 0.75$ to $r^2 = 0.998$. This indicates that there is a strong correlation between the model output and historical data. On the behavior validity, table 3 shows the results of total error from MSE breaks down into bias (U^M), unequal variance (U^S) and unequal covariance (U^C). The result in table 3 indicates that most of the variables except i.e. government expenditure, foreign debt and domestic debt have RMSE above 20%. This strongly indicates that the model endogenously tracks major variables quite well. Moreover, all the variables except i.e. life expectancy (female), life expectancy (male) and under-five mortality, shows that the major part of the error is with the covariation component as compared to bias and unequal variance which are relatively small. This clearly shows that simulated variables tracks the underlying trend well, but diverges point-by-point. This might indicate that the majority of the error is unsystematic with respect to the purpose of the model, and it should not therefore be rejected for failing to match the data points.

The high error associated with bias i.e. life expectancy (female), life expectancy (male) and under-five mortality might be due to the few data points available for historical data of these variables.

6. Model behavior: the base run

This section presents a base run simulation that is intended to replicate historical development and the future development base on the present. The simulation time frame is from 1960 to 2080.

6.1 Demographic transition

Figure 21 shows the evolution of total population, crude births rate, crude deaths rate and out-migration rate on the left hand side and infant mortality rate, life expectancy and total fertility rate on the right hand side from 1960 to 2080.

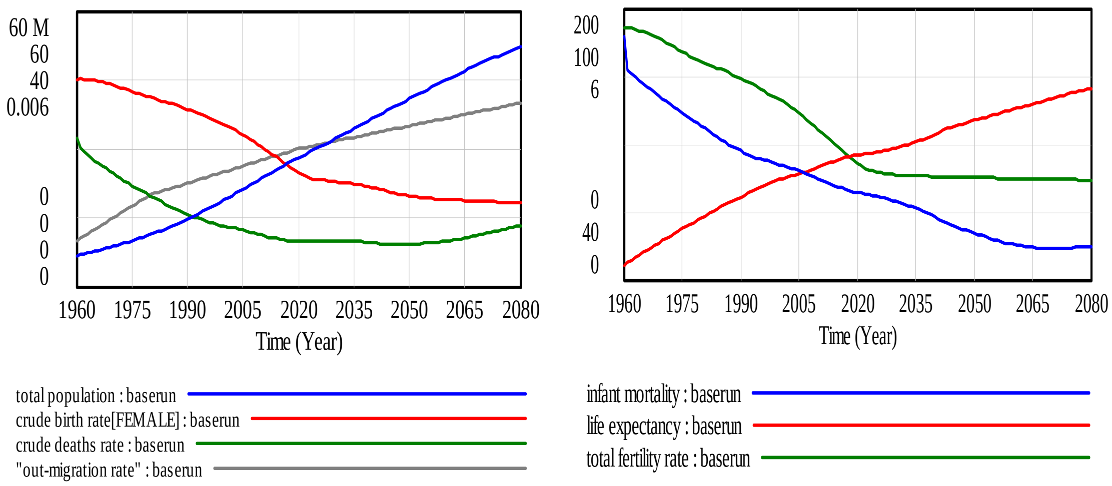

Figure 21: Base run: demographic transition

Ghana's total population have been increasing from approximately 6.8 million people in 1960 to around 18.9 million people in 2000 and by 2080, total population will be 52.1 million if current trend continues. The net annual population growth rate decreased from 2.5% in 1960 to 2.3% in 2000 and will be 0.59% in 2080. The main determinants of population growth, i.e. mortality and fertility have been declining over the years and will continue amidst some slowdown, which is consistent with the demographic transition theory. Out-migration on the other hand continues to rise as population increases over time.

Mortality, measured by the crude deaths rate shows a decreasing trend from 1960 to 2045, after which crude deaths rate started increasing. The crude deaths rate of 21 deaths per 1000 people in 1960 fell to about 8.7 deaths per 1000 people in 2000 and will decrease further to

6.1 by 2045 before increasing again to 8.7 by 2080 if the current trend continues. The significant decrease in mortality is an indication of fundamental improvement in Ghana's human health which is also evident in the improvement of the infant mortality rate and the life expectancy as shown on the right hand side of figure 21. The infant mortality rate was 179 infant deaths per 1000 live births in 1960 and has fallen over the years to about 85 by 2000 and will fall further to around 24 deaths per 1000 live births in 2080 if current trend continues. Life expectancy at birth has increased from 43 years in 1960 to approximately 62 years in 2000 and will be 82 years by 2080. The decline in mortality and increase in life expectancy at birth is caused by a higher literacy rate, increased access to basic health care and increased real per capita income in USD PPP[16]. As per capita income in USD PPP increases, normal life expectancy[17] to be achieved increases as well. Moreover, as literacy rate and access to basic health care increases, its effect on normal life expectancy is assumed to be positive, thus further increasing life expectancy at birth.

The crude birth rate remained above 40 births per 1000 people from 1960 until about 1985 when it started reducing. The crude birth rate declined from 45 births per 1000 people in 1960 to 35 births in 2000 and will be 18.2 births per 1000 people in 2080 if current trend continues. The crude birth rate remained higher than the crude death rate from 1960 to 2080, and this explains the population increase. While the decline in crude birth rate is substantial, it is far above the replacement level fertility rate of 8.7 births per 1000 people (crude death rate in 2080). The total fertility rate – the average number of children a woman would have during her life given the current fertility rate, fell substantially from 5.5 children in 1960 to 4 children in 2000 and will be 2.2 children in 2080. The factors responsible for the decline in total fertility rate are increase in the contraceptive prevalence rate, and a decrease in desired number of children per woman due to decline in under-five mortality rate, increased literacy rate and increased per capita income. As contraceptive usage increases due to an increase in literacy rate, and promotion of contraceptive use through public education, it is postulated that the total fertility rate will decline because of the reduction in the probability of unwanted children being born. In addition, as under-five mortality rate decrease, total fertility rate is expected to decrease due to the positive relationship between under-five mortality and total

[16] United States Dollars in Purchasing Power Parity

[17] Normal life expectancy is the life expectancy that considers income as the only determining variable.

fertility rate. Also, an increase in literacy rate and per capita gross national income is assumed to decrease total fertility rate.

In summary, in Ghana, birth rate has continuously been higher than the death rate over the years; consequently, the population has grown consistently from 1960 to 2000. The base run simulation indicates that birth rate will continue to exceed birth rate by 2080.

6.1.1 Age-sex structure

Figure 22 shows the age-sex structure distribution of Ghana's population for 1960, 2000, 2040 and 2080. The male population is on the left hand side and the right hand side portrays the female population. The population pyramid shows the male and female population into 5 years age cohorts from age 0 to age 80 and over. The x-axis represents the population size and the bar represents the population size in each age cohort.

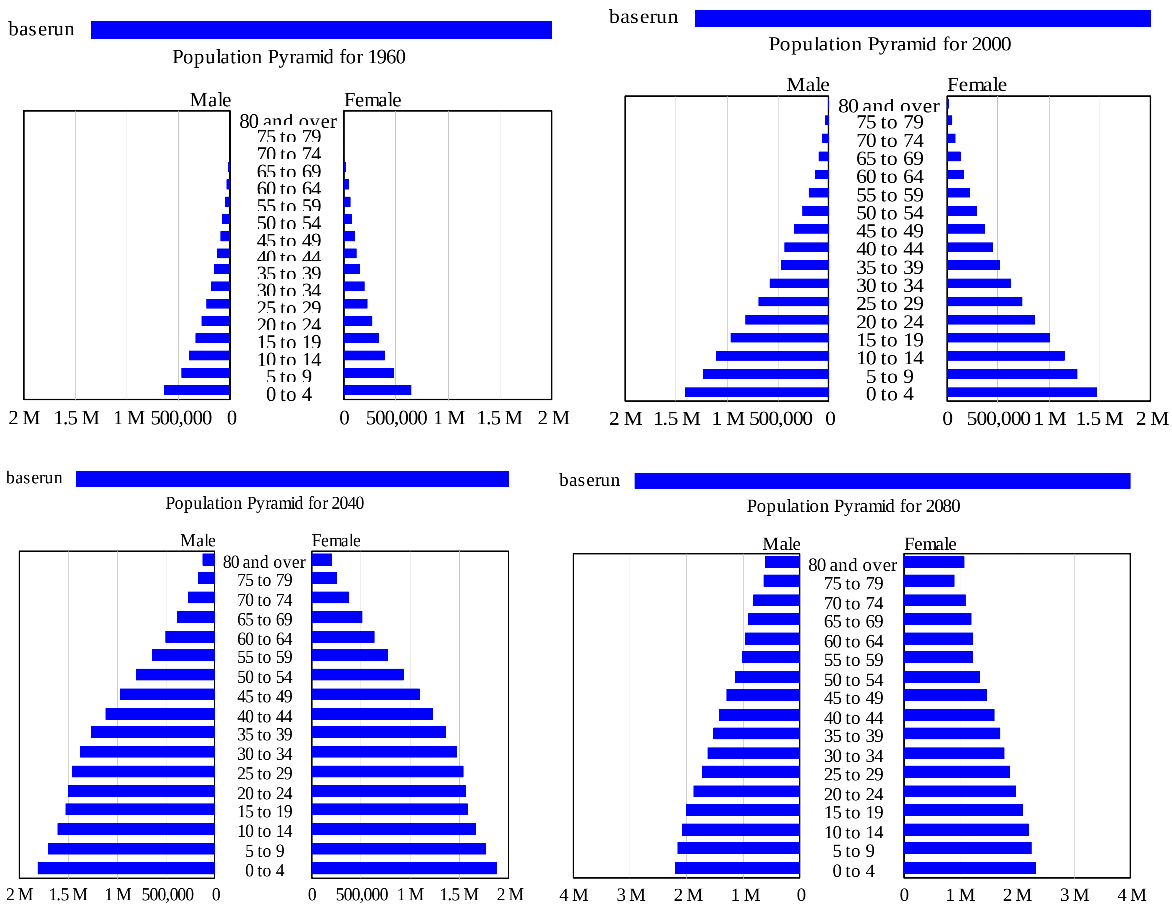

Figure 22: Population pyramid for 1960, 2000, 2040 and 2080

Ghana's population bears a youthful structure with a broad base consisting of large numbers of children and a conical top of a small number of elderly persons. The population pyramid shows that Ghana's population continues to expand because of the tremendous momentum built into its young age structure, as larger numbers of people are born each year. The structure of the population in Ghana as shown in figure 22 implies that even if the average number of children born per woman falls substantially as compared to what is it now, the young age structure will generate growth in population for decades to come as successively larger number of people enters their childbearing age. The shape of the population pyramids shows the transitional nature of Ghana's population from 1960 to 2080. The population is experiencing a transition from high births and deaths rates to a rapid and continuous drop in deaths rates without a corresponding reduction in births rate. Consequently, the proportion of the population within 15-60 years as well as the elderly (60+) years is expected to increase over time.

