

## Paper III



---

# Dynamic Analysis of Millennium Development Goals (MDG) Interventions: The Ghana Case Study

Matteo Pedercini

*Millennium Institute, Arlington VA, U.S.A.*

*And*

*System Dynamics Group, University of Bergen, Norway*

Gerald O. Barney

*Millennium Institute, Arlington VA, U.S.A*

## Abstract

An increasing number of countries are orientating their development strategies on the Millennium Development Goals (MDG), a broad set of development goals agreed by the United Nations (UN) in the year 2000. Developing coherent plans to achieve the MDG is complicated by the multi-disciplinary nature of the goals and by the complexity of the system being managed. To support this planning process, various approaches have been developed that facilitate the identification of the necessary interventions to achieve the MDG and their cost. The work described in this paper complements the most commonly used approaches for MDG planning by analyzing the impact of alternative interventions in an integrated socio-economic-environmental framework. Our framework is implemented with the System Dynamics method, ideally suited to capture the elements of dynamic complexity – feedback loops in particular – that make public policy analysis in this area particularly difficult. This allows us to estimate the impact of the MDG-related interventions on the economic and demographic development of the country under study, as well as the possible positive and negative synergies between different interventions, e.g. between education and health interventions. Results indicate that failure to account for these factors can lead to sub-optimal strategies. Our objective is to provide policy-makers with a comprehensive picture of the outcomes of alternative MDG interventions, and their implications for financing.

**Keywords:** Millennium Development Goals, Resource-Based Approach, System Dynamics, National Development, Synergy

## Acknowledgment

This work has been supported by the Capacity Development Group in the Bureau of Development Policy, UNDP. We are particularly grateful to Terence Jones and Rati Tripathi for their help and assistance. We are also indebted to the Millennium Project team for collaborating with us in this study and with Pål Davidsen and Birgit Kopainsky for the many insights provided. Finally, we would like to thank the three anonymous referees and the Editor-in-Chief of *Socio-Economic Planning Sciences* for their valuable comments and contributions.

**Note:** Another version of this paper has been accepted for publication in *Socio-Economic Planning Sciences*. A preliminary draft of this work was presented at 23<sup>rd</sup> International System Dynamics Conference, July 17-21, 2005, Boston, USA.

# Dynamic Analysis of Millennium Development Goals (MDG) Interventions: The Ghana Case Study

## 1. Introduction

Over the last forty years human and economic development worldwide has accelerated. Nevertheless, a large share of the world's population today still lives in poverty (WB 2005), and developing countries struggle to identify proper strategies to stimulate growth. Lack of economic growth is often combined with poor human development, which appears to be at the same time a cause and an effect of the lack of economic resources (Ranis et al. 2000). Lately, environmental degradation and climate change is adding a new dimension to poverty, further complicating the development process.

The last forty years have also been characterized by Washington Consensus' driven development initiatives in developing countries (Serra and Stiglitz 2008). In this context, development policies guidelines were often dictated by a few international organizations, with little space for developing countries to identify their own development paths and strategies. The Washington Consensus' guidelines led to scarce practical results, which are now forcing the steering of development policies towards a new paradigm (Hausmann 2006). In an effort to reconsider developing countries' needs and priorities, in the year 2000 the United Nations (UN) Millennium Summit unanimously agreed on a broad set of development goals known as the Millennium Development Goals (MDG) (UN 2000).

The MDG are a set of time-bound development goals agreed by all the world's countries and leading development institutions. The goals cover economic, social and environmental aspects of development, and are meant to be reached by all countries within 2015. Despite having been criticized from various perspectives (Gaiha 2003; Clemens et al. 2004), they have made the indubitable contribution of clarifying and quantifying development targets, which were often only implicitly considered in development agendas.

Under the auspices of the UN, an increasing number of developing countries are orientating their development strategies on the MDG with mixed results (UN 2007). The multidisciplinary nature of the goals and the complexity of the underlying system make it particularly difficult for policy-makers to estimate the necessary resources to reach the goals, and to establish policy priorities. The objective of this study is to develop an approach to support policy-makers in the identification of the necessary resources and interventions to achieve the goals.

## 2. MDG-based development strategies

In an increasingly dynamic world, public decision-makers are called to manage highly complex systems. The integrated socio-economic-environmental systems they operate in are rich in feedback loops, delays and are highly non-linear, their functioning often escaping our understanding (Sterman 2000). In this context, mid and long-term national development planning is a particularly difficult task, where policy-makers have to confront countless issues and opportunities, over a time horizon where little can be taken as constant. As a result of these difficulties, it is not rare that policies are implemented that lead to unexpected, often undesired, results (Saeed 1987; Moxnes 2000).

Over the last three decades a broad range of computer models have been developed to support the understanding of development processes and to provide the possibility of testing alternative policies (Pedercini 2003). More specifically, over the last few years new approaches have been developed to support policy-makers in the development of strategies to meet the MDG, and of MDG-based development plans. The most commonly used approach is the MDG-Costing approach, a bottom-up method initially developed by the UN Millennium Project (MP) (UN 2005).

The MP's MDG-Costing approach consists primarily in identifying a country's gaps with respect to each of the MDG; estimating a unit cost for each type of intervention required to fill the gap; and applying this unit cost to the total target population. Eventually, the costs for the individual goals are added-up, and the external financial needs are estimated based on the country's ability to generate internal resources.

As first application of the MDG-Costing approach, the UN Millennium Project (MP) has conducted a comprehensive cross-country analysis of the interventions and investments required to achieve the MDG in various pilot developing countries (Sachs et al. 2004). The MP's study proposes a series of spreadsheet-based models that are used to calculate the cost for the MDG-related interventions<sup>1</sup> (MDG interventions in the following). These models are practical and rich in details, but they rely on exogenous assumptions for economic and demographic growth, and thus they do not address two major issues of interest: (1) the impact of the MDG interventions on the economic and demographic development of the country under study; and (2) the possible positive and negative synergies between different MDG interventions. Given the long-term nature of MDG-based planning, these omissions might lead to inaccurate estimates of the necessary resources, and eventually to the development of sub-optimal strategies.

More recently, the World Bank has developed a Maquette (model) for MDG Simulation (MAMS) to provide a better assessment of the impact of MDG interventions on a country's overall economic development (Bussolo and Medvedev 2007). The model on which this approach is based consists of a dynamic Computable General Equilibrium (CGE) module coupled with an MDG module. The CGE module calculates the main macroeconomic balances, while the MDG module uses a series of logistic functions to determine progress on the various goals based on the level of services provided in the key sectors.

The major advantage of MAMS' economy-wide approach over the MP approach is that it allows designing MDG strategies with a special focus on absorptive capacity constraints. Also, the treatment used to calculate progress on the MDG allows representing some cross-sector impacts. However, demographic development in the model is exogenous, and thus MAMS cannot capture the cross-sector feedbacks that take place through changes in the target population size.

In order to address some of the limitations of the MAMS and the MP approaches, we develop an integrated simulation approach for MDG planning, based on the Threshold 21 (T21) model (Barney 2002). Our T21-MDG approach endogenously represents economic and demographic development, thus allowing the analysis of the major system-wide impacts of MDG interventions. Our approach in particular aims at providing a dynamic and long-term

---

<sup>1</sup> Current versions of these models may be downloaded from <http://www.undp.org/poverty/tools.htm> (Accessed February 21, 2008).

perspective; it looks at positive and negative synergies between policies; and it explicitly considers implementation delays.

The T21-MDG approach is implemented with the System Dynamics (SD) method. The SD method focuses on the relationship between structure and behavior of complex dynamic systems (Richardson and Pugh 1981). The SD method has been employed to look at a wide range of developmental issues in countries at various stages of development (Parayno and Saeed 1993; Arango 2007; Qureshi 2008). The SD method is particularly well suited for this type of application as it enables a proper representation of the elements of dynamic complexity – feedback loops, accumulations and non-linearity – that are at the heart of our investigation (Forrester 1961). Also, the SD method helps maintaining a certain degree of model transparency, which is essential to support a better understanding of the system (Größler et al. 2000) and to consequently increase policy-makers' confidence in the model.

