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Family Planning, Human Development and Growth in Uganda

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ABSTRACT

This paper analyzes the long-run economic and social impact of family planning policies in Uganda. In the analysis of this, we extend MAMS (Maquette for MDG Simulations; a CGE model for development strategy analysis) in terms of its treatment of demography. Our results indicate that, by reducing extremely high fertility rates, family planning measures significantly improve welfare. This conclusion holds under a wide range of assumptions regarding costs of family planning and under alternative government uses of the resulting increase in fiscal space – we permit the space to be used to reduce either foreign (aid) or domestic receipts (from taxes or borrowing) while keeping spending policies unchanged. Methodologically, our analysis suggests that integration of demographic and economywide models offer an indispensable perspective on the impact of family planning on economic development.

Summary

MAMS (Maquette for MDG Simulations) is a CGE model designed for the analysis of development strategies in different countries with an emphasis on issues related to poverty reduction and human development, including the achievement of the Millennium Development Goals (MDGs). For this paper, MAMS has been extended to include a demographic module that is integrated with the rest of the model. In the new module, fertility and mortality rates are endogenous and disaggregated by age and gender.

Our literature review strongly indicates that reductions in fertility and mortality rates are closely related to general improvements in human conditions (including education), urbanization, and changes in cultural traditions. In our model, we have tried to incorporate the key links between social and economic factors and demographic outcomes.

We study the effects of family planning on household welfare in Uganda, where the high population growth has been identified as one of the obstacles for blocking improvements in the quality of life of Ugandan families. Our results indicate that, by reducing extremely high fertility rates, these family planning measures clearly improve welfare. This conclusion holds under a wide range of assumptions regarding costs of family planning and under alternative government uses of the resulting increase in fiscal space – we permit the space to be used to reduce either foreign (aid) or domestic receipts (from taxes or borrowing) while keeping spending policies unchanged. Methodologically, our analysis suggests that integration of demographic and economywide models offer an indispensable perspective on the impact of family planning on economic development.

1 Introduction

1.1 Demographic situation in Uganda

Reducing high rates of fertility, which result in high rates of population growth, has been identified as one of the most urgent global problems waiting to be solved (Brown, 2008). Similarly, the Government of Uganda has stated that high population growth is one of the obstacles to more rapid improvements in the quality of life of Ugandan families (Republic of Uganda, 2008). In terms of fertility, Uganda is in the top echelon of countries with a total fertility rate (TFR) of close to 7 children. Its population is one of the most youthful in the world and the country's dependency ratio, at around 110 percent (UN 2009) is among the highest. The labor force will double in less than 20 years.

While fertility is highly valued in Uganda, a recent household survey nevertheless revealed an unmet demand for contraception among 41 percent of the households; the current contraceptive prevalence rate is as low as 24% (Republic of Uganda, 2008). In rural areas, use of contraceptives and access to family planning service are lower, whereas fertility levels are higher. Of the total number of births in all of Uganda, more than a quarter are unwanted, leaving a gap of two between the actual and wanted number of children. In addition, abortion is illegal except in situations where the woman's life or her mental health is under threat. UN reports suggest that illegal and unsafe abortions are common, especially among young women, and responsible for 35 percent of maternal deaths (see May, Mpuga and Ntozi, 2007).

1.2 The policy setting

The starting hypothesis of this analysis is that increased family planning services can help in reducing the extremely high fertility rates, permitting the country to reduce the dependency ratio, increase growth in GDP per capita and improve welfare. The Government of Uganda (GoU) has also voiced its determination to reduce Uganda's aid dependency over the longer term; given this, we will monitor whether more family planning could make it possible to reduce aid in the long run without negative welfare effects. At the same time, the short-run prospects for aid to family planning have improved as the US, a major donor, recently changed its policy, no longer withholding funding from NGOs that engage in family planning activities abroad. Against this background we will here analyze the effects of increased family planning, adopting an economy-wide perspective in order to be able to consider both direct and indirect effects of family planning activities.

The rest of the paper is organized as follows. In Section two, we review the links between economy and population issues. In Section three, we present the model. Section four presents the simulations and analyzes their results. Section five concludes.

2 The relationship between economy and population

The issue of the relationship between economic development and population growth is complex and intensively debated already since Malthus (1798). Different factions in the economic literature argue that more rapid population growth has positive, negative or no impact on per-capita growth in incomes and GDP. While there is a broad consensus that a larger population boosts the size of economy as a whole, it does not follow that a larger population would lead to improvements in per-capita incomes or other welfare measures. A causal effect may also run in the opposite direction as changes in per-capita incomes influence population growth.

There is a broader consensus on the observation that the age structure of the population matters, inter alia by influencing the size and composition of final demand (public and private), savings, and labor supply. At the global level, the main channels of impact to economy are identified to be changes in the labor force and savings behavior (Shi and Tyers, 2005).

Given the broad and complex links between demography and economic development and progress in computational technology, it has become more common to simulate alternative demographic scenarios or policies in CGE models with integrated demographic modules. Examples of such studies include Shi and Tyers (1995; a global model), Fougère et al. (2005; an overlapping generations model of Canada), and Chant (2008; epidemiological AIDS model linked to a Markov process transition model and a CGE model), as well as other MAMS applications that impose alternative exogenous population scenarios (World Bank, 2007a).

When making demographic projections, the three key variables are fertility, mortality and migration. For Uganda, given its phase of development and international environment, the one that

policy can influence most strongly is fertility. Below we discuss the importance and development of these variables.

2.1 Fertility

Two concepts often mentioned in the analysis of economic development and demography are “demographic transition” and “demographic dividend.” Demographic transition can be divided in into two phases: in the first, improvements in public health and general living conditions induce reductions in mortality rates, leading to increased population growth. In the second phase, a decline in fertility rates sets in with some delay. This transition produces a "boom" generation that is larger than those immediately before and after it. Over time, this generation will gradually advance through the age cohorts of the population (Bloom *et al.*, 2002).

The concept of demographic dividend refers to growth of maturing younger generations, which are being followed by smaller age groups due to fertility decline, leading to that a larger share of the population is in the age with high labor market participation (Klasen, 2005). The dividend part of the term refers to the possibility of faster economic growth as labor participation and saving rates increase. (Regarding savings, see Elbadawi and Mwega, 2000). In addition, as noted in World Bank (2007a), the dividend may also stem from a reduced need for public services per capita (especially in education) as the size of the cohorts in school age declines.

Many developed nations have already consumed their demographic dividend, i.e. they are approaching an era with a decreasing share of the population in labor force age, whereas Uganda may be about to start enjoying the dividend if it manages to embark on the second phase of the demographic transition. To date, reductions in fertility have been modest. According to May,

Mpuga and Ntozi (2007), the TFR has hovered around 7 for at least the last four decades. This imbalance in the age structure puts enormous strains on the delivery of public services in areas like health and education.

Progress in the demographic transition is by no means automatic. In order to fully "cash in" on the demographic dividend, once the TFR has declined, public policies and institutions have to meet several requirements. Perhaps most importantly, the labor market has to be able to absorb the relatively large population share in working age, either domestically or via migration to other countries – migration would limit the dividend unless the migrants send remittances. If so, institutional arrangements enabling temporary or permanent migration may be a relevant option, considering the coming decline of the labor supply in many European countries (Shi and Tyers 2005).

The decline in the TFR is not automatic. Table 1 summarizes the main determinants identified in the theoretic and empirical literature. Several of these determinants are underpinned by individuals' preferences and social attitudes, pointing to the need to consider the prospects for changing social attitudes toward fertility (see Klasen, 2005 on fertility reduction in Uganda).

In the long run, wealthier families may choose to have a lower number of children, as the economic value of children as a means of production is normally declining in relation to other kind of assets (see Becker and Murphy, 1990). With rising income and educational levels, the parents seem to be more inclined to invest more in the quality of children and reduce the size of the family. Similarly, high infant mortality may induce parents to "hoard" children as they are expecting that only a part of them reach adulthood. Rising wages and increased labor market participation of women increase the opportunity cost of children, leading to decreasing fertility rates. In European countries like Italy

and Spain, weak maternal (and paternal) benefits relative to wages, appear as the main factor behind record-low fertility levels.

Urbanization comes hand in hand with a declining share of labor in agriculture and an increasing level of education. Econometric studies of the determinants of fertility have come to the conclusion that female education is one of the most important single determinants, although also the educational level of the spouse has some importance (e.g. Drèze and Murthi, 2001; Klasen, 2005). Household surveys in Uganda confirm that parents' higher educational attainment, and living in urban area contribute to lower fertility (May, Mpuga and Ntozi, 2007).

In Uganda, as in many other countries, poorer families tend to have a higher number of children, potentially creating a vicious circle of high dependency rates and poverty (Klasen, 2005). In countries where the size of family is an important determinant of the allocation of land, it is rational for single households to have many dependents as these not only provide labor incomes but also may support claims for more land. These factors may be extremely important in the case of Uganda, as agriculture represents more than two thirds of employment (UBOS, 2003).

Institutional quality, or policy environment, may affect fertility in many ways. Access to medical care reduces morbidity and mortality, and improves women's reproductive health which, in its turn, may help achieve desired family sizes. According to household surveys, there is an unmet demand for contraception. If all Ugandan women were able to achieve their reproductive goals, total fertility would drop by almost two children to 5.3 (May, Mpuga and Ntozi, 2007).

In sum, there may be no easy, single policy for reducing fertility. For Uganda and most other countries, changes in fertility come hand in hand with other societal and economic changes. In the

words of Easterly (2002), development is the best contraceptive. The main exception to this rule is China's one-child policy, which helped reduce China's TFR from 6.1 in 1965-1970 to 1.7 in 2000-2005 (UN, 2007). However, such a policy is most likely neither a feasible nor a preferred option for Ugandan policymakers. China's experience does nevertheless provide an international benchmark for the maximum rate of TFR decline.

2.2 Mortality

As infant mortality declines and life expectancy rises, fertility starts to decrease, though often with a delay. Access to health services and contraception reduces the need for (illegal) abortions, reducing maternal mortality. Technological advances and increased income levels correlate with decreased mortality, although the channels of impact and patterns of causality are debated (Cutler et al., 2005; Bloom et al, 2002). In addition, better family-planning and prenatal care greatly reduce health risks related to childbearing, including those that stem from abortions.

2.3 Migration

The limited information that is available indicates that migration to and from Uganda has not been very extensive. The World Bank (2007b) has estimated that there are some 150,000 Ugandans living abroad, sending remittances to households (i.e., around 0.5 percent of the total number of Ugandans). In 2003, the base year of our analysis, these remittances were estimated at 735 billion Ugandan shillings (US$ 270 million), corresponding to US$1800 per migrant. Below, we assume that the net migration rate of 0.9 persons per 1,000 will apply through the whole study period 2003-

2030. Furthermore, we assume that the out-migrants add to the stock of persons sending remittances, although a "depreciation" of this stock of persons through mortality and reduced willingness to send remittances is set at an annual rate of around 10 percent. Different migration scenarios can be run by altering the parameters for net migration (disaggregated by age and gender), remittances per migrant, and the migrant depreciation rate. Together with our assumption of per-capita transfers increasing in par with the GDP growth, the annual growth of remittances amounts to roughly ten percent.

3 The model

This analysis of increased family planning actions in Uganda is conducted with MAMS, an economy-wide simulation model that the World Bank has developed to analyze development strategies in different countries with emphasis on issues related to poverty reduction and human development, including the achievement of the Millennium Development Goals (MDGs). It has been or is being used in around 35 country applications to analyze various types of questions (see www.worldbank.org/mams). Strategies for poverty reduction and the achievement of the broader set of MDGs typically have strong effects throughout the economy that feed back on poverty and human development through markets for labor, goods, services and foreign exchange. Therefore, economywide strategy analysis is a necessary complement to sectoral studies. We will here provide a brief description of MAMS with special reference to the disaggregation inherent in the Uganda database.