Table 4 shows the share of the population in absolute and relative terms in the various age cohorts.

Age Cohorts	**1960**	**1980**	**2000**	**2020**	**2040**	**2060**	**2080**
0-14	3.13E+06	4.92E+06	7.73E+06	9.65E+06	1.05E+07	1.18E+07	1.34E+07
15-59	3.40E+06	5.92E+06	1.01E+07	1.65E+07	2.24E+07	2.64E+07	2.91E+07
60+	2.85E+05	5.27E+05	9.87E+05	1.96E+06	3.61E+06	6.79E+06	9.68E+06
Total	6.82E+06	1.14E+07	1.89E+07	2.81E+07	3.66E+07	4.50E+07	5.21E+07
0-14	0.46	0.43	0.41	0.34	0.29	0.26	0.26
15-59	0.50	0.52	0.54	0.59	0.61	0.59	0.56
60+	0.04	0.05	0.05	0.07	0.10	0.15	0.18
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4: Population by Age Cohorts in absolute and relative terms

Leaving the share of population in relative terms for later discussion, we consider the share of population in absolute terms. The simulation outcome indicates significant increase in all age cohorts from 1960 to 2080. This is a reflection of the continuous increase in population over the years. Considering the share of population in relative terms (as a proportion of total population), table 4 shows that, the share of the population under 15 years (0-14) has been decreasing from 46% in 1960 to 41% in 2000 and will be 26% of the population in 2080. The relative reduction of the under 15 population is very significant and is mainly the result of a fertility decline. The age 15-59 has increased from 50% in 1960 to 54% in 2000 and is likely to be 56% in 2080. The relative increase in the age 15-59 is an indication of the improvement in the human health condition in Ghana and the significant increase in life expectancy at birth. The share of the elderly (60 and older) in the population increased slightly from 4% in 1960 to 5% in 2000 and is expected to increase significantly to 18% by 2080 due to the transition that the population is going through. This indicates that the aging process is slowly creeping in because of the improvement in health status which, consequently, increases the life expectancy at birth. The growth of the working age population and the elderly is also evident in the gradual broadening of the top of the population pyramid.

In summary, the population of Ghana is increasing and the increase is expected to continue due to the rapid drop in deaths rates without a corresponding rapid reduction in births rate. Moreover, the changes of the age structure are the outcomes of the dynamics of fertility and mortality through the demographic transition.

6.2 Education

Figure 23 shows the base run simulation of the educational expenditure, the educational capacity (schools), the enrollment fraction and the literacy rate from 1960 to 2080. The graph on the top left hand side shows the government educational expenditure and the capital educational expenditure used for building up the educational capacity for the three educational levels (primary, secondary and tertiary) in the model. On the top right hand side of figure 23 shows the simulation of the educational capacity available for the primary, the secondary and the tertiary education. On the bottom left hand side of figure 23, the simulation shows the average enrollment rate for the primary, the secondary and the tertiary education. Lastly, the bottom right hand side shows the literacy rate among the female and the male population.

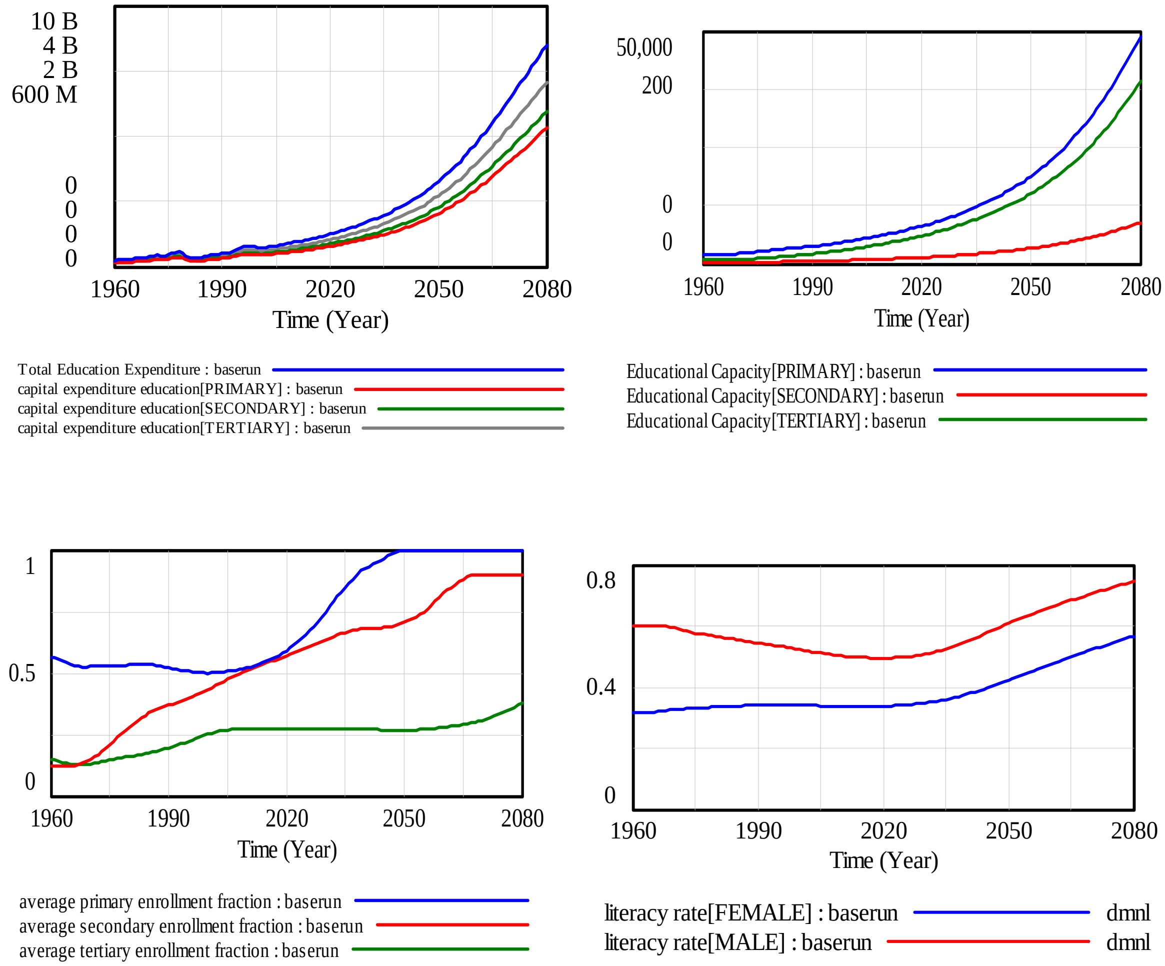

Figure 23: Base run: Educational expenditure, educational capacity, enrollment and literacy fraction

The behavior of the educational expenditure indicates that the government of Ghana's expenditure on education is very significant and this has been consistent over the years and is expected to continue to 2080. Historical data indicates that 11% of government's non-interest expenditure went to the educational sector in 1960 and increased to 14% in 2000 and is therefore assumed to remain constant over time. However, capital expenditure distribution to the three educational levels clearly shows that the governments' educational policy places more emphasis on primary education, followed by secondary education and tertiary education. It is estimated that 25% of the governments' educational expenditure goes to capital expenditure for primary education, while as 14% and 5% goes to the secondary and the tertiary education, respectively. Consequently, educational capacity in the primary level is expected to be higher as compared to the secondary and the tertiary education. The educational capacity simulation shows that by 2080, we expect primary education capacity to be approximately 48830 as compared to 1800 in 1960. The secondary and the tertiary educational capacity are simulated to be around 8806 and 157, respectively, by 2080. The increased primary educational capacity implies that more children within the primary school going age can be enrolled. This will then increase the primary enrollment fraction as well as the literacy rate. On the other hand, the relatively small secondary and tertiary educational capacity implies that not all the primary school graduates and the secondary school graduates can access secondary and tertiary education, respectively, due to inadequate capacity.

The enrollment simulation shows that the primary enrollment fraction decreased from 55% in 1960 to 49% in 2000 due to the inability of the primary educational capacity to keep pace with the increase in the population of primary school going age (age 7 populations). The primary enrollment fraction is expected to increase significantly from 49% in 2000 to 100% in 2080 due to an increase in government education expenditure. This will, subsequently, increase capital expenditure for primary education assuming government educational policy remains unchanged. It is important to note that educational capacity is calculated only based on the cumulative government capital expenditure on education. Therefore an increase in the educational capital expenditure subsequently increases educational capacity. The secondary enrollment fraction increased from 12% in 1960 to 38% in 2000 and will be 90% by 2080. The increase in the secondary enrollment rate is caused by a combination of increased secondary education capacity and a declining number of primary school graduates as a result of decreasing primary enrollment. Tertiary enrollment increased shapely from 15% in 1960 to 25% in 2000. However, the tertiary enrollment fraction will be 37% by 2080 due to lack of significant investment in tertiary education which, consequently, results in limited capacity and enrollment. The literacy rate simulation shows that in Ghana, there are more literate males than females. The literacy rate among the female population increased insignificantly from 31% in 1960 to 34% in 2000 and is expected to be 56% by 2080. On the other hand, the literacy rate among the male population decreased significantly from 59% in 1960 to 52% in 2000 and will be 74% by 2080.