The work described in this paper complements and builds on the MAMS and MDG-Costing approaches. In particular, we embed the micro-level cost estimations from the MP's study in an integrated economic-social-environmental framework. This allows us to estimate the impact of the MDG interventions on the economic and demographic development of the country under study, as well as the possible positive and negative synergies between interventions. Our objective is to provide policy-makers with a comprehensive picture of the impact of alternative MDG strategies, and their implications for financing.

### **3. The Model**

The model developed for this study is based on Threshold 21 (T21) integrated development model from the Millennium Institute (Barney 2002), which we expand in order to allow simulating a broad range of MDG interventions. The basic T21 provides a comprehensive, integrated, and dynamic representation of the economic, social, and environmental aspects of the country's development. The additional structural components we develop represent the implementation mechanisms of the interventions analyzed, they keep track of the cost of such interventions, and they estimate the potential financing from the different sources. The expanded T21 (T21-MDG) allows us to simulate individually and simultaneously a greater variety of MDG interventions and to capture their effect on the country's population and economy.

Although it deals with many interactions, the resulting T21-MDG model is quite transparent in its structure and assumptions. In particular, the model is implemented with a stock and flow method, where causal relationships among variables are graphically displayed, so that the basic functioning of each sector can be more effectively conveyed. Figure 1 is a high level representation of T21-MDG's structure, which is composed of three spheres – society, economy and environment – each sphere containing six sectors. The sectors in each sphere interact with other sectors, within the same sphere as well as in other spheres. The result is an integrated system where the major aspects of development are interrelated with each other. In this type of system, MDG interventions directed to a specific sector eventually affect the whole socio-economic-environmental development.

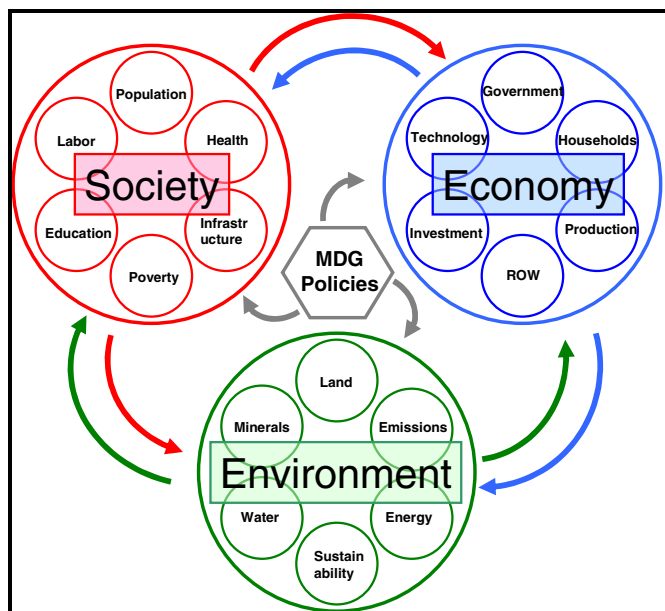


Figure 1: High level representation of the T21 model and the impact of MDG interventions.

Based on data availability, we select Ghana as the pilot country for our study, and we customize the general structured illustrated in Figure 1 to properly represent Ghana's most important development mechanisms. The following paragraphs summarize the central assumptions we use for the T21-MDG-Ghana and the analysis of MDG interventions, as well as the results of the calibration and validation processes.

### 3.1 General assumptions about population, economy and government

#### Population

The T21-MDG-Ghana model disaggregates the population into 82 age cohorts and by gender. The population cohort stocks are affected by four different flows: births (only for the first age cohort), deaths, migration, and aging (except for the last age cohort) (Sehgal 1989; Shorter et al. 1995). Births are calculated based on the size of the population in reproductive age and on the total fertility rate<sup>2</sup> (TFR). The TFR is a function of the level of income and education (Birdsall 1988). Mortality rates are determined based on the level of income and the level of services in the health sector (Rodgers 1979; Coale and Demeny 1983). Migration is exogenous, and reflects the latest projections from the United Nations Population Division (UN 2003).

#### Economy

Economic production in T21-MDG-Ghana is divided into agriculture, industry and services production. Production in each of these three sectors is calculated based on Cobb-Douglas (CD) production functions (Cobb and Douglas 1928), which we expand to include the effects of technology (Romer 1990), education (Sacredoti et al. 1998) and prevalence of malaria and HIV/AIDS (Haacker 2002) on total factor productivity. Investment is calculated endogenously based on private savings, public investment and foreign direct investment, and is allocated

<sup>2</sup> The total fertility rate is a concise indicator of fertility: it represents the number of children an average woman would have assuming that she lives her full reproductive lifetime.

among the sectors on the basis of sector-specific relative prices (Robinson et al. 1999). Consistency of the macro-economic framework is assured through the use of a Social Accounting Matrix (SAM) and conventional closure rules (Löfgren et al. 2002).

### ***Government***

The government sector is structured according to the International Monetary Fund (IMF) standard accounting framework (IMF 2001). The Government utilizes tax and non-tax revenue from the household/private sector to cover public consumption, public investment, and any transfers to the household/private sector. The Government allocates its resources across several sectors, including, but not limited to: administration, social security, education, health, water and energy, agriculture, and military. The level of service offered in each of these sectors depends on the amount of public expenditure and affects the development of the population and economy. In our analysis, we assume that constant tax rates and increased government spending for MDG interventions are maintained throughout the projection period, as also assumed in the MP's pilot study. Also consistently with such study, we assume that the external financing required to implement the MDG interventions will be covered by external grants.

### ***3.2 Assumptions about the MDG interventions***

#### ***Cost of the interventions***

The MP's pilot study has identified a set of MDG specific interventions and estimated their costs, both on the per capita (i.e., per person served) basis and the total cost basis, and their direct effect on the target population. We replicate such interventions and use the same unit (per capita) cost and direct effect estimates in our analysis. These cost estimations suffer at least two limitations: first, over the time period considered unit costs of intervention are unlikely to remain constant; second, scaling up interventions might influence unit costs. Nevertheless, by carefully replicating such assumptions, we ensure that any differences between the results of our analyses and that of the MP are not due to different parameterizations, but rather to the broader, more dynamic, and more integrated framework that we adopt. Our framework also allows relaxing the cost assumptions in the MP study, but this is beyond the scope of this analysis.

#### ***Timing of the interventions***

The timing of the MDG interventions significantly influences costs and feasibility of meeting the MDG by 2015. Even assuming that the funds for the interventions start flowing at the beginning of 2005, significant contracting and administrative delays will be encountered before the desired services are available to the population. We optimistically assume a delay of one year from the moment expenditure for MDG interventions is allocated, until the related services are delivered. By the time this study is being published, although Ghana has made good progress on the achievement of the MDG, comprehensive large scale interventions as those analyzed in his study have not yet been implemented.

#### ***Absorptive capacity constraints***

The absorptive capacity (physical and human capital) constraints constitute a limit to a country's ability to scale up interventions in the short term. The patterns of expenditure for the MDG interventions recommended in the MP's study and that we replicate in T21 implicitly take account of this issue. More specifically, we assume that the absorptive capacity constraints can be relaxed substantially over the medium term through systematic investments in human resources, administrative capacity, or infrastructure. As a consequence, the long



ramp up time of the MDG expenditures we adopt is assumed to avoid capacity constraints. Although our framework allows for the explicit consideration of absorptive capacity constraints, in this study we maintain the assumption in the MP study, to ensure that differences in results are due to the more dynamic and integrated nature of our approach.

### ***Governance issues***

Although part of the social services in the MDG related areas are provided by the private sector, we simulate the interventions as if they were entirely implemented through the public sector and based on foreign grants, in line with the financing scheme in the MP study. Public management of such large amount of funds can lead to (or worsen) corruption issues, with possible consequent reductions in efficiency. Our framework does not explicitly consider this issue, but by producing a detailed phase-out of the interventions, it provides a basis for monitoring and evaluating policy implementation.

### ***3.3 Calibration and Validation***

In order to calibrate the T21 model for Ghana, we develop a broad database based on internationally recognized data sources (UN 2003; FAO 2004; IMF 2004; IMF 2004; IMF 2004; WB 2005). The database contains historical data for 172 variables, over the period 1990 – 2004. The data was used to perform direct and indirect parameters' estimation, as well as to test the ability of the model to replicate historical behavior. Limited data availability prevents us from extending the calibration period further back in time. Nevertheless, we judge that 15 years constitute a sufficiently long observation period to estimate whether the model is able to replicate the system's performance in the medium and long-term.