MAMS integrates a mostly standard (recursive) dynamic computable general equilibrium (CGE) model with an additional MDG module that links MDG outcomes to a set of determinants, some of which are policy driven. Standard model features include production decisions driven by profit maximization, flexible prices clearing most markets, and imperfect substitutability/transformability in foreign trade – imports are imperfect substitutes for domestic commodities on the demand side whereas, on the supply side, outputs are imperfectly transformable between domestic sales and exports. One deviation from this is in the labor market, which is disaggregated into three segments on the basis of the educational attainment of the worker (less than completed secondary, completed secondary, or completed tertiary). In the labor markets, MAMS permits unemployment, with a lower limit for the unemployment rate. When unemployment is above this lower limit, the

reservation wage is the binding, minimum wage. It is sensitive to the unemployment rate and economy-wide changes in factor rents and wages.

In other areas, the model (and its database) tends to be relatively detailed in terms of sectors linked to MDGs, including individual sectors for health, education (by cycle and level) and water services, Government spending on agriculture and roads contribute to total factor productivity (TFP) in related sectors. A residual sector covers other government services. Outside the MDG and/or government sphere (a total of 10 sectors), the economy is split into agriculture, industry, transportation, and other private services. Activities use production factors, and intermediate inputs to produce an activity-specific output (in the case of the government, different types of services). Production decisions are driven by profit maximization. Apart from the three labor types, the factors of production includes a private capital stock and, for activities that, fully or in part, are operated by the government, function-specific government-owned capital stocks.

The government finances its activities from domestic taxes, domestic borrowing, and foreign aid (borrowing and grants). Provision of selected government services (including education and health) contribute directly to the MDGs and more broadly to the skill composition of the labor force. Changes in the capital stocks of government services in agriculture and in roads influence TFP in selected activities (all private agricultural activities and transportation services, respectively). Apart from the government, the institutions of the economy include one or more households (here disaggregated into rural and urban and by per-capita income into high and low income in each region), the rest of the world and an NGO (representing domestic non-profit institutions).

MAMS is intended to capture key interactions between the pursuit of the MDGs and economic evolution. To keep it relatively simple and given data constraints, it tries to focus on the ones with

the greatest cost and the greatest interaction with the rest of the economy. In this case, the MDGs covered are universal primary school completion (MDG 2; measured by the net primary completion rate), reduced under-five and maternal mortality rates (MDGs 4 and 5), and increased access to improved water sources (part of MDG 7). We also address achievements in terms of poverty reduction (MDG 1).

At the macro level, the rest-of-world (foreign exchange) balance is cleared via variations in the real exchange rate. The government balance is cleared via adjustments in one of the following variables: direct taxes, domestic borrowing, foreign borrowing, or foreign grants. In the savings – investment balance, government savings, foreign savings, and government investment are not free to vary (i.e., they are determined by policy or other relationships). The balance is either cleared by variations in private investment (if private savings are fixed or expressed as a function of per-capita incomes) or private savings (if private investment is fixed as a share of absorption).

For this analysis, a demographic sub-model has been developed, enabling feedback between the demographic indicators and the different parts of the economy (including the government and its spending and taxation, the labor market, and foreign aid) Population data for base year 2002/03 is included by each age cohort up to 95 years by gender, as well information on fertility and mortality by each age cohort.

Fertility and mortality rates are modeled by means of nested logistic and constant-elasticity (CE) functions (containing the determinants as argument) for each age cohort. The following determinants are included:

Per-capita consumption
Quantity of MDG-service goods supply per capita
Rate of urbanization
Educational level (share of labor force without at least completed secondary level education)

Government infrastructure
Selected MDGs: MDG 2 (universal primary education) and MDG 7a (Access to safe water)

These arguments are used as ratios to base-year levels, resulting in indices with values around unity. The resulting compound development indicator enters the logistic functions for fertility and mortality as an argument.

In the standard version of MAMS, the MDG production functions define the aggregate values of MDGs, like infant mortality or maternal mortality. In order to feed in the values of these functions in a disaggregate fashion to an endogenous population module, a link between the aggregate and disaggregate information has been constructed.

In order to calibrate the new, disaggregate demographic information with the results contained in the aggregate MDG variables, the parameter values of disaggregate demographic functions were fitted by a separate procedure to more aggregate values, where values of the base run MDGs were used as benchmarks. UN population (middle) projections were used as a starting point for our BASE scenario. The parameterization of this module is a challenge, as there are no directly suitable econometric results that are readily applicable to our case, although some guidance can be distilled from the earlier studies, e.g. World Bank (2007a; see Appendix 1 for a non-technical description of this module).

4 Simulations

In this paper, we focus on the effects of intensified family planning efforts on Uganda's economic development up to 2030 with special emphasis on household welfare and government finances,

inter alia considering the fact that the Government of Uganda (GoU) has voiced a determination to become less aid-dependent in the future (MoFPED, 2008).

Under the BASE scenario, which provides a benchmark for comparisons, the economy is calibrated to follow roughly the same pace of growth during the simulation period 2003-2030 as in the 8-10 years preceding FY 2003, the base year of our simulations. With the exception of education, all government services grow at the same rate as GDP, i.e. at 6.2 percent per year. For education, it is assumed that the government maintains service levels sufficient to gradually improve quality (services per student) in primary education at a rate of 3.5 percent per year and maintain unchanged quality at the secondary and tertiary levels.

Apart from BASE, we consider a set of family planning scenarios that are identical in terms of the family planning action but differ in terms of how government receipts are adjusted in response to changes due to this action.
The cost of additional family planning enters the government expenditure. It is defined as follows: [cost per couple] * [share of couples covered] * [population of women in fertile age (15-49)].

The cost of proving family planning services for a couple during a year is set at US$ 15 (Ush 30,000) , which is roughly comparable to the costs estimated for several developing countries in Lule, Singh and Afroze Chowdhury (2007) or in a World Bank study on Ethiopia (World Bank, 2007a). In other words, we assume constant returns to scale in our family planning activities; the same assumption is made for other production activities in the model (unless indirect effects are considered, for example the impact of trade openness on productivity).

The coverage of additional family planning services (we do not include in our simulation parameter any already existing family planning activities) starts at zero in 2006. It is assumed to cover 2% of women in fertile age in 2007, and thereafter to double its coverage each year until 2010, by which date the coverage has reached 16%. For the remaining period (2011-2030), it stabilizes at 20% of women in fertile age. The 20% level of coverage is slightly lower than the gap between actual and desired fertility level. In other words, we believe it to be a realistic estimate for the additional demand for contraception. The gradual increase in coverage is thought to reflect the inherent inertia in this kind of a social process. The continued action is also deemed justified, as new age cohorts enter the fertile age. In addition, the costs of protection are variable by nature.

For government services, the assumptions for the non-BASE scenarios are the same as for the base scenarios. In effect, with a time lag, lower fertility and birth rates reduce the size of the cohorts in school age, reducing the needs for government spending on education.

The introduction of family planning has implications for government spending and the budget balance, creating or reducing fiscal space. Rather than adjusting government spending, we will clear the government budget by adjusting government receipts, with the following alternatives for the different family planning scenarios:

fp-ftr	adjustment in foreign transfers
fp-tax	adjustment in domestic taxation
fp-db	adjustment in domestic borrowing
fp-fb	adjustment in foreign borrowing.

4.1 Economic and social development under BASE scenario

Under the BASE scenario, the economy grows at an average annual rate of 6.2 percent. During the simulation period, the growth rate of government consumption declines from an initial 8.5 percent (reflecting very rapid growth in secondary and tertiary education) to 4.7 percent, while the growth rates of private consumption, exports, imports and private investment increase by 1-2 percentage points, and that of government investments by less than that. The upward shift in the growth of government investments is due to a large increase in government spending in education dictated by the population growth (see Figure 1).

Employment growth for the three labor segments (with primary, secondary and tertiary educational attainment levels) mirrors the changing composition of the labor force, as the share of the educated increases. The wages of the least educated category of workers (with less than completed secondary education) get the highest growth rate as they are becoming scarcer due to extensive educational efforts. However, income differentials (absolute and relative) remain large.

The use of agricultural land is permitted to grow at an annual rate of one percent per year (among other things reflecting increased use of lands in the north as a consequence of peace and resettlement in this region). In the private sectors, the nominal GDP shares of private services and agriculture rise slightly during the simulation period at the expense of private industry. For agriculture, this reflects a cost push due to rapid growth in land rent – agricultural output prices evolve more favorably than output prices for other sectors. In terms of real growth, agriculture is below the economy-wide average whereas other private sectors and government sectors grow at rates above the economy-wide average. Government activities are also requiring an increasing share of nominal GDP, reflecting a combination of the lower productivity growth than for the private sector and the financial burden of a youthful population with a high dependency ratio (see Table 2).

All of the MDG-related social indicators improve. However, only the goal of halving the extreme poverty rate is attained by 2015. By 2030, primary schooling enrollment rate (MDG2), as well as access to clean water (MDG7a) have reached their 2015 targets (see Figure 2). Both the under-five and the maternal mortality rates are above (fall short of) the 2015 targets also in 2030.

4.2 Demographic results for the BASE scenario

Our total population forecast for BASE is very similar to UN 2008 Medium variant projection for Uganda (see Figure 3), partly a reflection of that key parameters were defined on the basis of the UN forecast. However, our scenario differs in that both reductions in fertility and mortality rates take place at a slower pace, leading to a higher dependency ratio (Figure 4). The slower mortality reduction implies a lower life expectancy at birth. The population pyramids of year 2003 and 2030 (Figure 5 and Figure 6) confirm the large population increase, including a doubling of the size of young age cohorts. In sum, it seems that the UN population projection foresees either faster economic and social development, or an increase in family planning-like measures exceeding what is included in our BASE, as the UN demographic transition is faster than in our BASE.

4.3 Family planning scenarios

The increase in family planning (FP) services under the FP scenarios represents around 24 percent of government consumption of health services in the base year 2002-03 (but a lower share of the current government health consumption of future years). The demographic outcomes for our FP scenarios are almost identical; i.e., the manner in which the government adjusts its budget has a negligible impact on population indicators. By 2030, the total population is around 53.7 million for all the FP scenarios as opposed to 61.0 million under BASE.

The time lag between action today and effects in the size and composition of population varies depending on the indicator. Figure 7 shows how the development of population in different age groups is affected by our increased family planning activities. We see that a discernible effect in the population aged 18-64 does not appear until at the very end of our simulation period. Irrespective of family planning policy, the population in economically active age will have doubled by 2023-2024. On the other hand, for the population in school-age, the impact of family planning actions is felt with a shorter time lag (also shown in Figure 7).

These changes are primary driven by changes in the TFR, the evolution of which is shown in Figure 8 with the changes reflecting responses to a combination of policy measures and changes in other determinants (reflecting economic and social development). A similar, if not as dramatic a decrease, is found in the gross mortality rate which changes, primarily due to decreases in maternal and under-five mortality rates, which by 2030 are around 6 and 5 percent below BASE values, respectively, under all the FP scenarios. By 2030, male life expectancy is 0.5 - 0.6 years higher than for BASE, whereas the increase for women amounts to 0.8 - 0.9 life years.