To summarize, using educational spending as a measure of governments' educational policy focus, it is established that the governments' focus historically has been on primary education. Therefore, investment in tertiary education significantly falls short of the desired investment. By 2080, the government is likely to achieve 100% enrollment fraction at the primary level, while secondary enrollment fraction is likely to be around 90%. However, only

37% of the secondary graduates will have access to tertiary education by 2080 due to lack of investment in tertiary education. It is recommended that government refocus its educational priorities on secondary and tertiary education to build the needed capacity to facilitate economic growth which will consequently have a positive effect on social development.

6.3 Health

The base run simulation in figure 24 shows some selected indicators that portrays the dynamics of the health sector in this socio-economic model. On the left hand side of figure 24, the graph shows health care spending (public and private), the number of health care centre, population-health care centre ratio and physical access to health care facility from 1960 to 2080. On the right hand side, we have simulation results for practicing physicians, population-physician ratio and access to basic health care.

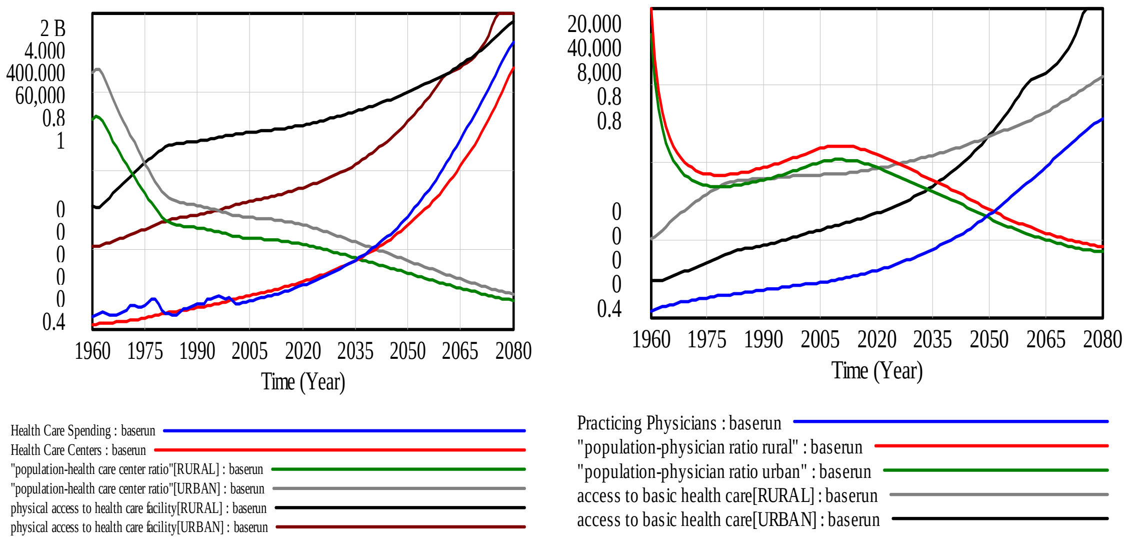

Figure 24: Base run: Educational expenditure, educational capacity, enrollment and literacy rate

Health care spending fluctuated from 1960 to 2000 as a result of government health spending. Government health care spending oscillated between 4% and 7% of government non-interest expenditure over the period. It is assumed that from 2000 to 2080, government health care spending will remain at 7% of non-interest expenditure. As absolute health care spending increases, a fraction of it would go to capital expenditure on health. Therefore, health capacity (health care centre) is expected to increase. According to the model, health care centre's increased from 60 in 1960 to approximately 367 in 2000 and is expected to be around 3289 by 2080. The population-health care centre ratio illustrates the average population per health centre. The population-health care centre ratio is disaggregated into rural and urban areas due to the observed differences in the distribution of health facilities to rural and urban areas. The population-health care centre ratio in the rural areas decreased from 265,270 people per health centre in 1960 to 117,710 in 2000 and it will decrease further to approximately 35,362 by 2080. The population-health care centre ratio in the urban areas decreased significantly from 48,723 people per health centre in 1960 to 21,620 in 2000. It is expected that population-health care centre ratio in the urban areas will reduce further to approximately 6,544 people per health centre by 2080. The high population-health care centre ratio in the rural areas compared to the urban areas establishes the skewed distribution of health facilities in the urban areas. The drastic expected reduction in population-health care centre ratio in rural is caused by the increase in health centre's due to increase in health care spending. On the other hand, the reduction in population-health care centre ratio in the urban areas is due to the significant increase in health centre's to accommodate the increase in population in the urban areas due to increase in health care spending coupled with the existing skewed distribution of health facilities in favor of urban areas. By 2080, population-health care center ratio in urban areas will be 5 times better than in the rural areas.

Physical access to health care facility measures the access to health care facility using a combination of the effect of population-health care center ratio to physical access to health care facility and the effect of distance on physical access to health care facility. Experience from studies in developing countries indicates that distance to health care facility is one of the critical factors that determine the use of the facility. The model simulation establishes that the fraction of population that have physical access to health care facilities in the rural areas increased from 30% in 1960 to 49% in 2000 and it will increase further to 77% by 2080. In the urban areas, the fraction of population that have physical access to health care facilities increased from 55% in 1960 to 63% in 2000 and it will increase to 99% by 2080. We can conclude that, the low physical access to health care facility in the rural areas from 1960 to 2000 is due to the longer distance to a health care facility as a result of low health care facility density[18] in rural areas.

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[18] Health care facility density refers to the number of persons per square kilometer of land area.

Practicing physicians increased from 400 in 1960 to approximately 2066 in 2000 and will increase to around 12832 by 2080. This gives a population-physician ratio of 39,790 in the rural areas and 7,308 in the urban areas in 1960. The population-physician ratio decreased sharply in the early 1960s due to the sharp increase in physicians and the population-physician ratio then increased again from 1980. During the period of 1960 to 1980, population-physician ratio in the rural areas decreased from 39,790 to 18,417 while that of the urban areas decreased from 7,308 to 3,382. From 1980, the population-physician ratio begins to increase, reaching a peak of 22146 in year 2010 in the rural areas and 4067 in year 2011 in the urban areas. The increase in the population-physician ratio is attributed to population increase in both urban and rural areas surpassing the increase in physicians in both areas. It is expected that by 2080, the population-physician ratio in the rural areas will have fallen to 9,134 and that of the urban areas is expected to fall to around 1,677.

From the forgoing discussion, it is expected that access to basic health care in rural Ghana will lag behind that of the urban Ghana due to better physical access to health care facility and low population-physician ratio in the urban Ghana. Access to basic health care was 20% in the rural areas in 1960 and 44% in the urban areas. However, access to basic health care in the rural areas increased from 20% in 1960 to 37% in 2000 and will increase to 62% by 2080. The urban areas also experience an increase in access to basic health care from 44% in 1960 to 50% in 2000 and will increase to 80% by 2080.

6.4 Labor

The dynamics of the labor sector is shown by figure 25. The left hand side demonstrates the expected demand for goods and services and employment for the three sectors of the economy, i.e. agriculture, industry and services. The right hand side shows total expected demand for goods and services, total employment, total work force and unemployment fraction for the economy in total.

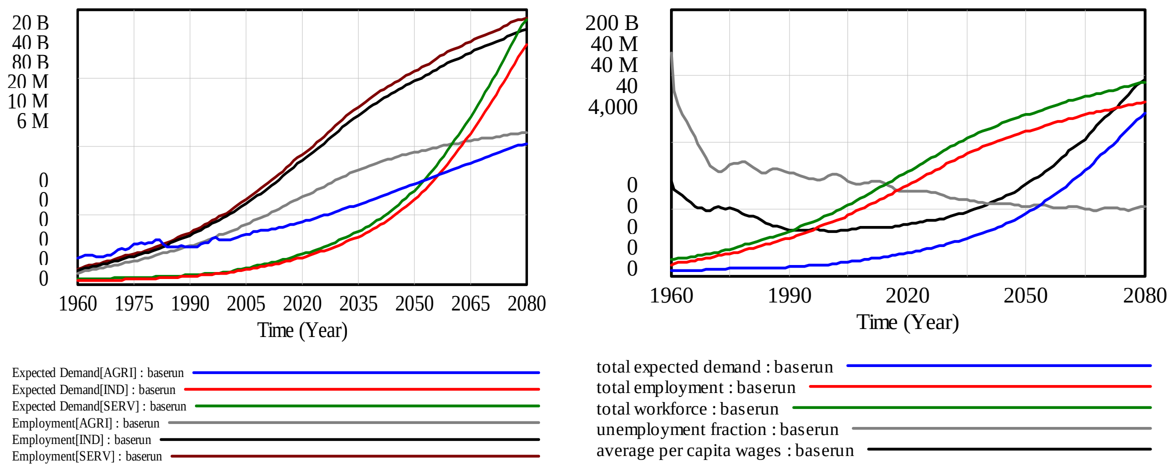

Figure 25: Base run: expected demand, employment, unemployment and total work force

The simulation result shows an increasing trend for expected demand in the agriculture, the industrial and the service sectors of the economy. As expected demand increase, the demanded labor to meet the demand for goods and services increases as well. Hence employment increases. The employment in the agricultural, the industrial and the service sectors of the economy increased from 1960 to 2080.