Table 1 reports the coefficient of determination ( $R^2$ ), the root mean square percent error (RMSPE), and the Theil's inequality statistics<sup>3</sup> for 6 major variables, resulting from the comparison of model's behavior with historical data. The RMSPE is an appropriate statistic to test goodness of fit of System Dynamics models, and its decomposition through Theil's inequality statistics helps to identify the causes of possible errors: these may be due to inadequacy of the model or to unsystematic variation in the historical data (Sterman 1984).

The first two indicators, total population and real gross domestic product (GDP) at market prices, provide an indication of how the model can retrace the demographic and economic development of the country over the last 15 years. The other four indicators cover the four major areas of intervention considered in our analysis: health, education, infrastructure, and hunger.

Overall, the RMSPE is under 5% for all indicators, suggesting that the model is able to reproduce to a large extent their historical performance. The  $R^2$  are also all above 90%, except that for the road network extension. Nevertheless, the decomposition of the error for this variable indicates that 98% of it is of unsystematic nature ( $U^c$ ), while the bias component ( $U^b$ ), and the unequal variation component ( $U^v$ ) are close to zero. This confirms that although the model does not capture the short term oscillations in the historical data (which are not relevant to our analysis) it captures well the average value and dominant trends.

---

<sup>3</sup> Theil's inequality statistics decompose the RMSPE into three components: its bias component ( $U^b$ ); its unequal variation component ( $U^v$ ); and its unequal covariation component ( $U^c$ ).

**Table 1: Summary statistics: Base scenario and historical data.**

Variable	RMSPE	Inequality Statistics			R <sup>2</sup>
		U <sup>M</sup>	U <sup>S</sup>	U <sup>C</sup>	
Total population	0.01	0.82	0.15	0.02	1.00
Real GDP market prices	0.03	0.20	0.39	0.40	0.99
Under five mortality rate	0.03	0.14	0.10	0.77	0.90
Average adult literacy rate	0.01	0.33	0.24	0.43	0.98
Road Network Extension	0.02	0.00	0.02	0.98	0.45
Agricultural production	0.03	0.53	0.02	0.44	0.95

The results of model's calibration provide some grounds to assess the ability of the model to replicate historical trends. However, in System Dynamics practice, behavioural validation is coupled to structural validation of the model: System Dynamics models are causal models and should endogenously generate the right behaviour for right reasons (Sterman 2000). For this purpose the structure of the model was continuously tested following the standard System Dynamics validation procedures (Barlas 1996).

Eventually, the validity of a System Dynamics model resides in its ability to provide insights in the key questions being addressed (Forrester 1961). As discussed in sections 1 and 2, the purpose of this model is to support the analysis of the impact of a variety of MDG interventions. The following section 4 demonstrates the usefulness of the model for this type of policy analysis.

#### 4. MDG simulations

Based on the model described above, we first simulate a "Base" (business-as-usual) scenario up to 2025, where no MDG interventions are introduced. This scenario indicates that, assuming unchanged external conditions, none of the MDG could be fully achieved in Ghana without specific interventions targeting the most vulnerable population. The projections provided by the Base scenario are not to be intended as predictions, but only as the likely consequences of the actual state of the system and policy regime. The Base scenario is used in this analysis as a reference against which the results from the MDG interventions can be compared and assessed, and we will thus not discuss in detail its results.

In this study we analyze the impact of the fourteen MDG interventions listed in Table 2, covering all the MDG, with exception of MDG 8 (which refers mainly to the engagement of the international community).

**Table 2: MDG interventions simulated with T21-Ghana grouped by type of intervention**

Intervention	Group
1. Maternal health	Health
2. Child health	
3. HIV/AIDS prevention	
4. HIV/AIDS treatment	
5. Malaria prevention and care	
6. Tuberculosis prevention and care	
7. Primary education	Education
8. Secondary education	
9. Adult learning programs	
10. Clean water	Infrastructures
11. Sanitation	
12. Energy provision	
13. Roads development	
14. Agriculture productivity	Hunger

For each of these fourteen interventions, we incorporate the cost and effect estimates from the MP's study into the T21-MDG-Ghana model. We then simulate the implementation of these fourteen MP interventions, and we analyze the time-specific results produced for the relevant indicators (UNDG 2003) by each intervention individually and then collectively. In this way, we assess the impact of the interventions on Ghana's socio-economic system and the positive and negative synergies between the interventions. The following sections present a selection of scenarios that highlight the insights gained from the analysis and form the basis for the conclusions.

#### ***4.1 The health, energy, water and sanitation interventions***

The MDG interventions can influence the size of the targeted population groups, thus changing the amount of resources needed to achieve the MDG. Some interventions will decrease the population (girl's education, for example), and some will increase the population (reducing infant mortality and HIV/AIDS, for example).

By providing essential services and infrastructure, the interventions in the health, energy, water, and sanitation sectors attempt to save human lives and increase quality of life. As a direct consequence of such interventions, the mortality rates of the target population groups are reduced, causing the target groups to grow beyond the level they would have reached otherwise. This extra growth in the groups to be served increases the resources needed to bring the target groups up to the MDG, creating the need for additional funds.

The interaction of the MDG and population are part of a complex feedback system, part of which is illustrated in the causal loop diagram<sup>4</sup> (Richardson 1986) of Figure 2. The interventions-to-mortality-to-population-to-interventions mechanism just described defines a feedback loop (Sterman 2000), the "Health Loop" illustrated in Figure 2.

The Health Loop is a "balancing loop", meaning that an increase in the per capita expenditure in the health, energy, water, or sanitation sectors leads to an increase in the target population, which tends to balance the initial increase in per capita expenditure. This balancing effect makes it more difficult to reach the goal of the intervention. The Health Loop, therefore, is a

<sup>4</sup> A causal loop diagram is a description of the causal relationships (the arrows in Figure 2) linking the variables in a system. The signs associated to each arrow indicate the polarity of the relationship: a positive (negative) sign indicates that an increase in the "source" variable generates an increase (decrease) in the "destination" variable.

source of “policy resistance,” i.e., a feedback structure that makes reaching the MDG more expensive than it would be the case if there were no feedback.

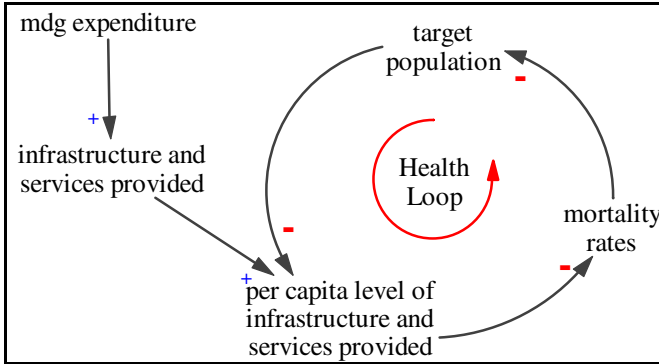


Figure 2: Health feedback loop.

The balancing feedback loop in Figure 2 works with different intensities for all the interventions in the health, water, sanitation, and energy sectors. Consider for example the MDG intervention intended to reduce under-five mortality. Figure 3 illustrates the development over time of the under-five population in two simulations from the T21 model, namely the “base” run (line (1) in the graph) and the “child health” run (line (2) in the graph). The base run represents the *momentum* or *business as usual* case in which no specific MDG interventions are introduced and government policies are assumed to continue along the current lines. The child-health run differs from the base run only in that the measures to improve child health recommended in the MP’s study are implemented.