In terms of government spending (Figure 9), FP leads to an initial, medium term increase but a rapid decline (compared to BASE) starting from 2017 as the smaller young age cohorts leads to smaller demands for education services (growth in health services is kept unchanged from BASE, leading to improved human development). As noted, the scenarios differ in terms of which type of government receipts that is adjusted.

Aggregate per-capita household welfare increases strongly as a result of family planning. In the final year, equivalent variation (EV) per capita is 15-35 percent larger than for the BASE,

depending on the scenario and the household group (Figure 10; EV per capita measures the value to the households of the improvement in consumption using base-year prices). In terms of timing, compared to the BASE, the change in per-capita EV is positive for all household groups starting from 2011 for all FP scenarios. Urban high-income households gain most in relative terms. Our scenarios also group into two different categories, depending on the "domesticity" of the macro closure variable responsible for adjustment to policy shock. If the increased budgetary sources are channeled to reduced domestic government receipts (from domestic borrowing or taxation) household incomes grow slightly more rapidly than for the other two foreign-oriented FP scenarios under which foreign aid (grants or borrowing) is reduced. However, the latter two scenarios may be interesting from the government point of view as they show how family planning can contribute to reducing Uganda's aid dependency. At the same time, by comparing to scenarios where the benefit of FP is channeled to domestic sources, we get a measure of the welfare cost of such an aid reduction.

The differences in aggregate GDP growth between BASE and FP scenarios are small. In fact, the economy as a whole grows at a slightly slower pace, primarily due to slower public sector growth. In all the FP scenarios, exports grow faster than under BASE due to more favorable price structure, as prices for non-tradable goods and services – which are also used as inputs in tradable sectors - are lower due to smaller population-induced demand. In scenarios where domestic macro variables are adjusted (fp-tax, fp-db), private capital stocks grow at rates close to identical to BASE, whereas when the benefit of family planning is "exported", the average annual growth rate of these stocks are lower. The total employment rate is highest under fp-tax, showing the stimulating impact of lowering the direct tax rates. By channeling the benefit to domestic sources and maintaining the aid inflows of the BASE, a larger share of domestic output is allocated to the domestic market while the

need for exports is smaller, leading to a 1.4 - 1.6 percentage points lower export share in GDP at the end of the simulation period than under fp-ftr or fp-fb (see Tables 3 - 6).

Increased family planning also leads to improvements in the MDG attainments (Figures 11-14; figures depict changes from BASE in the units of each indicator). In relative terms, the largest gains are recorded for the poverty rate; in the final year, it is 25 percent (or two percentage points) lower than for the final-year value under the BASE scenario. Maternal and under-five mortality rates are reduced by 5-7 percent (not percentage points) from BASE, whereas the net primary completion rate changes very little, as it already reaches the MDG goal under BASE. Access to clean water improves by 5-9 percent at the end of the simulation period. Again, we see that the scenarios may be split into two groups according to the domesticity of the adjusting government closure variable. The best MDG attainment results are recorded under fp-tax, although fp-db gives almost identical results.

In sum, so far our results indicate that a modest spending increase on family planning services can lead to substantial improvements in MDG indicators. In the next section, we will investigate the sensitivity of these results to our assumption regarding the yearly cost of protection per couple, which we use as a proxy for the family planning services in general.

4.4 Sensitivity of the results to the cost of FP

What if we increase the cost of family planning? We start by doubling the unit cost of FP. The result is that the final-year per-capita EV is higher under the FP scenarios than under the BASE, also under this assumption. The per-capita EV change is positive for all household groups already

from 2012 across all FP scenarios. The first year of lower public expenditure than under BASE is postponed by only one year to 2018.

Hence, our results are not very sensitive to the cost of family planning services. When the unitary cost of FP is fivefold, i.e. USD 76 (Ush 150,000) per year and couple, it would take only until year 2014 before all the household groups would have a positive change in per-capita EV in all the scenarios. However, government expenditure would be higher than under BASE until year 2023, when the cost-reduction caused by the decrease in the size of young age cohorts would offset the additional cost of family planning.

5 Conclusions

In this paper, we analyze the effects of an increase in government-financed family-planning services in Uganda. From the perspective of the welfare of the Ugandan population, the case if very strong. In our scenarios, we impose an increase in family planning so that it gradually covers an additional 20% of the couples in fertile age. The resulting decrease in total fertility brings about reductions in under-five and maternal mortality, increased life expectancy and, at the end of the simulation period in 2030, a 15.8-15.9 percentage-point reduction in the dependency ratio (from 93.4 to 77.5-77.6 dependents per 100 persons in labor force age).

The changing size of young age cohorts also reduces the strain on government finances and increases the fiscal space of the government compared to BASE. The macro results vary slightly according to assumption how this budgetary space is utilized. However, in all the scenarios per capita household welfare increases considerably. This outcome is very insensitive even to relatively large increases in the unit cost of FP. We should also note that the cost of increased protection can actually be very low, if intuitive ways of using media like TV and radio are utilized for entertainment-education programs for social change. Encouraging examples of using e.g. soap operas or radio programs as agents of social change can be found in places like Mexico, Rwanda, Sudan and Ethiopia (the three last ones being Uganda's neighbors).

This study adds to an increasing number of studies that, in a consistent and integrated manner, consider the interaction between demography and health with the rest of the economy. According to our assessment, such approaches are indispensable for evaluations of the broader effects of health and population policies. Further studies could augment our framework in different directions,

including the incorporation of more epidemiological information on diseases like HIV/AIDS and the costs of combating them.

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Tables

Table 1. **Determinants of fertility, literature overview**

Increase in:	Effect on TFR:
Educational level of women (and men)	Negative
Income level	Negative/Positive
Mortality	Positive
HD in general	Negative
Income inequality	Positive
Institutional quality (property rights, government services, public infrastructure)	Negative
Share of employed in agriculture	Positive
Children's labor force participation	Positive
Urbanization	Negative
Pension system coverage	Negative
Women's participation in the labor market	Negative
Availability of modern contraception	Negative
Son preference	Positive

Sources: May et al, 2007; Klasen, 2005, Ehrlich and Lui, 1997; Aassve et al, 2005; Becker and Murphy, 1990, Drèze and Murthi, 2001.

Table 2. Selected indicators for the economy under BASE

			2003	2010	2015	2020	2025	2030
base	Annual GDP growth at factor cost, %				5.5	6.2	6.5	6.7	6.6
base	Real exchange rate, % change (> 0 = depreciation)				0.0	-0.1	-0.1	-0.3	-0.6
base	Private investment (% GDP)			16.0	15.8	15.8	15.7	15.7	15.7
base	Government investment (% GDP)			4.7	5.1	4.7	4.7	4.5	4.3
base	Domestic savings (% GDP)			7.0	8.8	8.8	9.0	9.0	8.7
base	Domestic government debt (% GDP)			8.4	9.6	9.7	9.7	9.6	9.5
base	Exports % GDP			12.3	13.1	13.2	13.4	13.6	13.6
base	Exports (Ush bn) 2003-year prices			1463.0	2239.3	2983.8	4119.1	5722.6	7753.1
base	Trade deficit (% GDP)			-13.7	-12.1	-11.7	-11.4	-11.2	-11.3
base	Foreign Public Debt stock (% GDP)			71.0	74.2	75.2	74.4	72.4	70.2
base	Domestic gov revenue (% GDP)			11.3	14.4	15.3	14.8	13.7	12.8
base	Fiscal Deficit (% GDP)			11.2	12.7	12.8	12.7	12.3	11.9
base	Fiscal Deficit, including grants (% GDP)			4.2	5.2	5.3	5.2	5.1	4.9
base	Donor aid (% GDP)			11.3	11.7	11.7	11.6	11.3	10.9
base	Govt Expenditure (% GDP)			22.5	27.1	28.1	27.5	26.0	24.8
base	Unemployment rate	total		29.1	25.7	22.4	18.9	14.9	10.9
base	Unemployment rate	unskilled		30.0	26.7	23.3	19.6	15.5	11.1
base	Unemployment rate	skilled		10.0	8.1	9.2	10.1	9.5	8.1
base	Unemployment rate	high-skilled		10.0	7.1	7.0	8.2	9.2	9.4
base	Employment rate	total		70.9	74.3	77.6	81.1	85.1	89.1
base	Employment rate	unskilled		70.0	73.3	76.7	80.4	84.5	88.9
base	Employment rate	skilled		90.0	91.9	90.8	89.9	90.5	91.9
base	Employment rate	high-skilled		90.0	92.9	93.0	91.8	90.8	90.6
base	Agriculture % GDP			32.4	32.4	33.1	34.3	35.8	37.4
base	Industry % GDP			21.2	20.5	19.9	19.7	19.5	19.2
base	Services % GDP			46.4	47.2	47.1	46.0	44.6	43.5
base	GDP share sum			100.0	100.0	100.0	100.0	100.0	100.0
base	Headcount poverty rate, %	MDG 1		35.0	31.3	25.7	19.0	12.7	8.2
base	Primary school completion rate, %	MDG 2		15.5	26.2	49.8	74.6	90.7	97.5
base	Under-five mortality rate , %	MDG 4		14.0	12.0	10.4	9.2	8.3	7.6
base	Access to safe water, %	MDG 7a		56.0	59.1	61.9	65.4	69.5	74.2

Table 3. Selected indicators for scenario fp-foreign transfers

			2003	2010	2015	2020	2025	2030
fp-ftr	Annual GDP growth at factor cost, %				5.5	6.2	6.6	6.8	6.1
fp-ftr	Real exchange rate, % change (> 0 = depreciation)				-0.4	0.1	0.3	0.0	-0.7
fp-ftr	Private investment (% GDP)			16.0	15.9	15.8	15.6	15.5	15.5
fp-ftr	Government investment (% GDP)			4.7	5.2	4.7	4.4	4.3	4.2
fp-ftr	Domestic savings (% GDP)			7.0	8.7	8.8	9.4	10.2	10.0
fp-ftr	Domestic government debt (% GDP)			8.4	9.6	9.7	9.7	9.6	9.7
fp-ftr	Exports % GDP			12.3	12.8	13.1	14.4	15.7	15.6
fp-ftr	Exports (Ush bn) 2003-year prices			1463.0	2187.3	2980.8	4419.9	6580.2	8748.0
fp-ftr	Trade deficit (% GDP)			-13.7	-12.5	-11.7	-10.6	-9.6	-9.7
fp-ftr	Foreign Public Debt stock (% GDP)			71.0	73.7	74.9	75.7	75.0	74.0
fp-ftr	Domestic gov revenue (% GDP)			11.3	14.4	15.4	14.9	13.9	13.0
fp-ftr	Fiscal Deficit (% GDP)			11.2	13.1	12.9	11.9	10.8	10.6
fp-ftr	Fiscal Deficit, including grants (% GDP)			4.2	5.2	5.3	5.3	5.2	5.2
fp-ftr	Donor aid (% GDP)			11.3	12.0	11.9	10.8	9.8	9.5
fp-ftr	Govt Expenditure (% GDP)			22.5	27.5	28.3	26.9	24.7	23.6
fp-ftr	Unemployment rate	total		29.1	25.7	22.5	19.2	15.4	10.9
fp-ftr	Unemployment rate	unskilled		30.0	26.7	23.5	20.0	16.0	11.1
fp-ftr	Unemployment rate	skilled		10.0	8.1	9.3	10.1	9.6	7.9
fp-ftr	Unemployment rate	high-skilled		10.0	7.0	6.9	8.3	9.7	9.8
fp-ftr	Employment rate	total		70.9	74.3	77.5	80.8	84.6	89.1
fp-ftr	Employment rate	unskilled		70.0	73.3	76.5	80.0	84.0	88.9
fp-ftr	Employment rate	skilled		90.0	91.9	90.7	89.9	90.4	92.1
fp-ftr	Employment rate	high-skilled		90.0	93.0	93.1	91.7	90.3	90.2
fp-ftr	Agriculture % GDP			32.4	32.2	32.7	33.9	35.4	37.0
fp-ftr	Industry % GDP			21.2	20.4	19.9	19.9	20.1	19.65
fp-ftr	Services % GDP			46.4	47.3	47.3	46.2	44.5	43.4
fp-ftr	GDP share sum			100.0	100.0	100.0	100.0	100.0	100.0
fp-ftr	Headcount poverty rate, %	MDG 1		35.0	30.9	23.7	16.1	9.8	6.1
fp-ftr	Primary school completion rate, %	MDG 2		15.5	26.3	50.3	75.2	91.1	97.6
fp-ftr	Under-five mortality rate , %	MDG 4		14.0	11.6	9.9	8.7	7.8	7.3
fp-ftr	Access to safe water, %	MDG 7a		56.0	59.2	62.7	67.1	72.2	77.9