Total expected demand increased from approximately 3.7 billion in 1960 to around 8.1 billion in 2000 and will increase to 122.14 billion in 2080. The increase in production is a reflection of an increase in total expected demand. The total work force was 2.4 million in 1960 of which 1.6 million are employed. By 2000, the total work force had increased to 9.12 million, of which 7.75 million were employed. The simulation result indicates a slow-down of growth in total work force from 2035. This is attributed to the demographic transition which is changing the age structure of the population. Total employment increases from 1960 up to 2035. After the year 2035, the total employment increases at a decreasing rate. The increase in total employment is insufficient to reduce unemployment due to a more significant increase in the work force. The increase in total employment is caused by an increase in total expected demand and the reduction in average per capita wages. Production increase causes employment to increase. Also, a decline in average per capita wages causes employment to increase as more employees can be paid with the same amount of wages. Average per capita wages decreased significant from 1960 to 2000. After the year 2000, average per capita wages then started a gradual increase, and is expected to continue to do so up to the year 2050, when the average wages will be equal the 1960 wage level. After 2050, average per capita wages is expected increase significantly. The 1960 to 2000 decline in average per capita wages is attributed to unemployment. As unemployment increases, the effect of unemployment on wages decreases nominal wages resulting in a reduction in average per capita wages.

The unemployment rate is a reflection of the difference between total work force and total employment. The unemployment rate decreased sharply in the early 1960s, i.e. from 33.4% to 15.5% in 1973 and oscillated between 16.8% and 14% from 1973 to 2010. Unemployment rate is expected to decrease from 14% in 2010 to 10.4% by 2080. The decline in unemployment is caused by an expected continuous increase in total expected demand, and a slow-down in the increase of the total work force.

6.5 Production

The base run behavior of the agriculture, industry and service of the economy is shown in figures 26, 27 and 28 respectively. They are explained below:

6.5.1 Agriculture

The simulation result of the agriculture is evident in figure 26. The graph on the top left hand side of figure 26 indicates that from 1960 until 2000, the agricultural yield increased amidst some fluctuations. The fluctuation in agricultural yield is explained mainly by the variations observed in the yield per hectare. However, the increase in agricultural yield is predominantly a result of the increase in agricultural land in use.

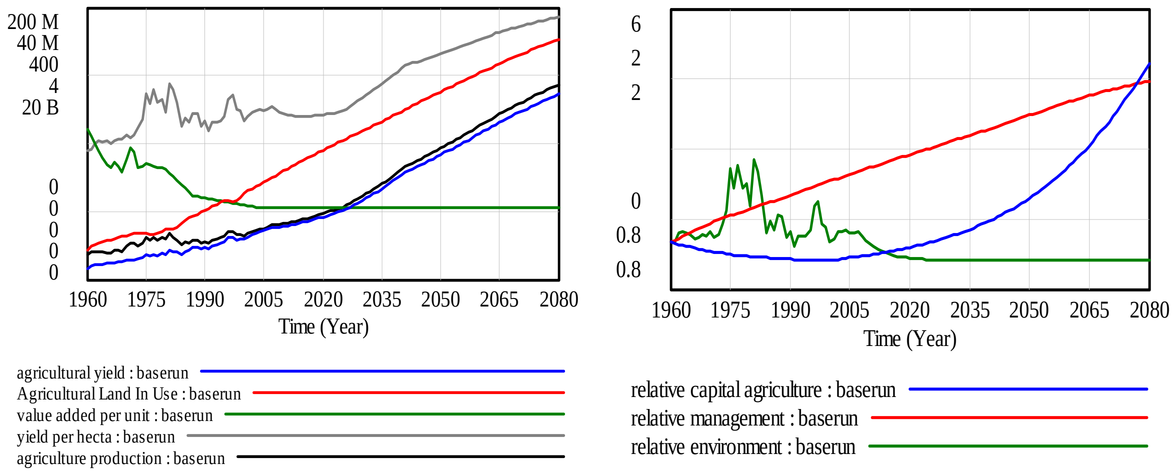

Figure 26: Base run behavior of agricultural sector

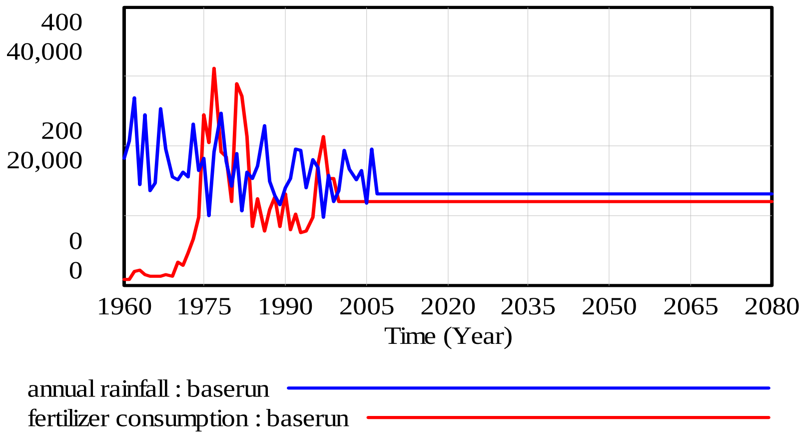

Figure 26: Base run behavior of agricultural sector

The graph on the top right hand side of figure 26 shows the three main factors that account for the variation in the yield per hectare. The three factors are management, agriculture capital and environment. The increase observed in management is due to improvement in human capital among the farmers. As the educational attainment increase as explained in the education sector for all workers in Ghana, it is expected that agricultural labor will duly benefit from an increase in knowledge. Also, the increase in agricultural capital is as a result of an increase in government investment in agricultural research and extension services. As agricultural research increases, the findings of the research are disseminated directly to farmers to help improve yield. Moreover, increase in extension services increases farm visit to advice farmers on new and better ways of farming. The fluctuations observed in the environment, is explained by the graph in the bottom of figure 26, which shows the behavior over time of annual rainfall and fertilizer consumption based on historic data. We confirm that the unstable rainfall and general reduction of fertilizer consumption account for the variation in the environment and, consequently, the yield per hectare from 1960 to 2000. It is important to note that, agriculture in Ghana is highly dependent on rainfall. The use of irrigation water for agriculture is very insignificant. The pattern of the fertilizer consumption clearly shows that fertilizer use for farming intensified in Ghana in the mid 1970s, then oscillated during the late 1970s and early 1980s. By the mid 1980s, fertilizer consumption declined significantly. Various studies in Ghana (Frimpong-Ansah 1991; Ayittey 1992; SAPRIN 2002) have implied that one of main factors that explain the reduction in fertilizer consumption is the removal of agricultural subsidies by the government since the implementation of structural adjustment program. The late 1990s saw a sharp increase and immediate fall of fertilizer consumption and we hypothesize that fertilizer consumption will stabilize at the current consumption level due to assumption of stable price.

The graph on the top left hand side shows the behavior over time of the value added per unit of agriculture product. It is evident that value added to agriculture, i.e. the real price of agriculture raw materials is generally decreasing over time. In 2000, the real price of agriculture raw materials stands at only 50% of the 1960 price. As explained by Junne (1991) the IMF and World Bank policies have undoubtedly contributed to the decrease in agriculture raw material prices (Junne 1991). The immediate effect of the currencies devaluation policy implemented by the IMF and World Bank in developing countries is that exporters receive more in terms of the domestic currency for the goods than before. This signal to farmers in most countries to increase their output for exportation and the resulting glut has helped to bring about the fall in the world market price. The export orientation of the IMF and World Bank policies for agriculture therefore made things worse.

Thus, it is not surprising that even though agricultural yield increased in general over the years, agricultural production, i.e. total output multiplied by the value added did not increase correspondingly. This is due to the price reduction of agricultural product.

6.5.2 Industry

The base run behavior of the industrial sector shows that industrial production increased over the 1960 to 2000 period.

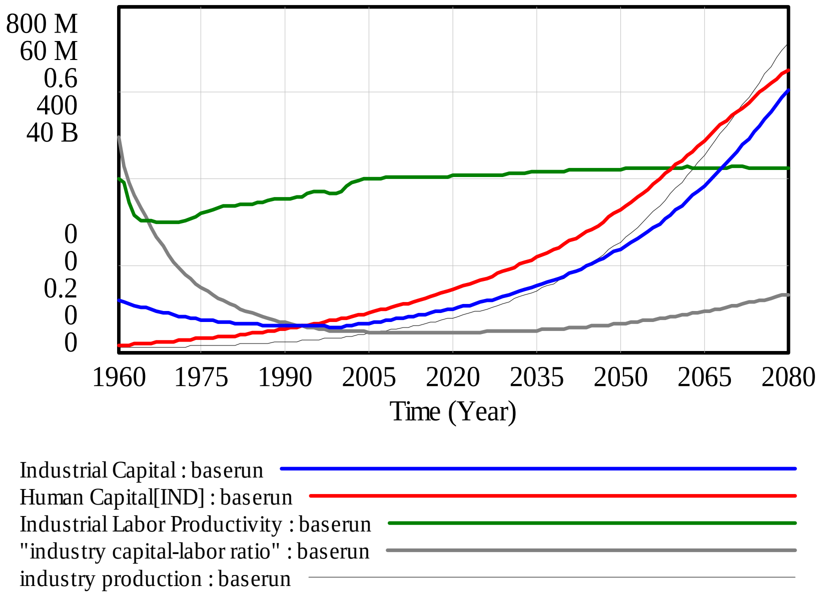

Figure 27: Base run behavior of industrial sector

The increase in industrial production is as a result of an increase in human capital. However, from 1960 to 2000, industrial capital and industrial labor productivity declined. A high industrial capital depreciation compared to the industrial capital acquisition explains the decline in the industrial capital level. The relatively low industrial capital acquisition is due to inadequate investment in industries and the high cost of industrial capital. The falling industrial labor productivity is explained by the declining capital-labor ratio due to low physical capital base of the industrial sector and declining technology. As growth in employment surpasses the growth in physical capital, capital available per employee, i.e. capital-labor ratio declines. As the capital-labor ratio decreases, coupled with low technology growth (in part due to a low physical capital growth) industrial labor productivity decreased. On the other hand, the steady increase in human capital is due to combination of gradual improvement in the average years of formal schooling among the industrial workforce and an increase employment. As investment in education increases, the educational capacity enabled an increase in the recruitment of educated people. Over time a more educated workforce become available for employment which, consequently, increases the average years of formal schooling among the workforce and, accordingly, the human capital in use. The industrial sector duly benefit from the increase in human capital.