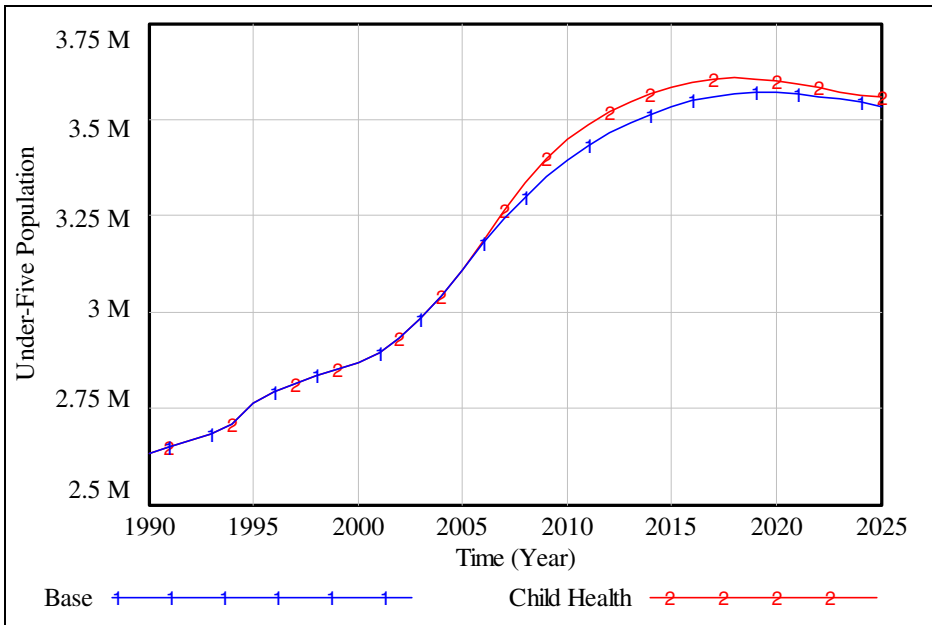


Figure 3: Under-five population in millions

As can be seen in Figure 3, the intervention to reduce under-five mortality leads to a faster increase in the under-five population starting from 2005. Although in both cases growth in the

under five population tends to slow down as a consequence of the reduction in fertility associated to the country's development, by 2015 the difference between the under-five population in the two cases is about 50,000 children. This expansion of the target group of the intervention means that the funds initially estimated to be sufficient to achieve the goal of providing proper care for all children under five will fall short because there will actually be more children in this age group to be provided care. The graph in Figure 4 reports the development over time of the fraction of children receiving proper care, in the base case (line (1) in the graph) and in the child health case (line (2) in the graph). Although very close to the target, by 2015 the MDG intervention does not reach the desired level of coverage, as a result of the policy resistance mechanism shown in Figure 2.

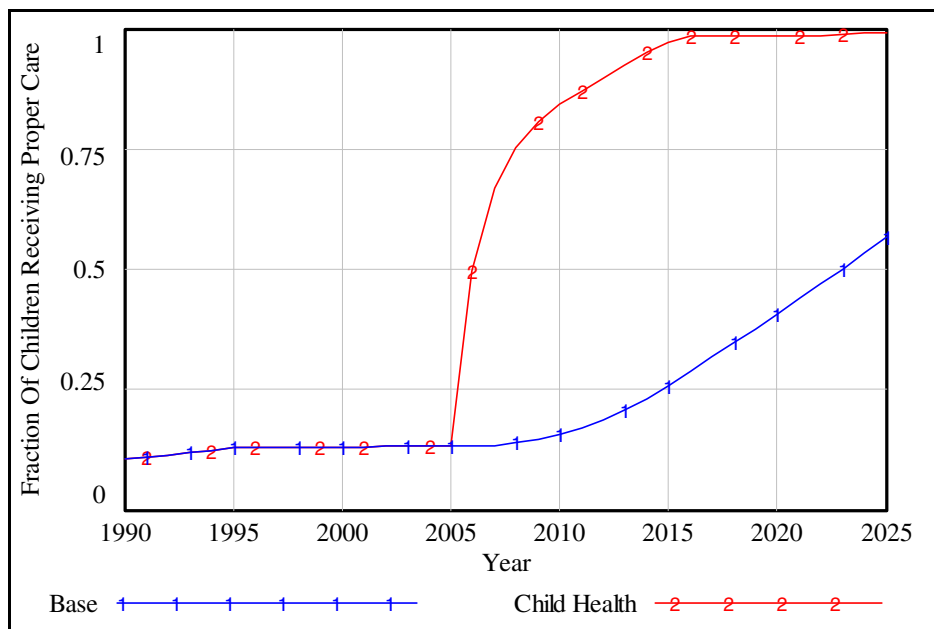


Figure 4: Fraction of children receiving proper care

All the interventions for health, energy, water, and sanitation produce, with different intensities, the same kind of feedback and balancing reaction. Since most of the interventions have overlapping target groups, there are feedback effects between the interventions. For example, an intervention to prevent and cure tuberculosis affects the mortality rates of the whole population, including children, and thus fighting tuberculosis will cause an increase in the under-five population and will increase the costs of reaching child health goals. This is an example of a negative synergy between the MDG, i.e., an example of where progress on one MDG makes reaching one or more other MDG more difficult.

The negative synergy effect is illustrated in Figure 5. The graph shows the development of under-five population in the two previous cases and in the case of all health, energy, water, and sanitation interventions being put in place (line (3) in the graph). In the latter case, by 2015 the target under-five population group grows to about 100,000 more persons than in the base case. Consequently, the fraction of children receiving proper care is lower than in the case in which only the child health interventions are implemented.

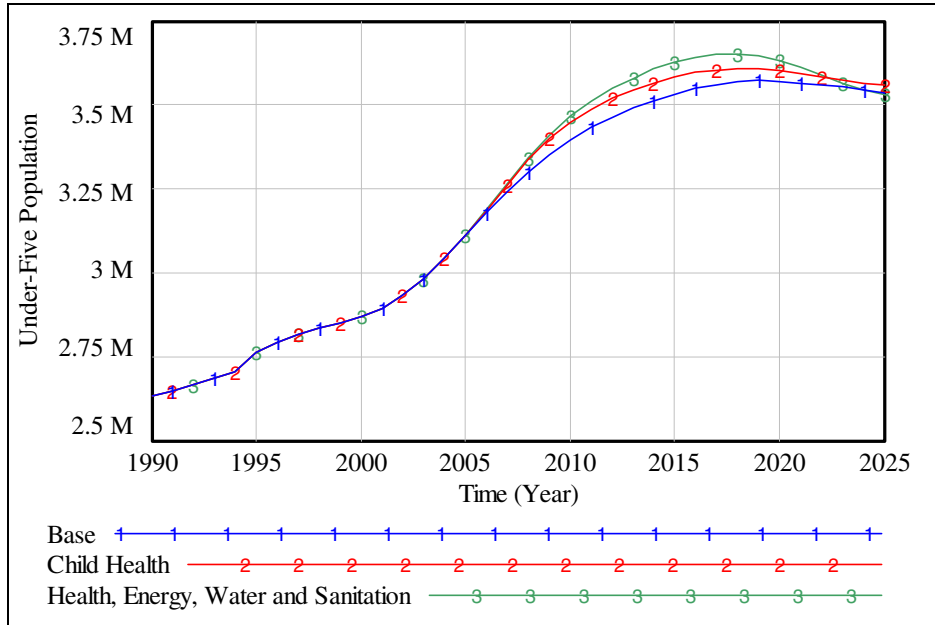


Figure 5: Under-five population in millions

The policy resistances and negative synergies illustrated above affect all interventions that aim at improving the quality of life and decreasing mortality. The more effective these interventions are in reducing the mortality of the population served, the stronger the policy resistances and negative synergies are and the more difficult it becomes to reach the goals. This non-linear nature of the relationship between expenditure and effectiveness of the MDG interventions in health, energy, water and sanitation can interfere with the progress toward the Goals.

#### 4.2 Interventions in the education sector

As described above, interventions reducing mortality create policy resistance and negative synergies. On the other hand, interventions in the education sector create policy reinforcement and positive synergies.

The interventions in the education sector provide teachers, infrastructure, and materials and aim at increasing attendance at school and raising the adult literacy rate<sup>5</sup>. Increasing the level of education and knowledge in the adult population can boost the contraceptive prevalence rate<sup>6</sup>, and consequently decrease the total fertility rate (Birdsall 1988). As the fertility rate and the births drop, the number of children to be enrolled in school decreases (with a delay of about 6 years), reducing the amount of resources required to ensure a 100% enrollment rate. These interactions define a feedback loop, the “Education Loop” in Figure 6.