Table 4. Selected indicators for scenario fp-taxation

			2003	2010	2015	2020	2025	2030
fp-tax	Annual GDP growth at factor cost, %			5.5	6.2	6.6	6.9	6.2
fp-tax	Real exchange rate, % change (> 0 = depreciation)			0.0	-0.1	0.0	-0.3	-0.7
fp-tax	Private investment (% GDP)		16.0	15.9	15.8	15.7	15.7	15.7
fp-tax	Government investment (% GDP)		4.7	5.3	4.7	4.4	4.2	4.1
fp-tax	Domestic savings (% GDP)		7.0	9.0	8.8	8.8	9.0	8.8
fp-tax	Domestic government debt (% GDP)		8.4	9.6	9.7	9.7	9.5	9.6
fp-tax	Exports % GDP		12.3	13.2	13.2	13.7	14.3	14.2
fp-tax	Exports (Ush bn) 2003-year prices		1463.0	2239.9	2997.2	4211.4	6038.3	8044.1
fp-tax	Trade deficit (% GDP)		-13.7	-12.2	-11.7	-11.3	-10.9	-10.9
fp-tax	Foreign Public Debt stock (% GDP)		71.0	74.3	75.2	74.3	72.2	70.7
fp-tax	Domestic gov revenue (% GDP)		11.3	14.8	15.5	14.1	12.1	11.0
fp-tax	Fiscal Deficit (% GDP)		11.2	12.8	12.9	12.7	12.3	12.0
fp-tax	Fiscal Deficit, including grants (% GDP)		4.2	5.2	5.3	5.2	5.1	5.0
fp-tax	Donor aid (% GDP)		11.3	11.7	11.8	11.6	11.2	11.0
fp-tax	Govt Expenditure (% GDP)		22.5	27.6	28.3	26.7	24.4	23.1
fp-tax	Unemployment rate	total	29.1	25.8	22.6	19.0	14.8	9.9
fp-tax	Unemployment rate	unskilled	30.0	26.8	23.5	19.8	15.3	10.1
fp-tax	Unemployment rate	skilled	10.0	8.2	9.3	9.9	9.1	7.1
fp-tax	Unemployment rate	high-skilled	10.0	7.1	6.9	8.1	9.3	9.3
fp-tax	Employment rate	total	70.9	74.2	77.4	81.0	85.2	90.1
fp-tax	Employment rate	unskilled	70.0	73.2	76.5	80.2	84.7	89.9
fp-tax	Employment rate	skilled	90.0	91.8	90.7	90.1	90.9	92.9
fp-tax	Employment rate	high-skilled	90.0	92.9	93.1	91.9	90.7	90.7
fp-tax	Agriculture % GDP		32.4	32.2	32.7	34.0	35.6	37.4
fp-tax	Industry % GDP		21.2	20.4	19.9	19.9	20.1	19.65
fp-tax	Services % GDP		46.4	47.3	47.4	46.1	44.3	43.0
fp-tax	GDP share sum		100.0	100.0	100.0	100.0	100.0	100.0
fp-tax	Headcount poverty rate, %	MDG 1	35.0	31.0	23.7	15.6	9.2	5.6
fp-tax	Primary school completion rate, %	MDG 2	15.5	26.3	50.3	75.2	91.1	97.6
fp-tax	Under-five mortality rate , %	MDG 4	14.0	11.6	9.9	8.6	7.8	7.2
fp-tax	Access to safe water, %	MDG 7a	56.0	59.2	62.7	67.2	72.3	78.0

Table 5. Selected indicators for scenario fp - domestic borrowing

			2003	2010	2015	2020	2025	2030
fp-db	Annual GDP growth at factor cost, %			5.5	6.2	6.6	6.8	6.2
fp-db	Real exchange rate, % change (> 0 = depreciation)			0.0	-0.1	0.0	-0.3	-0.7
fp-db	Private investment (% GDP)		16.0	15.9	15.8	15.7	15.7	15.7
fp-db	Government investment (% GDP)		4.7	5.3	4.7	4.4	4.2	4.1
fp-db	Domestic savings (% GDP)		7.0	9.0	8.8	8.8	8.9	8.7
fp-db	Domestic government debt (% GDP)		8.4	10.9	12.9	9.6	-0.9	-17.8
fp-db	Exports % GDP		12.3	13.2	13.2	13.6	14.1	14.0
fp-db	Exports (Ush bn) 2003-year prices		1463.0	2243.3	3000.1	4189.7	5961.7	7913.1
fp-db	Trade deficit (% GDP)		-13.7	-12.2	-11.7	-11.3	-11.0	-11.1
fp-db	Foreign Public Debt stock (% GDP)		71.0	74.3	75.1	74.5	72.5	71.1
fp-db	Domestic gov revenue (% GDP)		11.3	14.5	15.4	14.9	13.8	12.9
fp-db	Fiscal Deficit (% GDP)		11.2	13.2	13.3	11.9	9.7	7.6
fp-db	Fiscal Deficit, including grants (% GDP)		4.2	5.7	5.7	4.4	2.4	0.5
fp-db	Donor aid (% GDP)		11.3	11.7	11.8	11.6	11.3	11.1
fp-db	Govt Expenditure (% GDP)		22.5	27.7	28.7	26.8	23.5	20.5
fp-db	Unemployment rate	total	29.1	25.7	22.5	19.2	15.2	10.5
fp-db	Unemployment rate	unskilled	30.0	26.7	23.5	19.9	15.7	10.7
fp-db	Unemployment rate	skilled	10.0	8.1	9.3	10.1	9.5	7.7
fp-db	Unemployment rate	high-skilled	10.0	7.0	6.9	8.3	9.6	9.7
fp-db	Employment rate	total	70.9	74.3	77.5	80.8	84.8	89.5
fp-db	Employment rate	unskilled	70.0	73.3	76.5	80.1	84.3	89.3
fp-db	Employment rate	skilled	90.0	91.9	90.7	89.9	90.5	92.3
fp-db	Employment rate	high-skilled	90.0	93.0	93.1	91.7	90.4	90.3
fp-db	Agriculture % GDP		32.4	32.2	32.7	34.0	35.7	37.3
fp-db	Industry % GDP		21.2	20.5	20.0	19.9	20.0	19.49
fp-db	Services % GDP		46.4	47.3	47.3	46.1	44.4	43.2
fp-db	GDP share sum		100.0	100.0	100.0	100.0	100.0	100.0
fp-db	Headcount poverty rate, %	MDG 1	35.0	30.9	23.7	16.1	9.8	6.1
fp-db	Primary school completion rate, %	MDG 2	15.5	26.3	50.3	75.2	91.1	97.6
fp-db	Under-five mortality rate , %	MDG 4	14.0	11.6	9.9	8.6	7.8	7.2
fp-db	Access to safe water, %	MDG 7a	56.0	59.2	62.7	67.2	72.3	78.0

Table 6. Selected indicators for scenario fp - foreign borrowing

			2003	2010	2015	2020	2025	2030
fp-fb	Annual GDP growth at factor cost, %			5.5	6.2	6.6	6.8	6.1
fp-fb	Real exchange rate, % change (> 0 = depreciation)			-0.4	0.1	0.3	0.0	-0.7
fp-fb	Private investment (% GDP)		16.0	15.9	15.8	15.6	15.5	15.5
fp-fb	Government investment (% GDP)		4.7	5.2	4.7	4.4	4.3	4.2
fp-fb	Domestic savings (% GDP)		7.0	8.7	8.8	9.4	10.2	10.0
fp-fb	Domestic government debt (% GDP)		8.4	9.6	9.7	9.7	9.6	9.7
fp-fb	Exports % GDP		12.3	12.8	13.1	14.4	15.7	15.6
fp-fb	Exports (Ush bn) 2003-year prices		1463.0	2187.3	2980.8	4419.9	6580.2	8748.0
fp-fb	Trade deficit (% GDP)		-13.7	-12.5	-11.7	-10.6	-9.6	-9.7
fp-fb	Foreign Public Debt stock (% GDP)		71.0	74.9	76.8	73.5	65.0	56.7
fp-fb	Domestic gov revenue (% GDP)		11.3	14.4	15.4	14.9	13.9	13.0
fp-fb	Fiscal Deficit (% GDP)		11.2	13.1	12.9	11.9	10.8	10.5
fp-fb	Fiscal Deficit, including grants (% GDP)		4.2	5.6	5.4	4.3	3.3	3.1
fp-fb	Donor aid (% GDP)		11.3	12.0	11.9	10.8	9.7	9.4
fp-fb	Govt Expenditure (% GDP)		22.5	27.5	28.3	26.8	24.6	23.4
fp-fb	Unemployment rate	total	29.1	25.7	22.5	19.2	15.4	10.9
fp-fb	Unemployment rate	unskilled	30.0	26.7	23.5	20.0	16.0	11.1
fp-fb	Unemployment rate	skilled	10.0	8.1	9.3	10.1	9.6	7.9
fp-fb	Unemployment rate	high-skilled	10.0	7.0	6.9	8.3	9.7	9.8
fp-fb	Employment rate	total	70.9	74.3	77.5	80.8	84.6	89.1
fp-fb	Employment rate	unskilled	70.0	73.3	76.5	80.0	84.0	88.9
fp-fb	Employment rate	skilled	90.0	91.9	90.7	89.9	90.4	92.1
fp-fb	Employment rate	high-skilled	90.0	93.0	93.1	91.7	90.3	90.2
fp-fb	Agriculture % GDP		32.4	32.2	32.7	33.9	35.4	37.0
fp-fb	Industry % GDP		21.2	20.4	19.9	19.9	20.1	19.65
fp-fb	Services % GDP		46.4	47.3	47.3	46.2	44.5	43.4
fp-fb	GDP share sum		100.0	100.0	100.0	100.0	100.0	100.0
fp-fb	Headcount poverty rate, %	MDG 1	35.0	30.9	23.7	16.1	9.8	6.1
fp-fb	Primary school completion rate, %	MDG 2	15.5	26.3	50.3	75.2	91.1	97.6
fp-fb	Under-five mortality rate , %	MDG 4	14.0	11.6	9.9	8.7	7.8	7.3
fp-fb	Access to safe water, %	MDG 7a	56.0	59.2	62.7	67.1	72.2	77.9