We established that the slow growth in the industrial sector from 1960 to 2000 is explained by the low physical capital base of the industrial sector. This, consequently, affected labor productivity: hence the observed decline in labor productivity in the industrial sector.

6.5.3 Service

The service in the economy exhibits similar behavior as the one explained for the industry. As shown in figure 28, services production increased along side human capital from 1960 to 2000 and the increase continued to 2080. The increase in human capital is as a result of an increase in educational attainment, i.e. average years of formal schooling due to an improvement in education. However, service capital and service labor productivity declined from 1960 to 2005 as shown in figure 28. The decline in service capital is attributed to a high service capital depreciation compared to the service capital acquisition due to inadequate investments. On the other hand, the service labor productivity decline is attributed to a declining capital-labor ratio and technology growth.

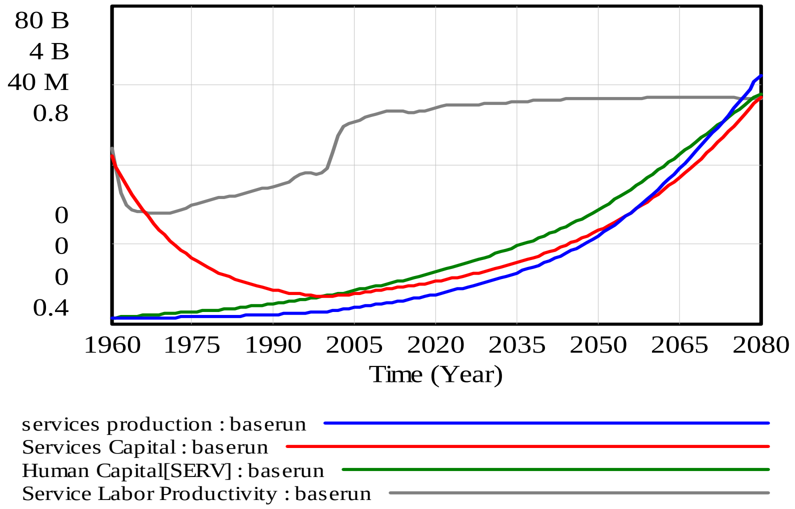

Figure 28: Base run behavior services sector

6.6 *Public Debt*

Figure 29 shows the behavior of the total debt over time, budget deficit, interest's payment and foreign debt adjustment on the left hand side and the domestic and foreign interest rates and the real exchange rate change on the right hand side.

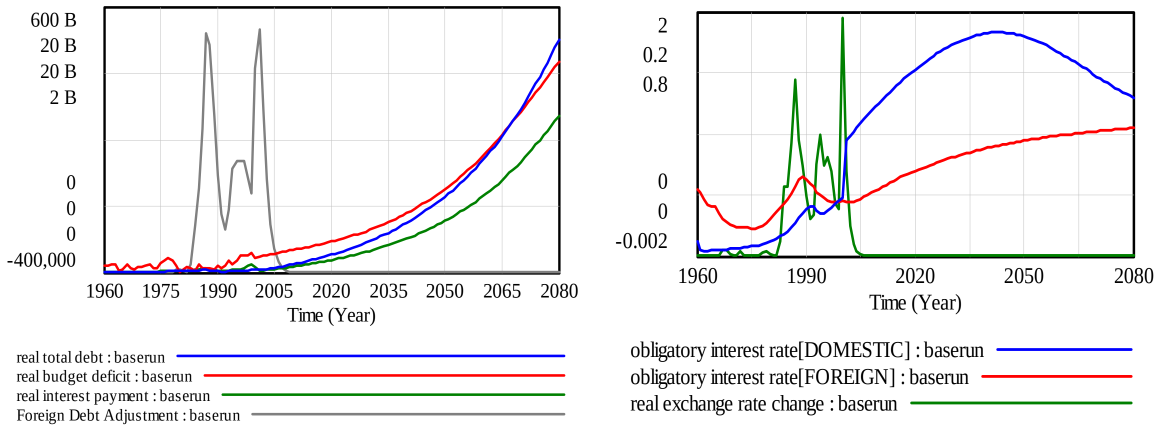

Figure 29: Base run behavior showing government revenue, expenditure, public debt, foreign debt adjustment, interest payments and interest rates

The behavior of the budget deficit indicates that government expenditure consistently exceeded revenues and grants from 1960 to 2000 and the base run simulation indicates that budget deficit will continue to increase to the year 2080. The gap between expenditures and revenues (budget deficit) is closed by borrowing, consequently, debt builds up. The total debt increased from 1960 to 1980 amidst some fluctuations, and then decreased suddenly in the early 1980s, but started to increase again from the early 1990s and is expected to increase to the year 2080. As total debt increases, interest payments on debt increase which, in turn, increase government expenditures and the budget deficit. Domestic and foreign interest rates on the right hand side of figure 29 shows that the interest rate charged on public debt from both domestic and foreign sources.

The obligatory interest rate is separated into that for domestic debt and that associated with foreign debt. The domestic obligatory interest rate dropped sharply from 0.11 in 1960 to 0.04 in 1961. From 1961 to 1980, the obligatory domestic interest rate increased gradually from 0.04 to 0.12. The period 1960s to 1980 was an era when the financial sector in Ghana was characterized by a fixed ceiling on interest rates, credit guidance for different sectors and fixed ceiling on credits. Interest rate controls ensures that the government governs the interest rate. This explains, perhaps, the slow increase in interest rate from 1960 to 1980 (Mensah 1997) regardless of the high inflation rate in the economy, - well above the interest rate. The domestic obligatory interest rate then rose sharply from 0.12 in 1980 to 0.41 in 1992. This sharp increase is attributed to the significant accrual of interests in the early 1980s and the high interest rate charged on domestic borrowing. From 1980, the domestic interest rate increased from 0.10 to 0.24 in 1992. The interest rate rose due to the gradual deregulation of the financial sector when the Financial Sector Structural Adjustment Program (FINSAP) was adopted (Mensah 1997). As a result, the interest rate increased towards the market conditions. From 1992, the domestic obligatory interest rate was briefly reduced until it increased once more and reached 0.48 in 2000 and is expected to be 1.23 by the year 2080. On the other hand, foreign obligatory interest rate decreased from 0.05 in 1960 to 0.02 in 1976. This reduction is attributed to the shift of government borrowing from private borrowing in the financial market to concessional loans from bilateral and multilateral sources. The relatively low interest rate on concessional loans compared to private credit, (Krassowski 1974; Killick 1978) ensures that the obligatory interest rate decreases during the period. The foreign obligatory interest rate increased significantly during the period 1977 to 1990, from 0.02 to 0.06. The increase in the obligatory interest rate from 1977 to 1990 is ascribed to the combined effect of an increase in the interest rate on concessional loans and increase in accrual of interest. The interest rate on concessional foreign borrowing increased during the period 1977 to 1990 from 0.02 to 0.03 as a response to the rise in the interest rate worldwide. Moreover, the increase in accrual of interest stepped up the accumulation of accrued interest which, invariably, increased the obligatory interest rate. The obligatory interest rate decreased slightly from the 1991 level of 0.05 to 0.04 in 2000. This follows the reduction of interest rate on concessional loans. The obligatory interest rate is expected to be 0.1 by the year 2080

The graph in figure 29 i.e. right hand side shows that from 1960 to 1980, the change in the real exchange rate was negative. This is due to the implementation of a fixed currency exchange regime (Islam and Wetzel 1991; Boafo-Arthur 1999). From 1980, the change in the real exchange rate became positive and then increased sharply between 1983 and 1986. This sharp increase is attributed to the deregulation of the currency exchange market during the Structural Adjustment era (Boafo-Arthur 1999). Subsequently the exchange rate adjusted to the market rate as a result of the deregulation amidst some fluctuations after 1990, - based on the strength of Ghana’s balance of payment.

7. Policy Analysis and Discussion

7.1 Policy Analysis

In this study, we have subjected four fiscal policies to an experimental investigation. The main focus of the policy analysis is by seeking the most successful fiscal policy that facilitates the improvement of socio-economic development (SEDI) and ensure fiscal sustainability (cumulative budget deficit and debt-GDP ratio). The experiments are supposed to guide our selection of fiscal policy to achieve these twin goals. We conducted an ex-ante simulation analysis from 2000 to 2080 to examine the impact of each fiscal policy (overall policy) and policy combinations (distributional policies) on the twin goals. Three distributional policy[19] areas were tested for each fiscal policy (overall policy) to further explore their impact. The permutation of the distributional policy and the overall policy gave twelve policy combinations alternatives, which were tested to evaluate their impact on socio-economic development and ensure fiscal sustainability. The twelve policy combinations are: *P1br* is expansionary policy with base case expenditure pattern, *P1ei* is the expansionary policy with economic investment focus, *P1si* is the expansionary policy with social investment focus, *P2br* is the contractionary policy with base case expenditure pattern, *P2ei* is the contractionary policy with economic investment focus, *P2si* is the contractionary policy with social investment focus, *P3br* is the balanced budget policy with base case expenditure pattern, *P3ei* is the balanced budget policy with economic investment focus, *P3si* is the balanced budget policy with social investment focus, *P4br* is the combined policy with base case expenditure pattern, *P4ei* is the combined policy with economic investment focus, and *P4si* is combined policy with social investment focus. Table 5 shows the policy setup.