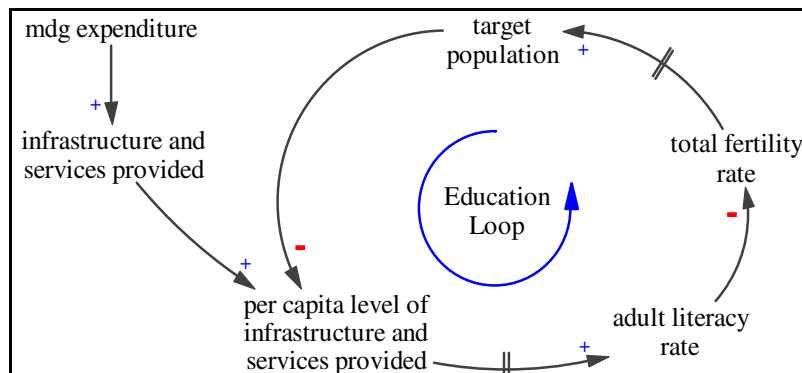
The Education Loop in Figure 6 has a reinforcing effect. An increase in the expenditure for education is followed, with a significant delay<sup>7</sup>, by a reduction in the number of children and, therefore, an increase in the amount of resources available per student. This mechanism enhances the effectiveness of the educational interventions. The Education Loop is therefore a

<sup>5</sup> Adult literacy rate is defined as the percentage of population aged 15 years and over who can both read and write.

<sup>6</sup> Contraception prevalence rate is defined as the proportion of women of reproductive age using a contraceptive method.

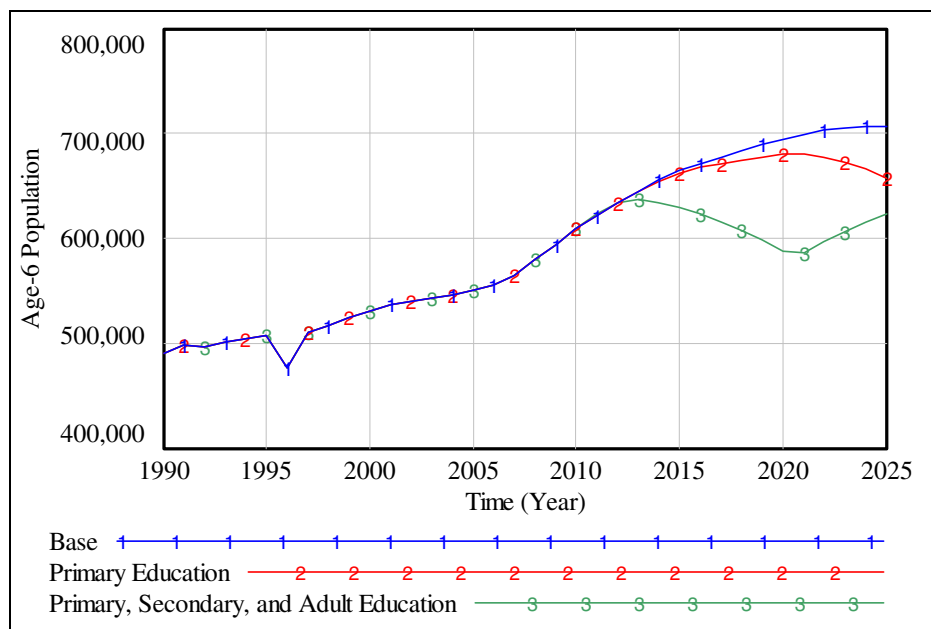
<sup>7</sup> In CLDs delays are indicated by a double bar crossing the arrows that represent relationships among variables.

source of policy reinforcement, and reduces the amount of resources needed to reach the educational MDG.



**Figure 6: Education feedback loop**

An example of this phenomenon is illustrated in Figure 7, which shows the development of the age-6 population in the three cases, (1) the base case, (2) the “primary education” case, and (3) the “primary, secondary, and adult education” case.



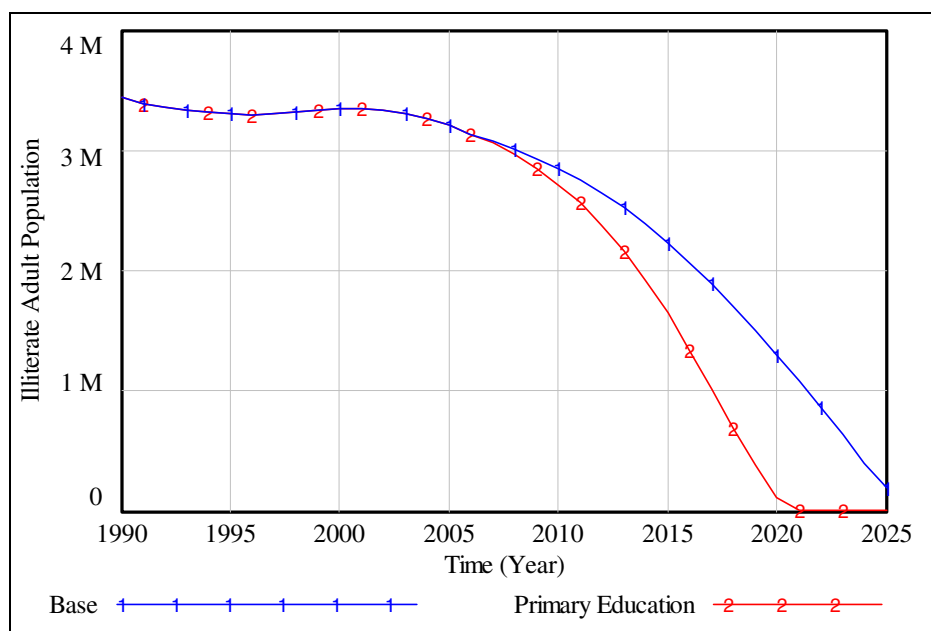
**Figure 7: Age-6 population**

In the primary education case we assume that the government implements the measures recommended by the MP to improve the primary education system. In that case, the age-6 population cohort develops at a slower rate, and by 2025 is about 7% lower than in the base case. However, there is no significant difference between the two target groups in the time horizon of the MDG. This is due to the delays present in the system. Once the resources are allocated and human and physical capital are in place, it takes several years before the people receiving high quality primary education enter their reproductive age, and even longer before their children will start going to school.

This feedback mechanism works similarly for the secondary and adult education interventions, although with different intensities and delays. In particular, the interventions in the secondary and adult education sectors impact more rapidly on the total fertility rate. This is due to the fact that the target groups of such interventions are already in their reproductive age, and therefore a change in their education level influences the fertility rate relatively quickly.

In the primary, secondary and adult education case, the development of the age-6 population cohort slows significantly by 2012, and already in 2015 is about 5% lower than in the base case. This illustrates that even in the relatively short time horizon of the MDG (considering the inertia in demographic development), the education interventions create important synergies.

A reduction of fertility has little immediate effect on the target group for adult education program, due to the long time lag between the moment the fertility rate changes and the moment the adult population changes. Nevertheless, the adult education interventions benefit from another type of synergy deriving from the combined primary and secondary education programs. As shown in Figure 8, when the graduation rate from primary and secondary education programs increases, the number of illiterate adults decreases, thus reducing the resources needed for adult literacy programs.



**Figure 8: Illiterate adult population, in millions**

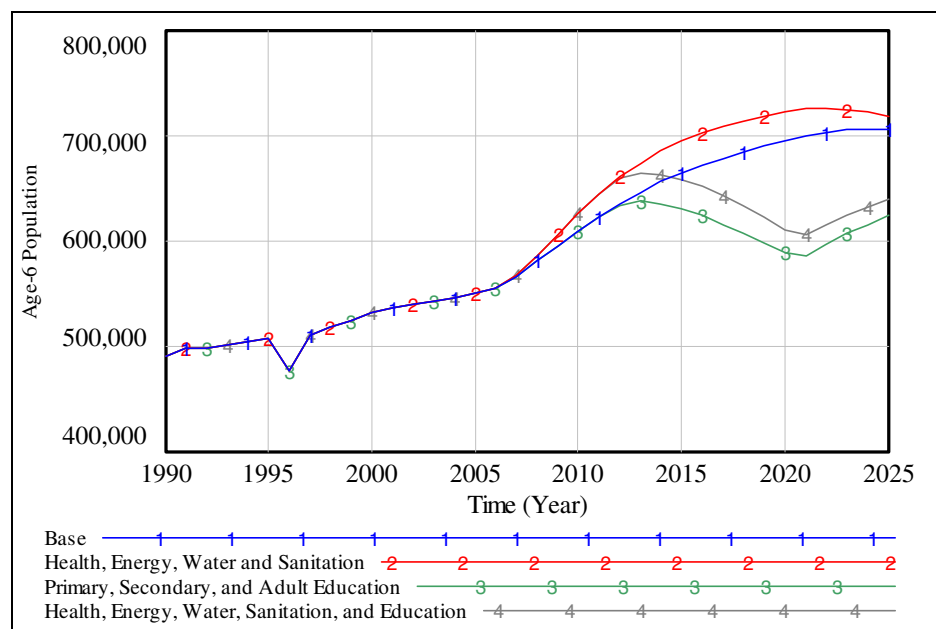
Our analysis suggests that the synergies between the various education-related interventions are quite strong. In particular, the more effective the individual interventions are, the stronger are the synergies between them, and the less are the resources needed to achieve the goals. This non-linear nature of the relationship between expenditure and effectiveness of the education-related interventions can speed up the progress towards the MDG.