Figures

Figure 1. Real growth of GDP components, percent under BASE scenario 2009-2030

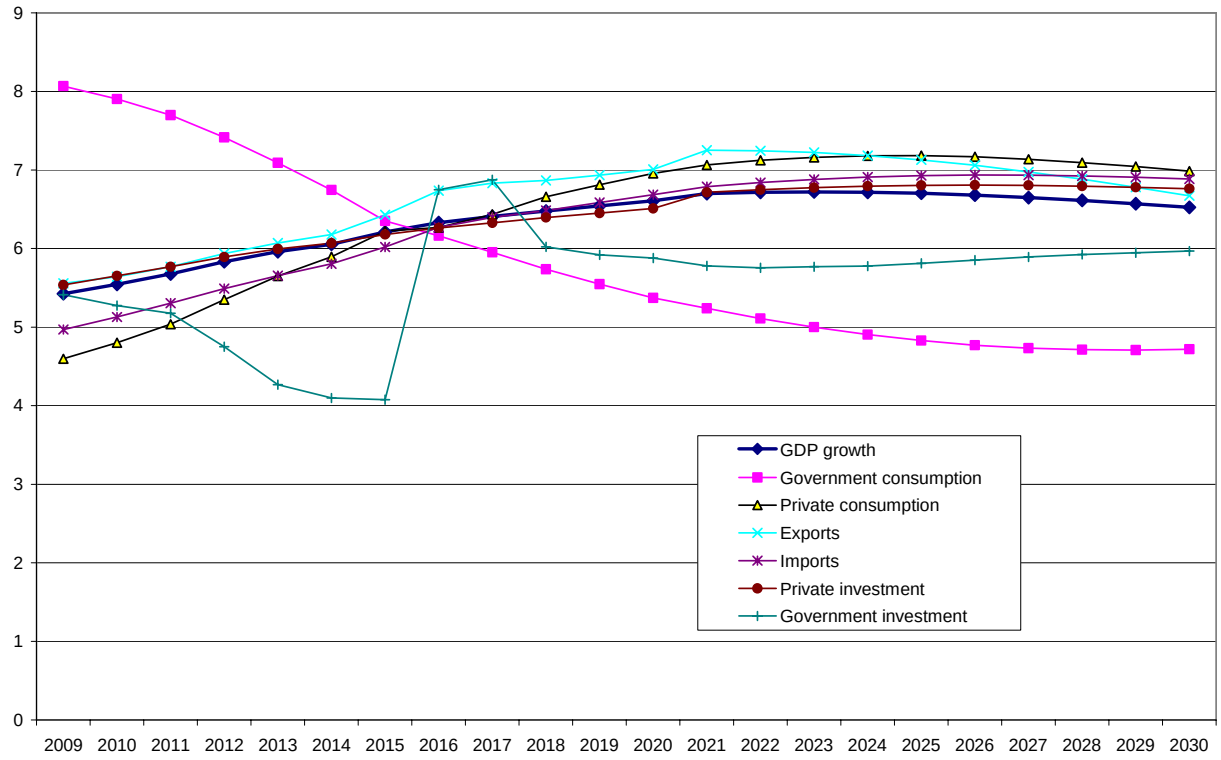


Figure 2. MDG indicators under BASE

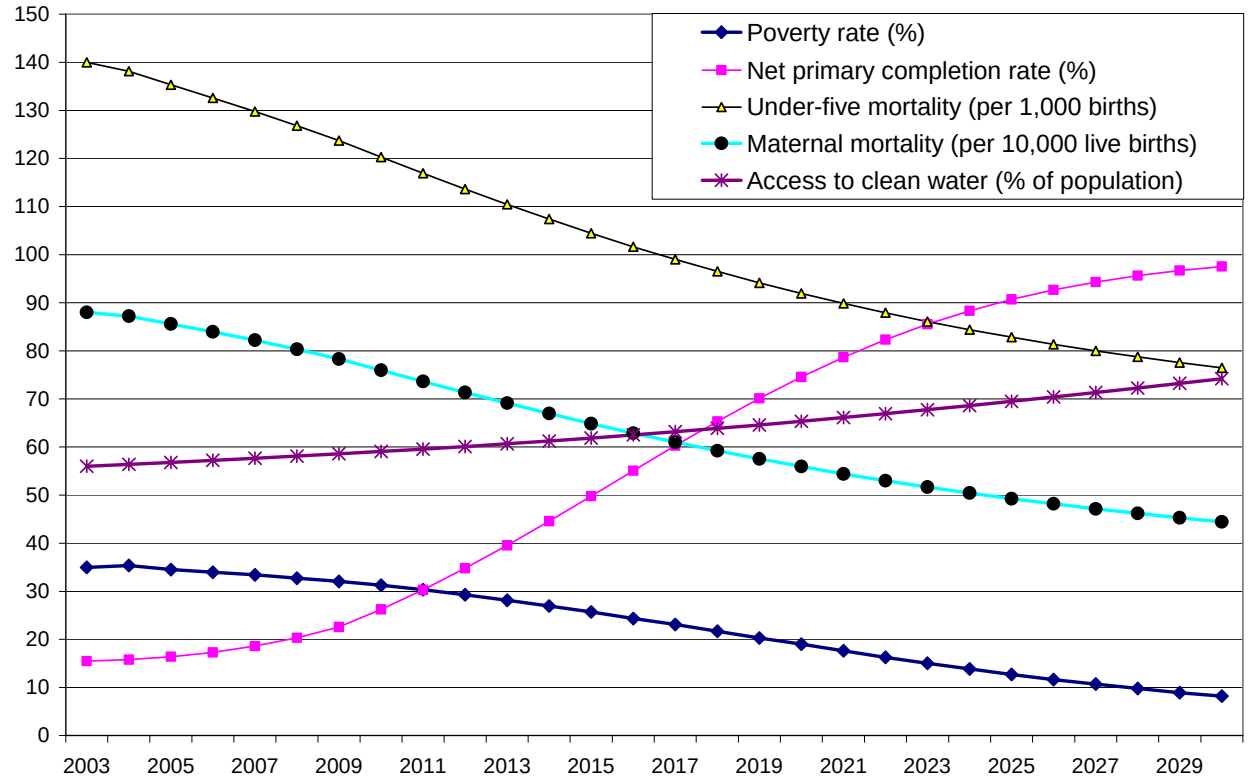


Figure 3. Population under BASE vs UN Medium variant projection 2008

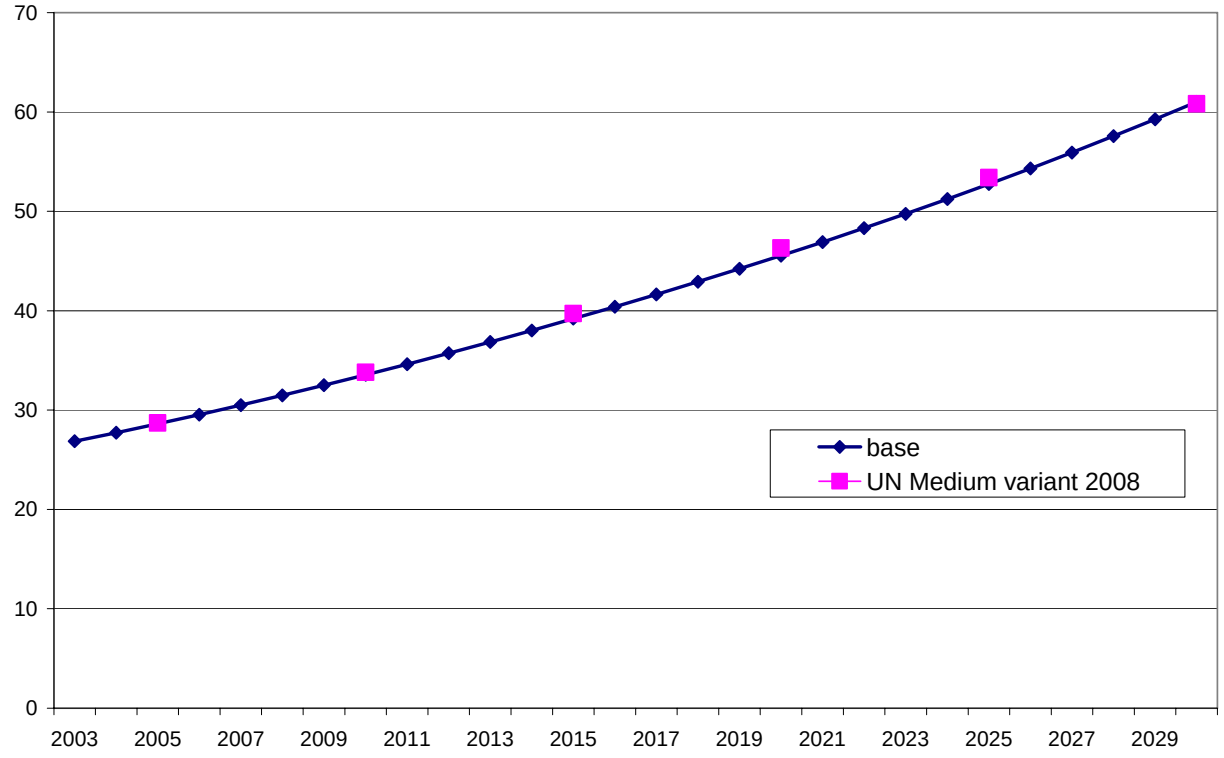


Figure 4. Dependency ratio according to BASE scenario and UN Medium variant projection 2008