[19] The distributional policy are; base case (br), economic investment (ei) and social investment (si)

Policy / Expenditure	Expansionary policy (P1)			Contractionary Policy (P2)			Balanced Budget Policy (P3)			Combined Policy (P4)		
	Fractional expenditure			Fractional expenditure			Fractional expenditure			Fractional expenditure		
	P1br	*P1ei*	*P1si*	*P2br*	*P2ei*	*P2si*	*P3br*	*P3ei*	*P3si*	*P4br*	*P4ei*	*P4si*
Functional Expend[20]												
1.General services[21]	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
2.Com/soc. Services[22]	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
3.Economic services[23]	0.23	**0.38**	0.23	0.23	**0.38**	0.23	0.23	**0.38**	0.23	0.23	**0.38**	0.23
4.Education	0.14	0.14	**0.21**	0.14	0.14	**0.21**	0.14	0.14	**0.21**	0.14	0.14	**0.21**
5.Health	0.04	0.04	**0.12**	0.04	0.04	**0.12**	0.04	0.04	**0.12**	0.04	0.04	**0.12**
6.Unallocated expend[24]	0.25	**0.10**	**0.10**	0.25	**0.10**	**0.10**	0.25	**0.10**	**0.10**	0.25	**0.10**	**0.10**
Expenditure Policy												
Medium term												
1. Expend.[25] (% GDP)		0.35			0.22			0.25			0.40	
2.Tax rev[26](% GDP)		0.25			0.25			0.25			0.25	
Long term												
1.Expend (% GDP)		0.40			0.25			0.30			0.25	
2.Tax rev (% GDP)		0.30			0.30			0.30			0.30	

Table 5: Policy Setup and Analysis

The four policies and the distributional policy areas experimented are described as follows:

Expansionary Fiscal Policy (P1): This policy will ensure that government increases expenditure to facilitate economic and social investment. The assumption underlying this

[20] Functional expenditure

[21] General services expenditure consists of the following spending: general public service, defense, public order and safety

[22] Community and social services expenditure consists of the following spending: social security and welfare services, housing and community amenities, recreational, cultural and religious services

[23] Economic services expenditure consists of the following spending: fuel and energy, agriculture, forestry and fishing, mining, manufacturing and construction, roads and railways, other transportation and communication and other economic services.

[24] Unallocated expenditure consists of the following spending: transfers to other levels of government, social efficiency fund, others

[25] Expenditure

[26] Tax revenue

policy is that as government increases expenditures, investment and social services increase, which helps to stimulate the economy. Consequently, production increases which result in increased tax revenue. However, this policy is associated with a high budget deficit resulting in high public debt due to government expenditure consistently exceeding tax revenue. In the ex-ante policy experimentation, this policy is implemented by increasing expenditure from 34% of GDP in 2000 to 35% by 2010 (medium term) and to 40% by 2080 (long term). On the other hand, tax revenue is demonstrated to increase from 19% of GDP in 2000 to 25% by 2010 and to 30% by 2080.

Contractionary Fiscal Policy (P2)*:* With this policy, government expenditure is reduced to decrease budget deficit and consequently public debt. This policy is often used or recommended in times of public debt crisis. The underpinning argument for the contractionary policy is that, as public debt increases, government spending should be reduced to generate budget surplus to service the public debt. On the other hand, the contractionary policy is argued to focus mainly on fiscal balance ignoring social and economic development, which suffers as a result of the cut in government spending. In the ex-ante policy experimentation, this policy is implemented by decreasing expenditure from 34% of GDP in 2000 to 22% in 2010 and to increase to 25% by 2080. It is important to note that tax revenue for 2010 is assumed to be 25% of GDP by 2010 and is to increase to 30% by 2080.

Balanced Budget Fiscal Policy (P3)*:* The balanced budget policy ensures that government spending is fully funded by tax revenue. This policy ensures that government avoids the possibility of overspending which results in public debt. In the ex-ante policy analysis, this policy is implemented by ensuring that government spending and tax revenue are always equal. That is government expenditure is assumed to reduce from 34% of GDP in 2000 to 25% by 2010 and increase to 30% by 2080.

Combined Policy (P4)*:* This policy is a combination of expansionary fiscal policy in the medium term and contractionary fiscal policy in the long term. The combined policy ensures that government expenditure exceeds its revenue in the medium term to build human and physical capital to increase production and socio-economic development. When the foundation of the economy is perceived to be strong, government fiscal policy is changed to a contractionary policy to ensue that the previous deficit is financed through a future surplus.

This policy is implemented by increasing government expenditures from 34% of GDP in 2000 to 40% by 2010 and then reducing it to 25% by 2080. However, government tax revenue is assumed to be 25% of GDP by 2010 and to 30% by 2080.

Distributional Policy

Three distributional policies are identified and tested to evaluate their impact on socio-economic development and fiscal sustainability. They are;

Base case (br): This distributional policy maintains the status quo by ensuring that the functional expenditure distribution of government expenditure remains unchanged from the pervious year.

Economic Investment (ei): This distributional policy ensures that government expenditure prioritizes economic investment as the engine of growth. This policy is implemented by assuming that 38% of the government expenditure is earmarked for economic investment. This is achieved by reducing the fraction of government expenditure for unallocated expenditure from 25% to 10% and shifting the 15% difference to economic investment to make it 38%.

Social Investment (si): The social investment distributional policy will ensure that government expenditure focuses on education and health. This policy is implemented by reducing the fraction of government expenditure for unallocated expenditure from 25% to 10% and shifting the 15% to education and health. As a result, the education expenditure fraction increases to 21% and the health expenditure to 12%.

7.2 Policy Discussion

The policy discussion describes the future consequence of the policy interventions on the socio-economic development and fiscal sustainability in Ghana. Table 6 shows the results of the policy experimentation. For the purpose of this analysis, the success of a policy depends on its ability to increase socio-economic development indicator, i.e. SEDI, increase cumulative budget surplus and to reduce debt-GDP ratio.

Policy / Indicators	Expansionary policy (P1)			Contractionary Policy (P2)			Balanced Budget Policy (P3)			Combined Policy (P4)		
	P1br	*PIei*	*PIsi*	*P2br*	*P2ei*	*P2si*	*P3br*	*P3ei*	*P3si*	*P4br*	*P4ei*	*P4si*
Impact on:												
SEDI[27]	0.60	0.61	0.61	0.56	0.57	0.57	0.57	0.59	0.59	0.57	0.58	0.59
Fiscal Sustainability												
1.Cum.bud def.[28] (+/-)	3.3E+11	3.6E+11	3.4E+11	-1.1E+11	-1.2E+11	-1.2E+11	6.1E+09	6.1E+09	6.1E+09	4.4E+10	4.3E+10	4.3E+10
2.debt-GDP Ratio	3.30	3.15	3.27	0.02	0.02	0.02	0.12	0.10	0.11	0.89	0.82	0.86

Table 6: Result of Policy Analysis

The outcome of the first fiscal policy (P1) is evident in the simulation result portrayed in figure 30. Considering the impact of *P1* on SEDI, the *P1ei* and *P1si* produced slightly higher SEDI as compared to *P1br*. As shown in table 6, it is expected that the implementation of *P1br* will increase SEDI to 0.60, while that of *P1ei* will give SEDI of 0.61 and *P1si* resulting in SEDI of 0.61. On the other hand, the impact of *P1* on debt-GDP ratio indicates that *P1ei* gives slightly lower debt-GDP ratio, i.e. 3.15. The implementation of *P1si* gives debt-GDP ratio of 3.27, while that of *P1br* indicate a debt-GDP ratio of 3.30. Considering the cumulative budget deficit, policy *P1ei* generate the highest budget deficit (3.6E+11) as shown in table 6, while policy *P1si* generates budget deficit of (3.4E+11), and policy *P1br* results in a budget deficit of (3.3E+11).

Evaluating the expansionary policy (P1) to the base run simulation as shown in figure 30 indicates that P1 increases SEDI slightly as compared to the base run simulation and significantly decreased the debt-GDP ratio over time. This indicates that the expansionary policy performs better as compared to the current policies pursued by the government.

[27] Socio-economic development indicator consists of various indicators of education, health, social services and income as a measure of socio-economic development or progress.

[28] Cumulative budget deficit

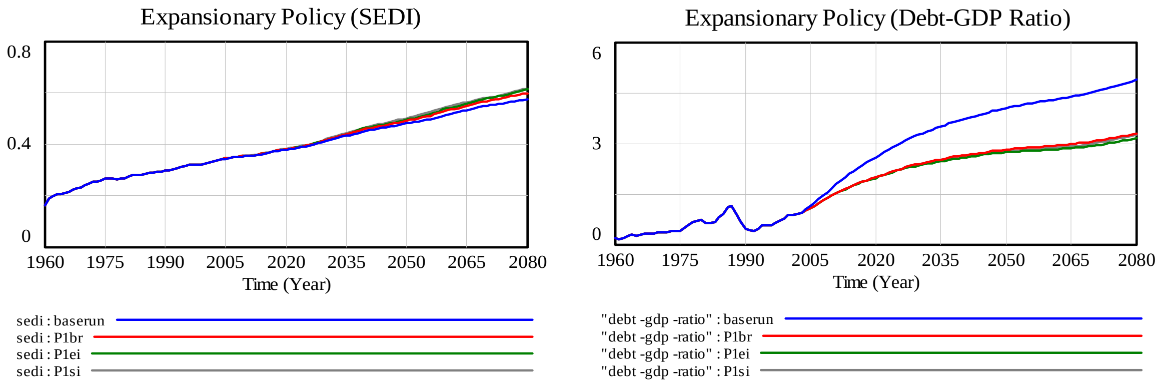

Figure 30: Results of Expansionary Policy Runs

Figure 31 shows the expected outcome from the simulation of the contractionary fiscal policy (P2). It is evident that policies *P2br, P2ei, P2si* reduce SEDI slightly as compared to the base run simulation also shown in figure 31, but significantly reduce the debt-GDP ratio. Moreover, as shown in table 6, the cumulative budget surplus from implementing *P2br, P2ei, and P2si is* very significant compared to what is obtained under expansionary policies. The simulation outcome from P2 shows that, *P2ei* and *Psi* policies give the slightly higher SEDI (0.57) between the three contractionary policies, while *P2br* produce a SEDI of 0.56. Moreover, the three contractionary policies, i.e. *P2br, P2ei, and P2si* considerably reduce the debt-GDP ratio from 0.88 in 2000 to 0.02 by 2080. The effect of the contractionary policies on the budget deficit is reported in table 6. The implementation of policies *P2br, P2ei, and P2si* results in a cumulative budget surplus of 1.1E+11, 1.2E+11, 1.2E+11 respectively. The simulation outcome of P2 shows that policy *P2ei* and *P2si* yields the highest cumulative budget surplus followed by *P2br.*

Comparing the simulation analysis of the contractionary policies to the expansionary policies and the base case simulation clearly shows that, if the main goal of government is to achieve socio-economic development, then the expansionary policies is the best fiscal policy option to pursue. If on the other hand, the main goal of government is to ensure fiscal sustainability, then the contractionary policy is the best policy option to pursue as compared to the expansionary fiscal policy and the base case simulation.