### 4.3 Interactions between health and education interventions

In the previous paragraphs we discuss individually the effect of the health and education interventions on the population. However, most of the interventions in the health and education sectors have overlapping target groups. Consequently, changes in population generated by the health interventions also affect the effectiveness of the education interventions, and vice versa. What happens then when education and health interventions are jointly implemented?

Although the number of interacting feedback loops increases, the same principles described above for the single interventions apply. Figure 9 illustrates the development of the age-6 population cohort in four cases, (1) the base case, (2) the all-health-interventions case, (3) the all-education-interventions case, and (4) the health-energy-water-sanitation- education case. In the latter case, all the health and education interventions are simultaneously simulated.



**Figure 9: Age-6 population**

In this more comprehensive simulation, the age-6 population cohort grows faster than in the base case until 2012, just as in the case in which the health-interventions are implemented. This is due to the positive impact of health interventions on the population. In 2012, however, a shift in the system's behavior occurs: after a delay of about 7 years, the decrease in the fertility rate caused by the education interventions begins to affect the size of the school-age population. This effect is even stronger than the effect of improved health on population. The age-6 population diverges from the path followed in the case of all-health-interventions, and by 2020 is substantially lower than what is observed in the base case. This same mechanism is also at work for the target groups of all-health-interventions, but with different time delays and intensities.

As illustrated in Figure 9, not only do the interactions of the MDG interventions with the population influence the total amount of funds needed to reach the MDG, but also the timing of when the resources are needed. For example, considering the interventions in the education sector, Figure 9 suggests that a larger allocation of resources to education is needed in the

early years of the interventions and that the allocation of resources needed declines substantially in the years after 2012. Similar insights can be gained for all the MDG interventions. Such insights emphasize the importance of properly considering the impacts of feedbacks between the interventions and on the demographic development of the country.

#### ***4.4 Time delays: shooting a moving target***

The time-bound nature of the MDG, which are supposed to be achieved by 2015, makes the analysis of the delays involved in the MDG interventions essential. Optimistically, we estimate time lags of one year between the moment the necessary investments and interventions start, and the time the benefits and services actually reach the target population. These delays are incorporated in T21 and used to simulate the MDG interventions.

These delays affect the progress towards the MDG in two ways. A delay in the implementation of the interventions will lead to a delay in the provision of the necessary services, and can, therefore, postpone the achievement of the MDG. Delays can also make reaching the MDG both harder and more expensive: the resources needed for MDG interventions are based on population figures, which are rapidly evolving. Any change in the time frame of the interventions would imply a change in the size of the target groups, and therefore implies an adjustment of the amount of resources required to reach the MDG.

As an example, consider the interventions in the energy sector. In this case, a certain amount of capital, both physical and human, needs to be created to serve the target population by 2015. If capital formation is delayed by one year, the necessary services for the planned target population will be provided only by 2016. However, by 2016 the total population will have increased, making the services provided insufficient to reach the MDG targets. The population of Ghana is projected to grow at a rate of about half million people per year between 2015 and 2020. This rapid demographic growth creates a new challenge for reaching the MDG: any delay in the implementation of the interventions may lead to higher financing needs.

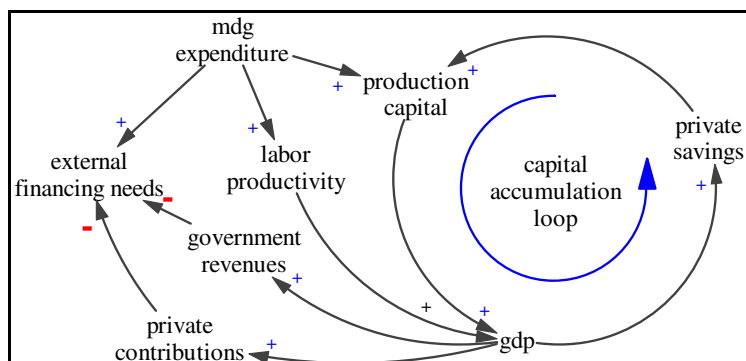
#### ***4.5 The impact of MDG interventions on economic development***

The MP's study calculated the external financing needed to reach the MDG for Ghana based on existing economic growth projections. The MDG interventions, however, influence the economic development of Ghana and change the amount of public and private resources available from domestic sources for the MDG. The economic impact of the interventions modifies the external financing needs of the country, and influences the long-term sustainability of the interventions.

The MDG interventions influence the economy both through labor productivity and through investment. On the productivity side, MDG interventions that reduce mortality and morbidity and that raise the education level have a positive impact on workers' productivity (Bloom et al. 2001; Bosworth and Collins 2003). On the investment side, the public investment required to meet the MDG results in capital accumulation, in particular in the service sector, and in a consequent increase in employment.

For Ghana, the interventions required to achieve the MDG by 2015 require a substantial increase in public expenditure, something on the order of 20% of GDP. Part of this expenditure consists of investment, which brings about acceleration in capital accumulation, in particular in the service sector. The acceleration in the growth of the capital stock should boost employment and economic production and increase the per capita income. Private savings therefore increase, increasing capital accumulation even more. The feedback

mechanism just described is illustrated in Figure 10, and defines the “Capital Accumulation Loop”.



**Figure 10: Capital accumulation loop and financing needs**

The capital accumulation loop is conceptually similar to the accelerator principle, and has a reinforcing effect. Any MDG intervention introduced causes an initial increase in the production capital, which is amplified by the consequent increase in income, savings, investment, and capital accumulation.

In a different way, but with similar results, the MDG interventions also affect labor productivity. The interventions in the education sector increase the level of education and skills of the labor force. The interventions in the health, energy, water and sanitation sectors improve the workers' health and quality of life. The interventions in the agriculture and transportation sectors directly aim at increasing productivity by providing better infrastructure, materials and techniques. In combination, these factors have an important impact on the overall labor productivity. As illustrated in Figure 10, labor productivity impacts GDP and further strengthens the capital accumulation loop.

Figure 11 illustrates the development of Ghana's real GDP for two scenarios: (1) the base case, and (2) the “all-MDG-interventions” case. In the latter scenario, we assume that all the MDG interventions recommended by the MP are put in place. In this case, GDP is projected for 2015 to reach a level about 14% higher than in the base case. The sharp increase in public expenditure, however, does not immediately benefit the economy because it takes time to augment the country's production capacity to meet the increased demand. This means that initially Ghana relies on imports to provide the necessary goods and services for the MDG interventions.