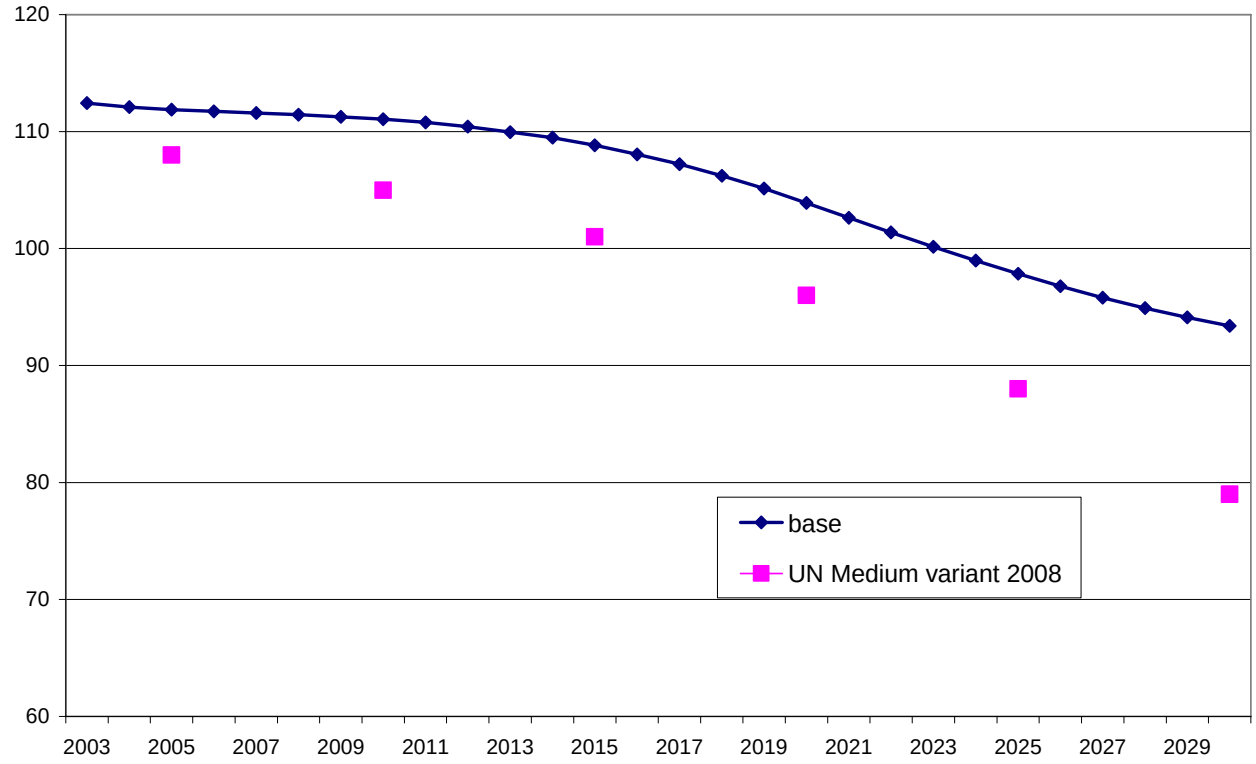
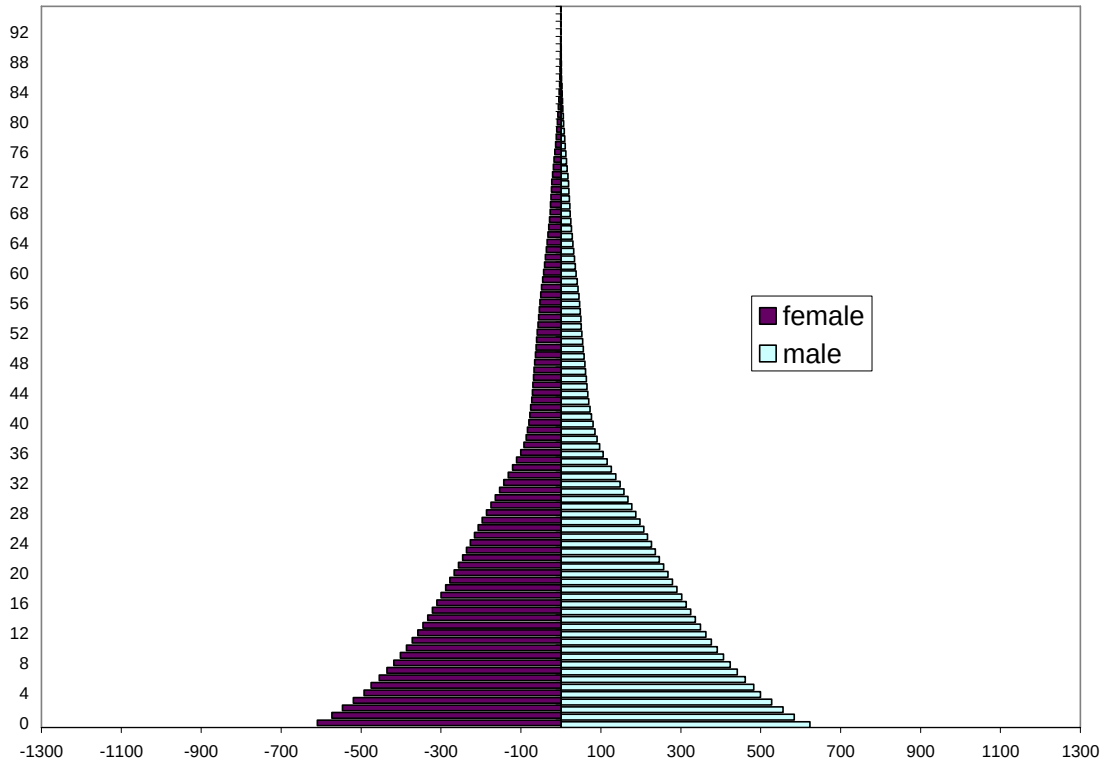
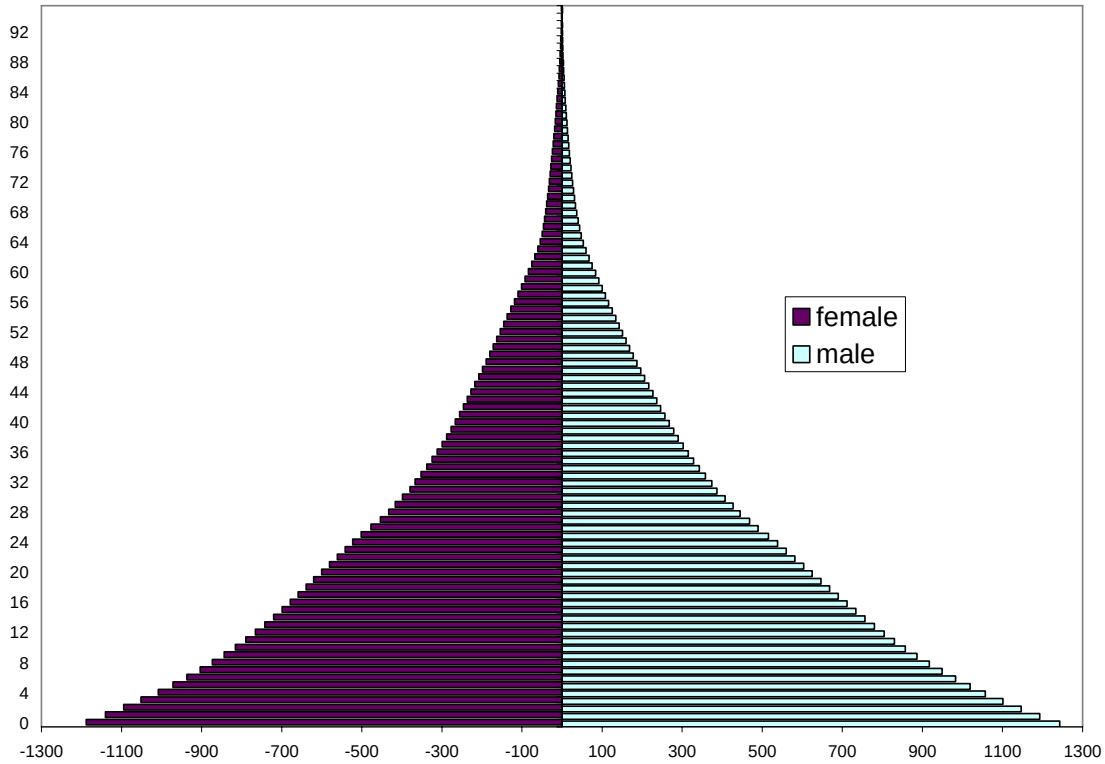


Figure 5. Population in Uganda 2003, in thousand persons



Source: UN Population secretariat.

Figure 6. Population in Uganda 2030, base scenario, in thousand persons



Source: model results

Figure 7. People in school and working age under base and fp-ftr, in thousand persons