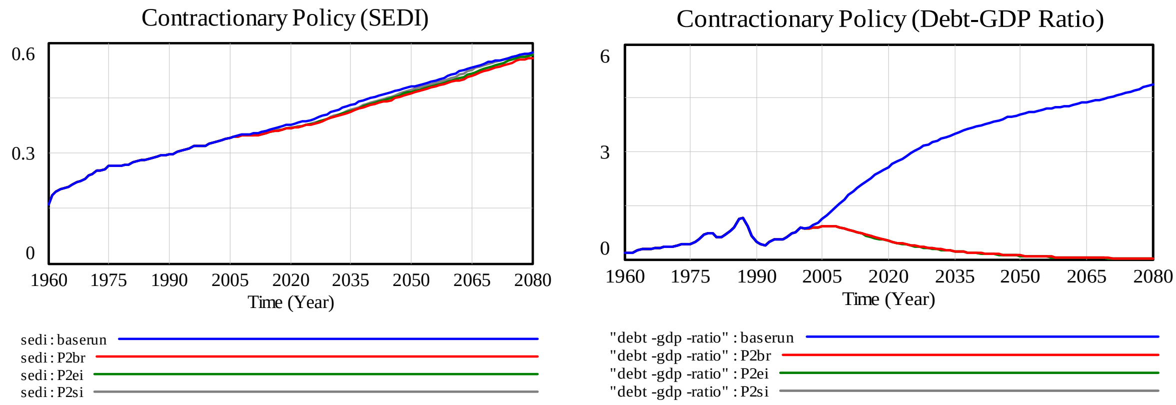

Figure 31: Results of Contractionary Policy Runs

The outcome of the balanced budget fiscal policy is apparent in the simulation of figure 32. The simulation result evidently shows that the balanced budget policy did not significantly change SEDI compared to the base case simulation. But, the balanced budget policy significantly reduces the debt-GDP ratio and the accumulated budget deficit over the simulation period. Policies *P3br, P3ei, and P3si* yield SEDI of 0.57, 0.59 and 0.59 respectively. The simulation result indicates that *P3ei* reduces debt-GDP ratio from 0.88 in 2000 to 0.10 by 2080. This indicates that the best balanced budget fiscal policy with respect to the debt-GDP ratio is *P3ei*. Policies *P3si*, and *P3br* shows debt-GDP ratio of 0.11 and 0.12 respectively. The cumulative budget deficit from the balanced budget policies indicates that all the three policies i.e. *P3br, P3ei, and P3si* produced a similar cumulative budget deficit of 6.1E+09 over the simulation period.

Comparing the balanced budget fiscal policies to the other policies, as portrayed in table 6, shows that the balance budget policy is the second best policy with regard to the socio-economic development. Also, the balanced budget policy is the second best policy to reduce debt-GDP ratio significantly. Moreover, apart from the expansionary fiscal policy that generates budget surpluses, the balanced budget policy is the fiscal policy with the least accumulated budget deficit over the policy simulation period. This makes the balanced fiscal policy an attractive fiscal policy in pursuit of the twin goal of socio-economic development and fiscal sustainability.

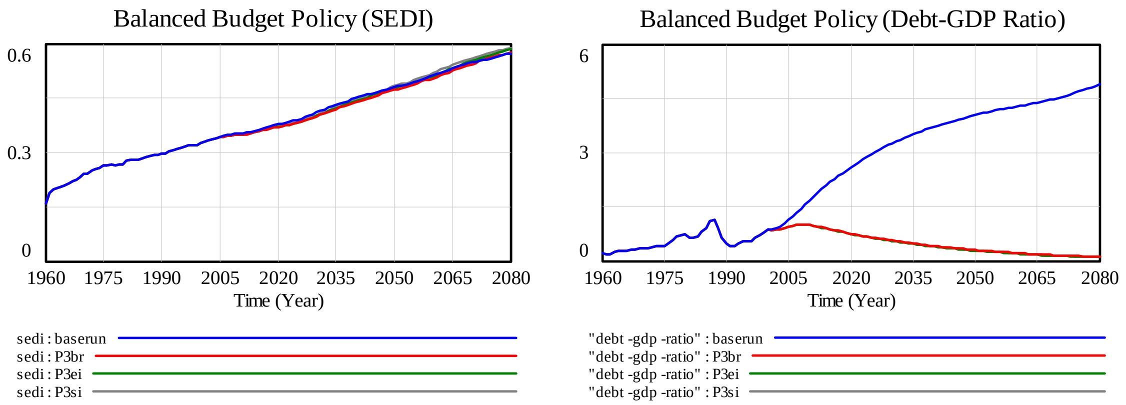

Figure 32: Results of Balanced Budget Policy Runs

The simulation in figure 33 shows the outcome of the combined policy experiment. The simulation result shows that SEDI increases slightly as a result of P4 compared to the base run. However, the debt-GDP ratio is significantly decreased by P4. The results portrayed in table 6 indicate that at the end of the simulation period, the combined policy accumulates a budget deficit. Policies *P4br, P4ei, P4si* shows SEDI values of 0.57, 0.58, and 0.59 respectively. This is slightly higher than the base case simulation. The result for the debt-GDP ratio also indicates that policies *P4br*, *P4ei*, *P4si* reduce the debt-GDP ratio from 0.88 in 2000 to 0.89, 0.82 and 0.86, respectively. The cumulative budget deficit from the combined policy is 4.4E+10 for *P4br*, 4.3E+10 for *P4ei*, and 4.3E+10 for *P4si*.

Comparing the combined policy results with the other policies, we may conclude that the combined policy result for SEDI is quite comparable to the good results from the balanced budget fiscal policy. This makes the combined policy the third best policy to increase socio-economic development. On fiscal sustainability, the combined policy result is only better than the expansionary policy and less desirable to the contractionary and balanced budget fiscal policies. That is, apart from the expansionary policy, the combined fiscal policy gives higher debt-GDP ratio than the contractionary and the balanced budget policies. Moreover, the combined policy is the policy with the second largest cumulative budget deficit. This makes the combined policy the third desirable policy with respect to the cumulative budget deficit.

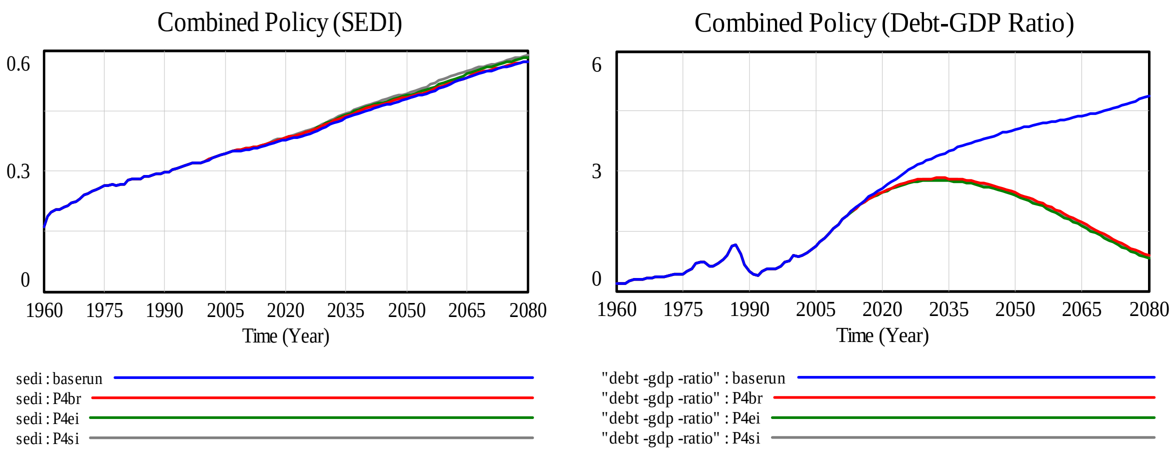

Figure 33: Results of Combined Policy Runs

Policies	Ranking of Policy Indicators		Overall ranking
	SEDI	Fiscal Sustainability	
Expansionary policy (P1)	1st	4th	4th
Contractionary Policy (P2)	4th	1st	3rd
Balanced Budget Policy (P3)	2nd	2nd	1st
Combined Policy (P4)	3rd	3rd	2nd

Table 7: Policy Ranking

To summarize, the policy simulation results, (as shown in table 7) indicates that the expansionary fiscal policy is the best policy to increase and enhance socio-economic development in Ghana. With the expansionary fiscal policy, as government expenditure increases, social and economic investment increases, which, consequently, increase production and access to social services, i.e. health and education. On fiscal sustainability, the simulation results lead us to conclude that the contractionary fiscal policy is the best policy in that it significantly reduces the public debt burden in Ghana. Concerning the contractionary fiscal policy, as the government expenditures reduce; budget surplus is accumulated over time to service outstanding public debt. This evidently decreases the debt-GDP ratio. The balanced budget deficit was identified as the second best fiscal policy with respect to the socio-economic development and debt-GDP ratio. The combined policy is the third best policy with respect to improving socio-economic development and in reducing the debt-GDP ratio.