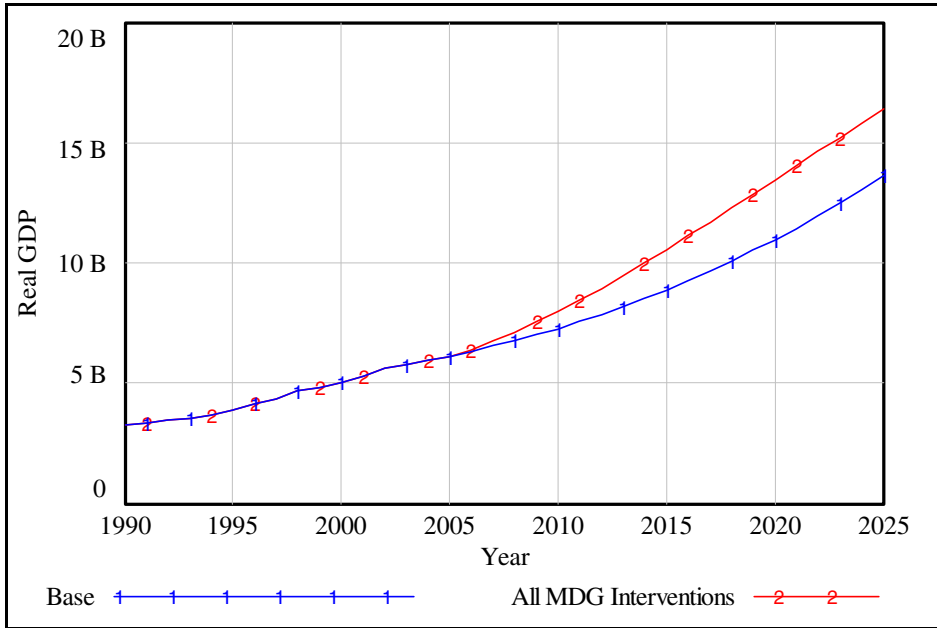


Figure 11: GDP in billions of real U.S. Dollars (base year 2000)

The acceleration of economic growth and imports has important implications for the financing of the MDG intervention, as discussed in the following paragraphs.

**4.6 External financing and sustainability**

The acceleration of GDP growth observed in Figure 11 has a direct effect on the government’s revenue. Since we assume the tax rates to be fixed at the current levels until 2025, changes in the level of income are proportionally reflected in government revenue. Moreover, imports are projected to grow more than proportionally to GDP, generating an even faster increase in import taxes. Consequently, as shown in Figure 12, the government tax revenue by 2015 is expected to be about 23% higher in the all MDG interventions case (line (2) in the graph) than in the base case (line (1) in the graph).

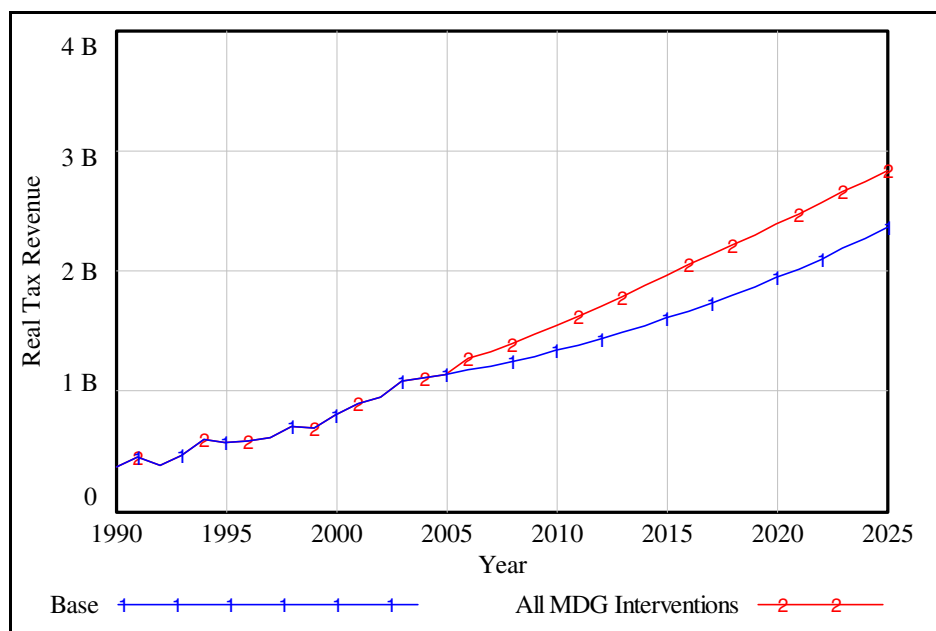


Figure 12: Tax revenue in billions of real U.S. Dollars (base year 2000)

The increase in GDP also generates an increase in the household revenue, and therefore in the private disposable income. Both households and government can provide a significant contribution to the financing of MDG interventions. The government allocates part of its revenue for the MDG interventions, and private households/firms, contribute to financing the MDG services according to their income level. Therefore the mechanisms illustrated in Figure 10 should reduce the amount of resources needed from external sources to achieve the MDG by increasing the amounts the government and the private household/firms can contribute from their increased income.

The projected reduction in the external financing needs for the MDG resulting from the acceleration of economic growth appears to be significant, both in absolute and relative terms. The MP's study assumes that the government will contribute to the MDG expenditure with about 9% of the GDP and that households will contribute to the cost of some interventions depending on their level of income. When incorporating such assumptions in T21 and simulating all the recommended MDG interventions, the required external financing by 2015 turns out to be about 10% lower than calculated by the MP. Table 3 reports the projected private and public contributions as well as the total expenditure for the MDG in 2015. The numbers in Table 3 are not intended to be precise forecasts, but are indicative of the direction in which the system moves when considering the impact of the MDG interventions on the economy of Ghana.

**Table 3: Contributions to MDG expenditure in USD2000**

<b>Contribution to MDG expenditure</b>	<b>2006</b>	<b>2010</b>	<b>2015</b>
MDG expenditure in USD2000	1,534,051,072	1,989,995,776	2,550,837,248
Relative difference with respect to MP estimation	0.00	0.00	0.00
Government contribution to MDG in USD2000	373,444,320	547,962,048	955,121,856
Relative difference with respect to MP estimation	0.00	-0.01	0.14
Private contribution to MDG in USD2000	189,221,056	254,121,392	364,427,264
Relative difference with respect to MP estimation	0.05	0.05	0.07
External financing needed for MDG in USD2000	971,385,728	1,187,912,192	1,231,288,320
Relative difference with respect to MP estimation	-0.01	-0.01	-0.10

The domestic contribution to the MDG expenditure projected by T21 begins very close to that calculated by the MP, but grows more rapidly between 2010 and 2015, driven by the growth of GDP. As a result, the amount of external financing needed for the MDG decreases from the initial 15.2% of GDP in 2006 to 11.7% in 2015. This reduction is even more evident if one looks beyond 2015. In 2025 the external financing needed is projected to be below 4% of Ghana's GDP, with profound consequences for the sustainability of the MDG interventions. The simulations show that, in the long term, Ghana will be able to pay for most of the necessary interventions and will rely only limitedly on external financing. After the initial injection of foreign capital, the country economy strengthens and provides most of the resources needed for achieving and maintaining the MDG. The MDG interventions consequently become more easily sustained in the long run.

## **5. Summary findings and conclusions**

This study embeds the cost and impact assumptions from the MP's study in an integrated development planning model designed to assess the impact of the MDG interventions on Ghana's economy and population. The study identifies (1) positive and negative synergies between interventions, and the associated policy resistance and amplification; (2) the role of time delays in achieving the Goals; (3) the implications for financing of the MDG. These three areas of insights are described more in detail in the following paragraphs.

### **5.1. Positive and negative synergies**

The MDG interventions are implemented in a complex feedback system that can be the source of either policy resistance or amplification. Also, the target groups of many MDG interventions are overlapping, so that the impact of one intervention on the population may affect the effectiveness of another, creating positive and negative synergies.

These phenomena have two major consequences. First, the effective cost of achieving the MDG may differ from what is projected when the impacts of the MDG interventions on population are not considered. In general, the interventions aiming at improving quality of life and reducing mortality tend to cost more than expected and make it more expensive to reach the other MDG. The interventions improving education tend to cost less than expected and help reaching the other Goals. Second, the interactions between policies also shift the recommended pattern of expenditure over time for each intervention. The MDG interventions rapidly impact population by reducing mortality, while only in the medium term affect fertility. Consequently, a larger allocation of resources is needed in the early years of the interventions and the allocation of resources needed declines substantially when approaching 2015.

## 5.2. Time delays

We identify time delays that can significantly influence the achievement of the MDG. Not only can these delays slow down the achievement of the Goals, but they can also make it substantially more difficult and expensive. The MDG are based on targeting population groups whose size and needs evolve over time. Providing the level of service planned for 2015 in 2016 will not just be late, it will be inadequate to serve fully the rapidly growing population. Consequently, it is necessary to recalibrate the patterns of expenditure to consider the rapid development of the demographic figures if expenditure delays are expected or encountered.