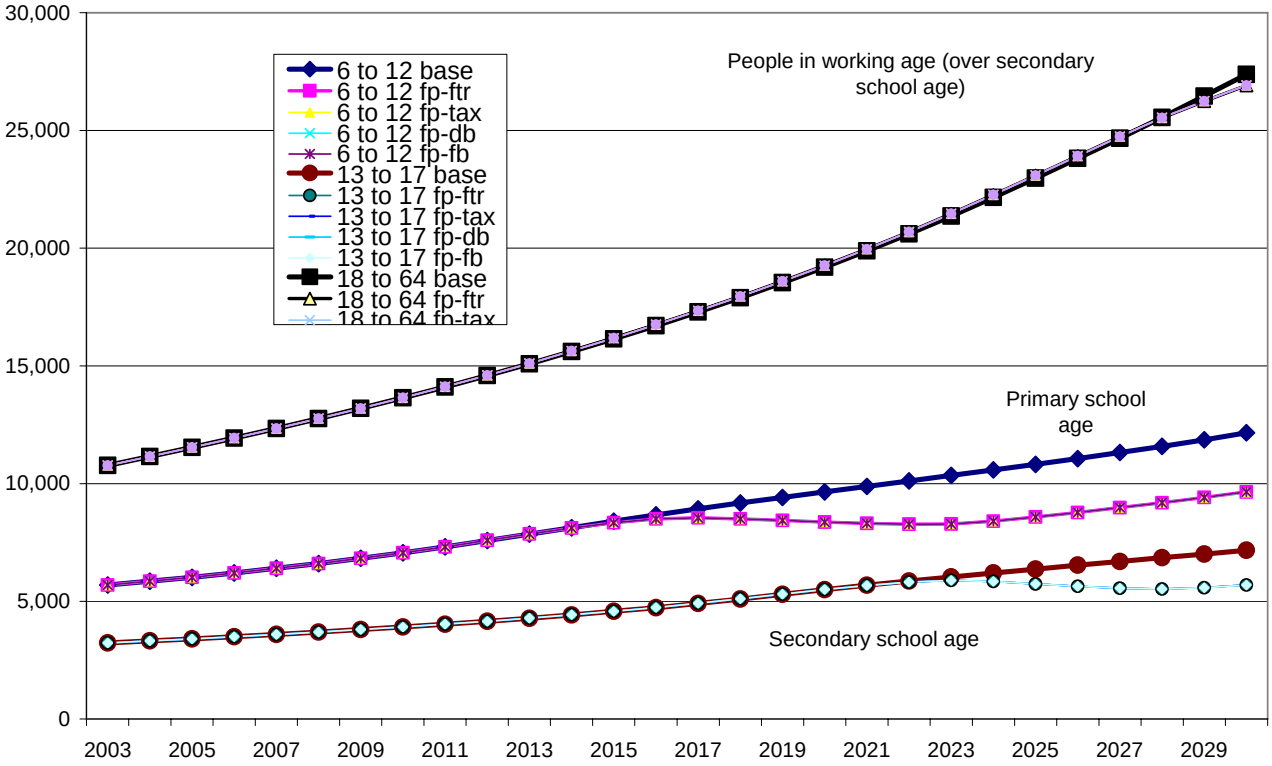


Figure 8. Total fertility rate under different scenarios

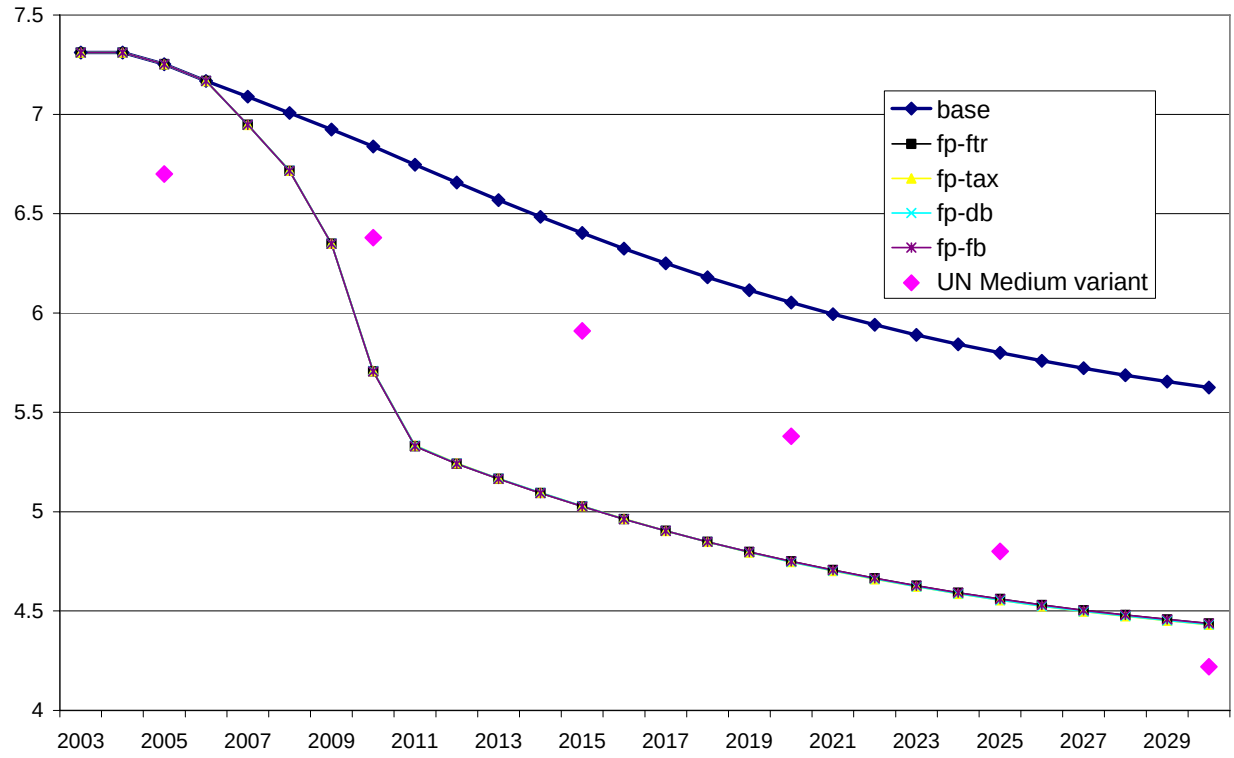


Figure 9. Difference from BASE in government outlays, in million 2003-year USD

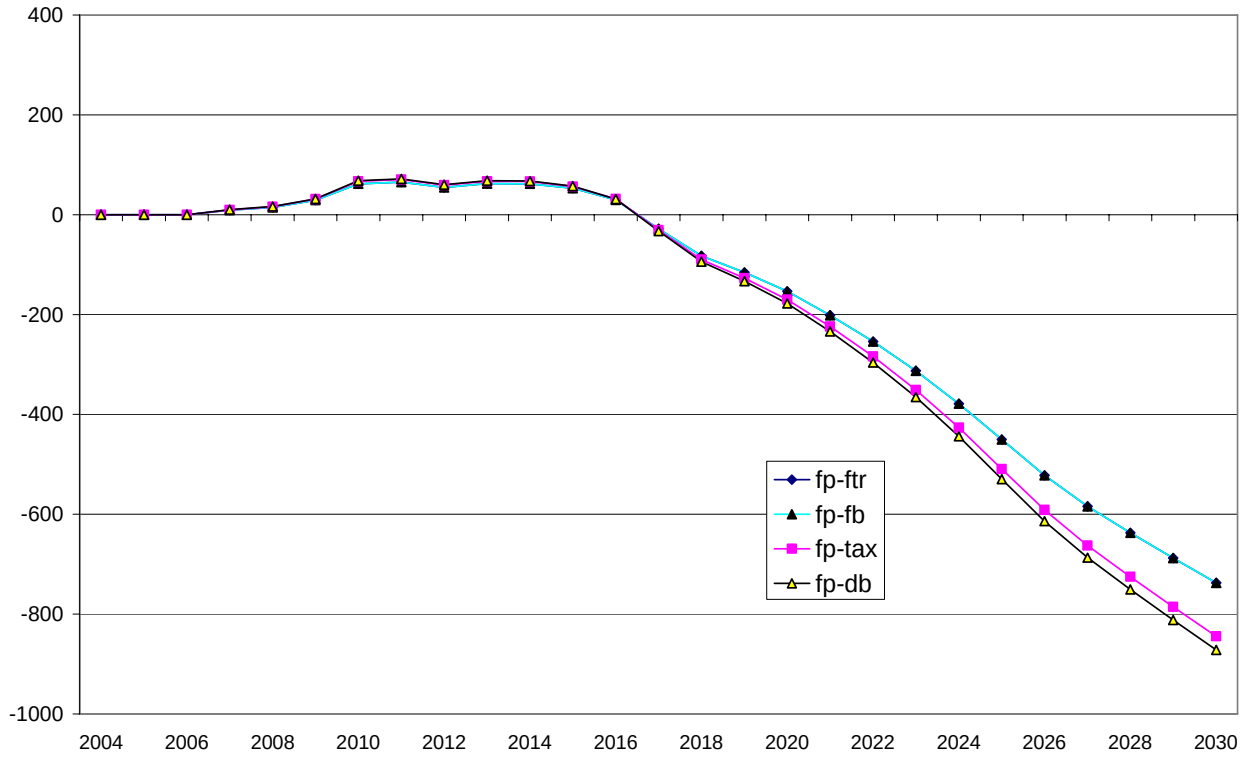


Figure 10. Change in final-year per-capita equivalent variation as percent of base-year per-capita consumption under BASE