From the forgoing analysis, the best policy aimed at achieving the twin goal of enhancing socio-economic development and ensures fiscal sustainability in Ghana is the balanced budget fiscal policy. The balanced budget fiscal policy is the most workable policy for the government of Ghana to pursue because it guarantees significant improvement in the socio-economic development while, at the same time, ensuring fiscal sustainability. Though a contractionary fiscal policy reduces debt-GDP ratio much more, the simple fact that it reduces socio-economic development slightly does not make the contractionary policy the most desirable policy**.**

To elaborate on the policy choice, i.e. the balanced budget fiscal policy, it is expected that the government expenditures is funded by government revenues and grants to avoid debt accumulation. We believe that if the government adopts this fiscal policy, innovative ways to generate revenue for the government will be pursued to increase government revenues. This is based on the empirical evidence that significant revenue due to the government is not realized due to an ineffective tax system and revenue collection structures, especially at the local level. Moreover, because a significant part of the economy in Ghana is informal, tax evasion is very prevalent and, by instituting the right structures, government revenues is expected to increase significantly to finance expenditures. It is important to note that, this study is not against government borrowing for effective investment that will increase economic growth.

8. Scenario Analysis

The scenario analysis simulates the impact of two experimented scenarios on the four fiscal policies discussed as part of the policy analysis section. The two scenarios are debt forgiveness and currency exchange rate increase.

Foreign interest rate increase scenario (S1)*:* The foreign interest rate increase scenario is based on the fact that current government borrowings are concessionary borrowing from the IMF and the World Bank. This scenario assumes that if loans are acquired from the private financial market, interest on loans will exceed the current interest rate on foreign borrowing. The scenario is implemented by assuming that by 2080, foreign interest rate will increase from 2.9% to 10%. This scenario assesses the impact of increasing tax revenue on socio-economic growth and fiscal sustainability.

Currency exchange rate increase scenario (S2)*:* The currency exchange rate increase scenario is informed by the observed constant devaluation of local currency due to factors such as bad macroeconomic management, high trade deficit and devaluation policies from IMF and the World Bank. For example, in 1990, the Ghanaian currency (cedi) did exchange for the US dollar at a rate of 1 US dollar to 326.3 cedi. By 2000, 1 US dollar was exchanged for 5455 Ghana cedi. As explained in the public debt module, the constant increase in exchange rate of Ghana cedi to US dollars has a significant effect on public debt accumulation. This scenario is implemented by assuming that by 2080, 1 US dollar will exchange for 15455 cedi. This scenario assesses the impact of further increase in exchange rate of Ghana cedi to US dollar on socio-economic development and fiscal sustainability.

Scenarios	**Expansionary Policy (P1)**	**Contractionary Policy (P2)**	**Balanced Budget Policy (P3)**	**Combined Policy (P4)**
Scenario 1				
SEDI	0.55	0.56	0.57	0.55
Fiscal Sustainability				
1.Cumm.budget deficit (+/-)	3.1E+11	-1.1E+11	6.1E+09	6.0E+10
2.Debt-GDP Ratio	4.15	0.02	0.13	1.23
Scenario 2				
SEDI	0.60	0.56	0.57	0.57
Fiscal Sustainability				
1.Cumm.budget deficit (+/-)	3.3E+11	-1.1E+11	6.1E+09	5.9E+10
2.Debt-GDP Ratio	3.46	0.02	0.12	0.94

Table 8: Result of Scenario Analysis

The outcome from the scenario 1 simulation as shown in table 8 and figure 34 establishes that the balanced budget and contractionary fiscal policy are the two best fiscal policies to be implemented to ensure stable socio-economic development and fiscal sustainability in an event that interest on foreign debt increases. As shown in table 8, under scenario 1 the balanced budget fiscal policy (P3) yields a SEDI of 0.57 and a debt-GDP ratio of 0.13 with an accumulated budget deficit of 6.1E+09. On the other hand, contractionary policy (P2) yields a SEDI of 0.56 and a debt-GDP ratio of 0.02 with an accumulated surplus of 1.1E+11. Under scenario 1, if the main concern of the government is fiscal sustainability, then, the contractionary policy is the best policy because it produces the least debt-GDP ratio as compared to balanced budget policy. However, if the objective of the government is to improve socio-economic development under scenario 1, then the balanced budget policy is best policy to achieve socio-economic development growth.

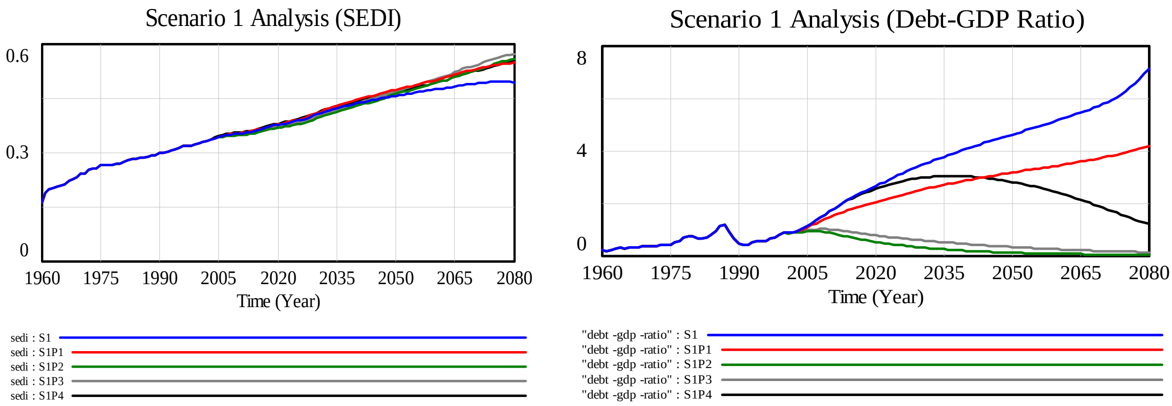

Figure 34: Results of Scenario 1 Simulation

The outcome of the scenario 2 simulation is evident in table 8 and figure 35. We established that in an event of currency exchange rate increase, the balanced budget and contractionary fiscal policy will be the best fiscal policies to pursue to avoid accumulating new public debt to increase the public debt burden and at the same time ensures sustainable improvement of socio-economic development. The balanced budget and contractionary fiscal policy proved to be the fiscal policies that maintains the gradual improvement in socio-economic development and also ensures fiscal sustainability. Table 8 indicates that, under scenario 2, the balanced budget fiscal policy yields a SEDI of 0.57 and a debt-GDP ratio of 0.12 with a cumulative budget deficit of 6.1 E+09, while the contractionary fiscal policy yields a SEDI of 0.56 and a debt-GDP ratio of 0.02 with a cumulative budget surplus of 1.1E+11. The expansionary fiscal policy guarantees the highest socio-economic development (SEDI of 0.60) with a significantly high debt-GDP ratio which makes the policy unsustainable.

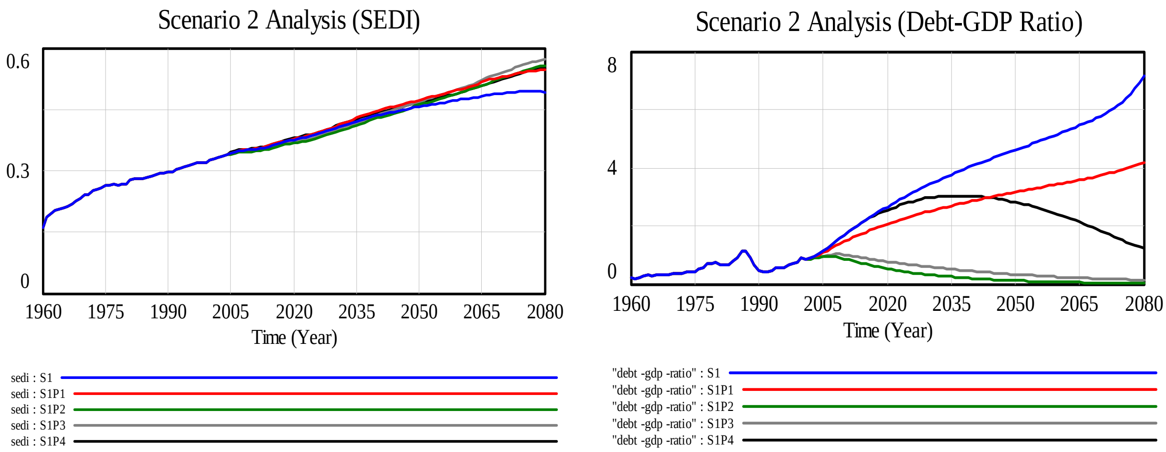

Figure 35: Results of Scenario 2 Simulation

In summary, the scenario analysis demonstrates that it is important for the government to maintain fiscal discipline when interest rate on public debt increases. Furthermore, we established that the only way for the government to achieve fiscal sustainability during continuous currency exchange rate increase is to avoid over spending i.e. to ensure that expenditure are funded by revenues and grants. When the government manages to operate a balanced budget, it is believed that the government can achieve the twin goal of socio-economic development and fiscal sustainability.

9. Conclusion

This paper presents a dynamic socio-economic model for assessing the impact of government fiscal policy on socio-economic development and fiscal sustainability. The model captures the interactions between the social, economic and public finance sectors of the economy. The base run simulation of the model establishes the theory explaining the observed behavior and evolution of the major variables. We designed a method for estimating socio-economic development and fiscal sustainability which utilized the synthetic data from the model to assess the desirability of the fiscal policy experimented. An ex-ante policy analysis was conducted to understand and assess the impact of each alternative fiscal policy proposed on socio-economic development and fiscal sustainability. In addition, a scenario analysis was conducted to assess the impact of each scenario on the proposed fiscal policies.

To summarize, the policy simulation results indicates that an expansionary fiscal policy is the preferred policy when one needs to increase and enhance socio-economic development. On fiscal sustainability, the simulation result concludes that contractionary fiscal policy is the best policy to significantly reduce the public debt burden in Ghana. The balanced budget policy was found to be the second best fiscal policy to increase the socio-economic development and decrease the debt-GDP ratio. The combined policy is the third best policy in terms of increasing socio-economic development and reducing the debt-GDP ratio. We, therefore, recommended the balanced budget fiscal policy as the most workable fiscal policy for the government of Ghana to pursue in order to achieve the twin goal of socio-economic development and fiscal sustainability. Though a contractionary fiscal policy reduces debt-GDP ratio much more significantly than the balanced budget fiscal policy, the simple fact that it reduces socio-economic development does not make the contractionary policy the most desirable one.

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