## 5.3. Implications for financing

Given the size of the investment required to reach the MDG and the positive effect of the interventions on labor productivity, a substantial growth of the economy is to be expected. As a consequence, the revenues of government and households grow rapidly, increasing the domestic capacity of contributing to the financing of achieving the MDG. In particular, the external financing needs are projected to be about 10% lower in 2015 than expected when not considering the impacts of the interventions on the local economy. This domestic revenue supplement is also very important in view of the sustainability of the interventions. This analysis shows that, after an initial period of substantial financing from abroad, Ghana becomes increasingly capable of helping itself along towards the MDG.

## 5.4. Conclusions

By expanding the T21 model to properly represent the functioning and the impact of the MDG interventions analyzed, we are able to capture the inherently complex response of the system to such interventions. The model allows us to identify relevant insights for policy-making that complement, from a different perspective, the information provided by the other common tools used for MDG planning. Ignoring the dynamic response of the system to the interventions analyzed is likely to lead to the development of a sub-optimal MDG strategy. We suggest that our approach be used in combination with MDG-costing and MAMS in order to provide policy-makers a clearer picture of the impact of alternative MDG strategies, and their implications for financing. While relaxing some key assumptions implicitly adopted in the MP team's approach, this study does not fully address some practical implementation issues such as absorption capacity and corruption, which can be determinants for the success of an MDG strategy. Further research is required to extend our analysis in this direction.

## References

- Arango, S., 2007, "Simulation of alternative regulations in the Colombian electricity markets", *Socio-Economic Planning Sciences*, 41(4): 305-319.
- Barlas, Y., 1996, "Formal Aspects of Model Validity and Validation in System Dynamics", *System Dynamics Review*, 12(3): 183-210.
- Barney, G. O., 2002, "The Global 2000 Report to the President and the Threshold 21 model: influences of Dana Meadows and system dynamics." *System Dynamics Review*, 18(2): 123-136.

- Birdsall, N., 1988, Economic Approaches to Population Growth, *Handbook of Development Economics*, T. N. S. H. Chenery, Amsterdam, Elsevier Science Publishers B.V., 1: 478-542.
- Bloom, D. E., D. Canning, et al., 2001, "The Effect of Health on Economic Growth: Theory and Evidence", *NBER Working Paper Series*, (WP8587), National Bureau of Economic Research, Cambridge, MA.
- Bosworth, B. and S. M. Collins, 2003, "The Empirics of Growth: An Update", *Brookings papers on economic activity*, (2), Brookings Institution, Washington D.C.
- Bussolo, M. and D. Medvedev, 2007, "Challenges to MDG Achievement in Low Income Countries: Lessons from Ghana and Honduras", *World Bank Policy Research Working Paper*, The World Bank, Washington D.C.
- Clemens, M. A., C. J. Kenny, et al., 2004, "The Trouble with the MDGs: Confronting Expectations of Aid and Development Success", (WP40), Center for Global Development, Washington D.C.
- Coale, A. J. and P. Demeny, 1983, *Regional Model Life Tables and Stable Population* New York, Academic Press.
- Cobb, C. W. and P. H. Douglas, 1928, "A Theory of Production", *The American Economic Review*, 18(1): 139-165.
- FAO, FAOSTAT, Food and Agriculture Organization of the United Nations, December 2004
- Forrester, J. W., 1961, *Industrial Dynamics*, Cambridge, MA, Productivity Press.
- Gaiha, R., 2003, "Are Millennium development Goals of Poverty Reduction Useful?" *Oxford Development Studies*, 31(1): 59-84.
- Größler, A., F. H. Maier, et al., 2000, "Enhancing Learning Capabilities by Providing Transparency in Business Simulators", *Simulation & Gaming*, 31(2): 257-278.
- Haacker, M., 2002, "Modeling the Macroeconomic Impact of HIV/AIDS", *IMF Working Paper*, (WP/02/195), International Monetary Fund, Washington D.C.
- Hausmann, R., Dani Rodrik, Andrés Velasco 2006, "Getting the Diagnosis Right, A new approach to economic reform", *Finance & Development*, 43(1).
- IMF, 2001, "Government Financial Statistics Manual 2001", International Monetary Fund, Washington D.C.
- IMF, 2004, "Balance of Payments Statistics Yearbook 2004", International Monetary Fund, Washington D.C.
- IMF, 2004, "Government Finance Statistics Yearbook 2004", International Monetary Fund, Washington D.C.



- 
- IMF, 2004, "International Financial Statistics Yearbook 2004", International Monetary Fund, Washington D.C.
- Löfgren, H., R. L. Harris, et al., 2002, "A Standard Computable General Equilibrium (CGE) Model in GAMS", *Microcomputers in Policy Research 5*, International Food Policy Research Institute, Washington D.C.
- Moxnes, E., 2000, "Not only the tragedy of the commons: misperceptions of feedback and policies for sustainable development", *System Dynamics Review* 16(4): 325-348.
- Parayno, P. P. and K. Saeed, 1993, "The Dynamics of Indebtedness in the Developing Countries: The Case of the Philippines", *Socio-Economic Planning Sciences*, 27(4): 239-255.
- Pedercini, M., 2003, "Potential Contribution of Existing Computer-Based Models to Comparative Assessment of Development Options", *Working papers in System Dynamics*, University of Bergen, Bergen.
- Qureshi, M. A., 2008, "Challenging Trickle-down Approach: Modelling and Simulation of Public Expenditure and Human Development - The Case of Pakistan", *International Journal of Social Economics*, 35(4): 269-282.
- Ranis, G., F. Stewart, et al., 2000, "Economic Growth and Human Development", *World Development*, 28(2): 197-219.
- Richardson, G. P., 1986, "Problems with Causal-Loop Diagrams", *System Dynamics Review* 2(2): 158-170.
- Richardson, G. P. and A. L. Pugh, 1981, *Introduction to System Dynamics Modelling with Dynamo*, Cambridge, MA, Productivity Press.
- Robinson, S., A. Yunez-Naude, et al., 1999, "From stylized to applied models: Building multisector CGE models for policy analysis", *The North American Journal of Economics and Finance* 10(1): 5-38.
- Rodgers, G. B., 1979, "Income and Inequality as Determinants of Mortality: An International Cross-Section Analysis", *Population Studies*, 33(2): 343-351.
- Romer, P., 1990, "Endogenous Technological Change", *The journal of political economy*, 98(5): s71-s102.
- Sacerdoti, E., S. Brunshwig, et al., 1998, "The Impact of Human Capital on Growth: Evidence from West Africa", *IMF Working Paper*, (WP/98/162), International Monetary Fund, Washington D.C.
- Sachs, J. D., J. W. McArthur, et al., 2004, "Ending Africa's Poverty Trap", *Brookings Papers on Economic Activity*, 35(1): 117-240.

- Saeed, K., 1987, "A Re-evaluation of the Effort to Alleviate Poverty and Hunger", *Socio Economic Planning Sciences*, 21(5): 291-304.
- Sehgal, J., 1989, "An Introduction to Techniques of Population and Labor Force Projections", International Labor Office, Geneva.
- Serra, N. and J. E. Stiglitz, 2008, *The Washington Consensus Reconsidered*, Oxford, Oxford University Press.
- Shorter, F. C., R. Sendek, et al., 1995, "Computational Methods for Population Projections", The Population Council, New York.
- Sterman, J. D., 1984, "Appropriate summary statistics for evaluating the historical fit of system dynamics models", *Dynamica*, 10(2): 51-66.
- Sterman, J. D., 2000, *Business Dynamics: Systems Thinking and Modelling for a Complex World*, McGraw-Hill Higher Education.
- UN, 2000, "United Nations Millennium Declaration", U. N. G. Assembly, United Nations, A/RES/55/2,
- UN, 2003, "World Population Prospects: The 2002 Revision", United Nations Population Division, New York.
- UN, 2005, "Preparing National Strategies to Achieve the Millennium Development Goals: a Handbook", UN Millennium Project - United Nations Development Programme, New York.
- UN, 2007, "The Millennium Development Goals Report", United Nations, New York.
- UNDG, 2003, "Indicators for monitoring the Millennium Development Goals", United Nations Development Group, New York.
- WB, 2005, "World Development Indicators 2005", World Bank, Washington D.C.