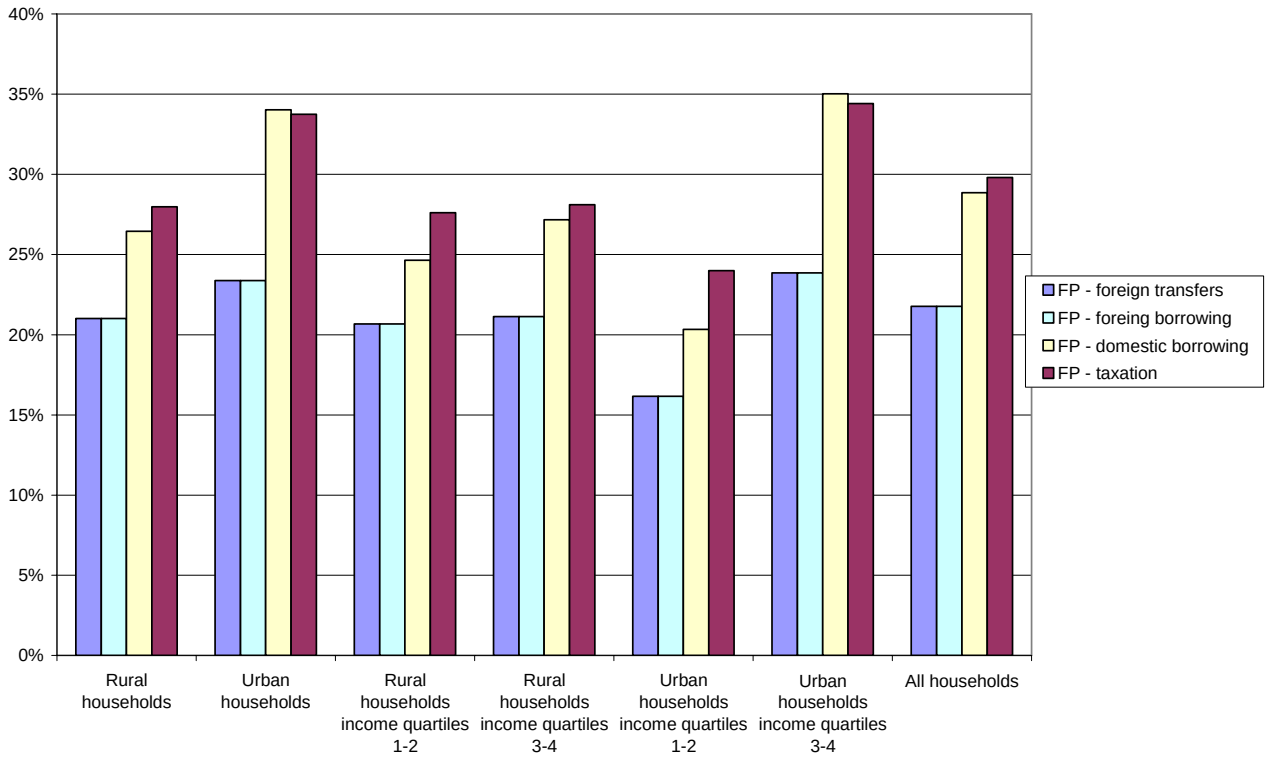


Figure 11. Difference in MDG attainment under fp-ftr, deviation from BASE values

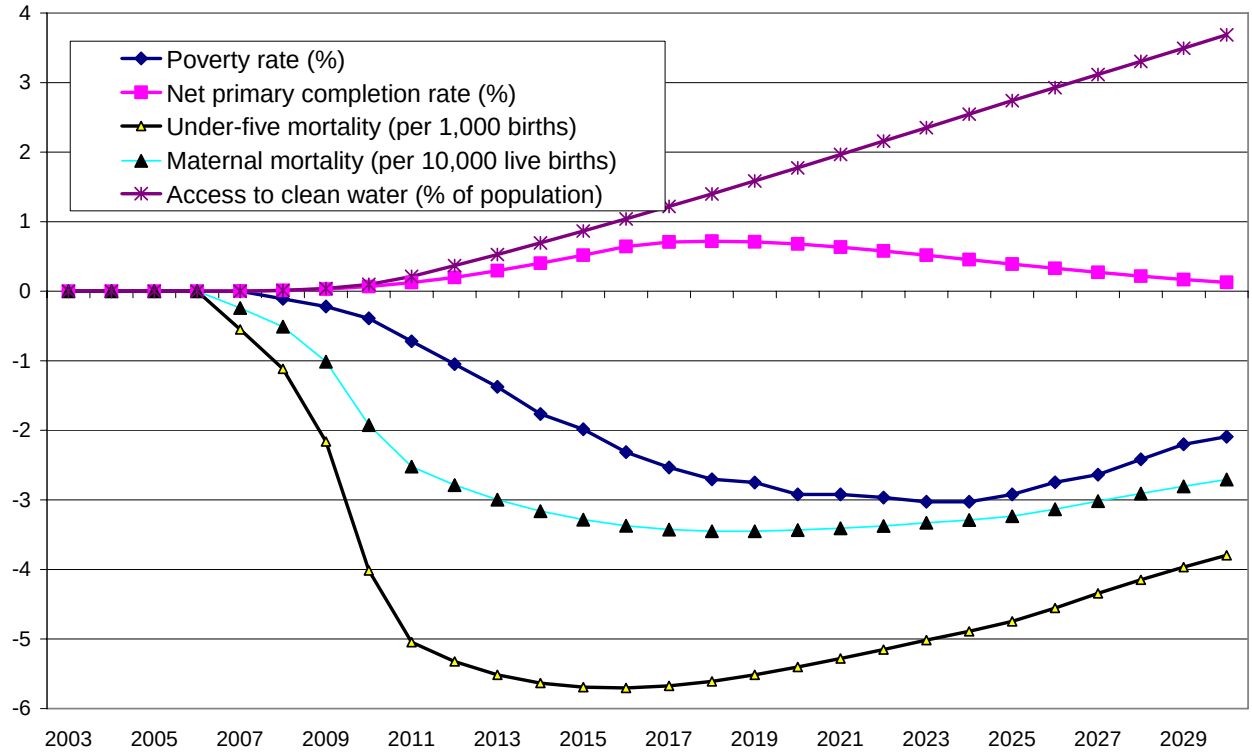


Figure 12. Difference in MDG attainment under fp-fb, deviation from BASE values

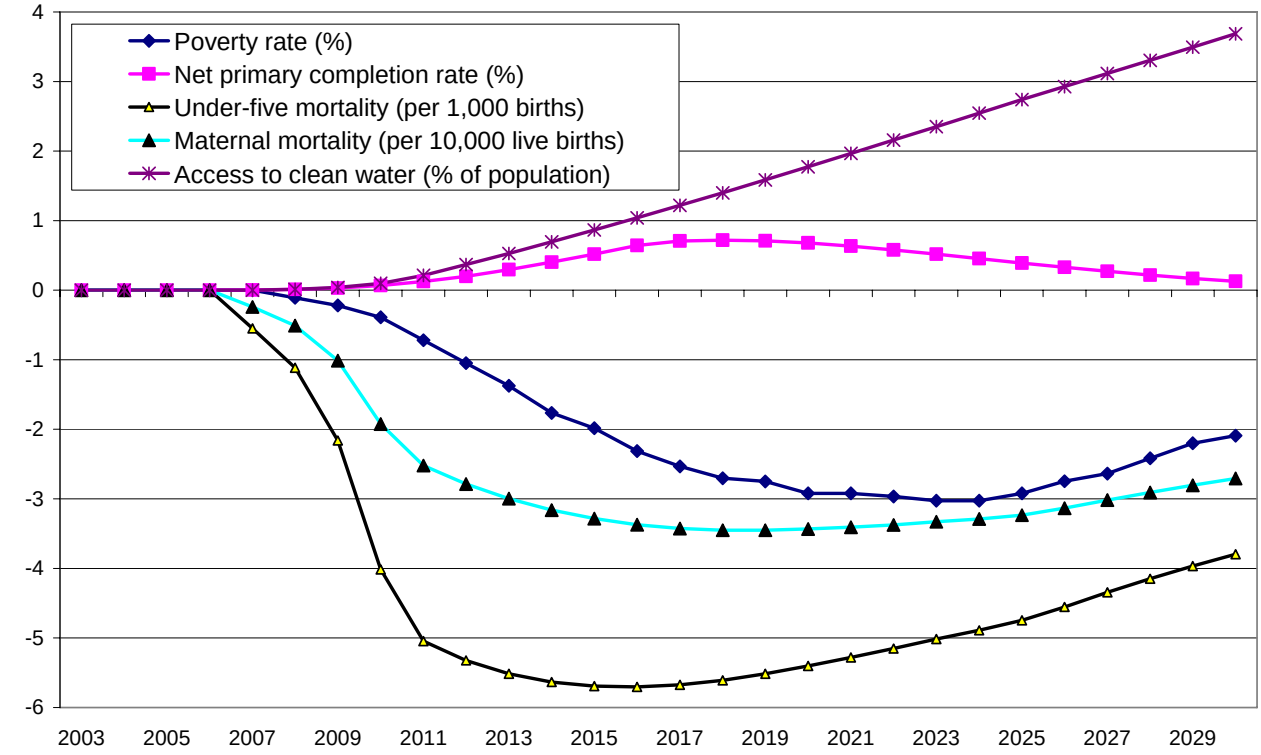


Figure 13. Difference in MDG attainment under fp-db, deviation from BASE values

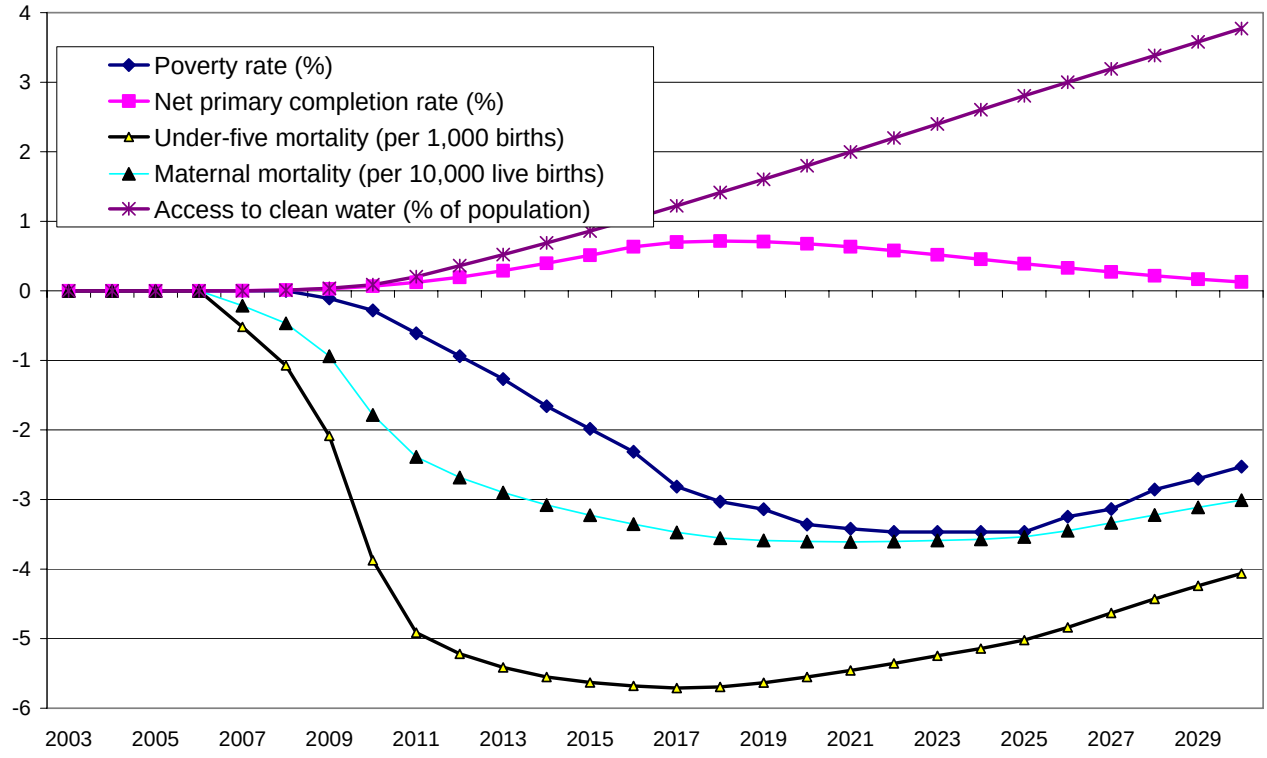
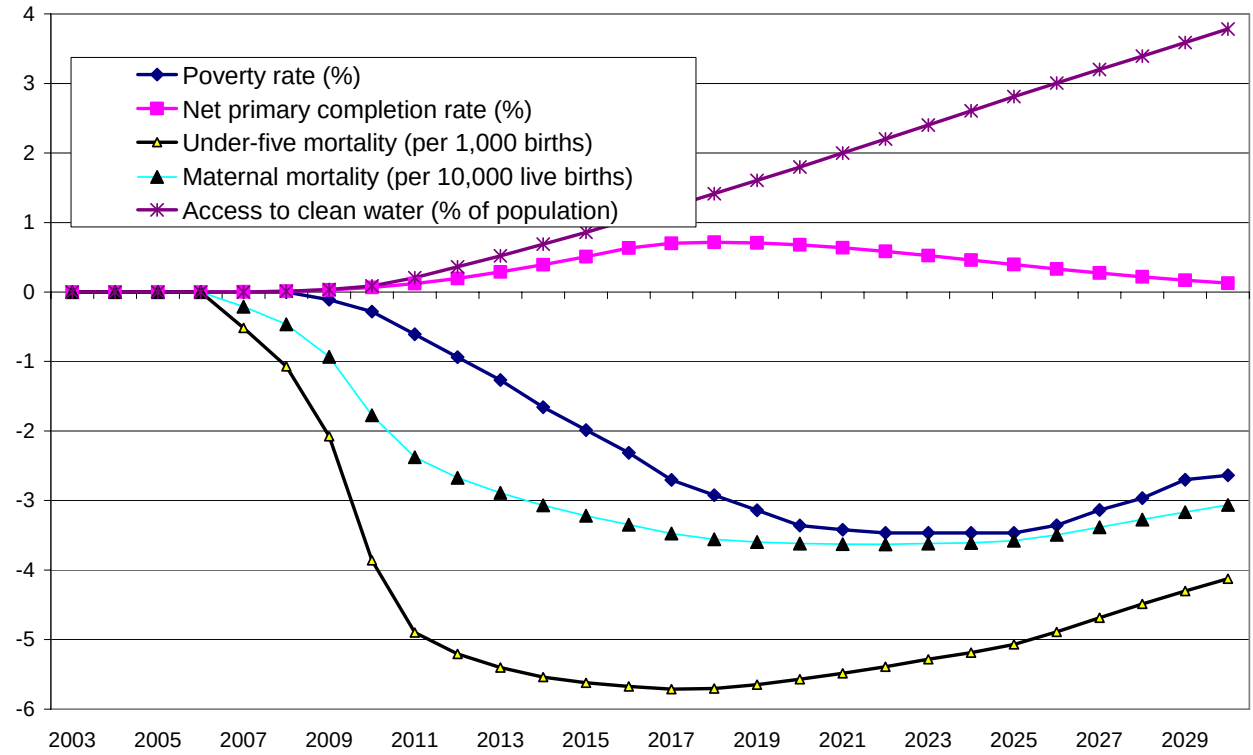


Figure 14. Difference in MDG attainment under fp-tax, deviation from BASE values



Appendix 1. Non-technical Description of the Demographic Module

Fertility and mortality are both modeled with a nested, two-tier function. At the bottom, a constant elasticity function creates a general development indicator that enters the logistic functions for fertility and mortality rates.

Intermediate general development indicator $ZDEMG_{dmg}$ (dmg = fertility, maternal mortality, other mortality)

$$ZDEMG_{dmg} = CE\begin{pmatrix} QQ; poptot; QHPC; \\ MDGVAL_{mdg}; QFINS_{flab}; QFINS_{fcapgov\,\inf} \end{pmatrix}$$

$$\begin{bmatrix} \text{intermediate} \\ \text{variable for} \\ \text{demographic} \\ \text{indicator} \end{bmatrix} = CE\begin{bmatrix} \text{per capita service level; per capita hhd consumption;} \\ \text{MDG indicators 2 and 7a; share of educated of labor force;} \\ \text{infrastructure capital stock} \end{bmatrix}$$

Maternal mortality rate $MATMORTRATE_{a,g}$ (a = age, g = 'female')

$$MATMORTRATE_{a,g} = LOG\left(ZDEMG_{mmrt}; MDG5ADJ\right)$$

$$\begin{bmatrix} \text{maternal} \\ \text{mortality rate} \end{bmatrix} = LOG\begin{pmatrix} \text{intermediate general development indicator;} \\ \text{adjustment factor btw aggregate MDG5 value} \\ \text{and disaggregate maternal mortality values} \end{pmatrix}$$

Other mortality causes

$$MORTRATE_{a,g} = LOG\left(ZDEMG_{mrt}; MDG4ADJ\right)$$

$$\begin{bmatrix} mortality\ rate\ for \\ other\ causes\ than \\ maternal\ mortality \end{bmatrix} = LOG\begin{pmatrix} \text{int}ermediate\ general\ development\ indicator; \\ adjustment\ \ factor\ btw\ aggregate\ MDG4\ value \\ and\ disaggregate\ mortality\ values \end{pmatrix}$$

Fertility rate

$$FERTRATE_{a,g} = LOG\left(ZDEMG_{frt}\right) * \left(1 - FAMSERV\right)$$

$$\begin{bmatrix} fertility\ rate\ for \\ 15-49\ olds\ per \\ age\ group\ and \\ gender\ of\ child \end{bmatrix} = LOG\left(\begin{matrix} \text{int}ermediate\ general\ development\ indicator; \\ adjustment\ \ factor\ btw\ aggregate\ MDG4\ value \\ and\ disaggregate\ mortality\ values \end{matrix}\right) * \left(\begin{matrix} 1-\ family\ \ planning \\ service\ effect\ on \\ fertility \end{matrix}\right)$$

Population by age and gender at time t $POPUYR_{a,g,t}$

$$POPUYR_{a,g,t} = f\left(\begin{matrix} POPUYR_{a,g,t-1}; MORTRATE_{a,g,t}; \\ MATMORTRATE_{a,g,t};\ FERTRATE_{a,g,t-1}; MIGRATE_{a,g,t} \end{matrix}\right)$$

$$\begin{bmatrix} Population\ by \\ age\ and\ \ gender \\ at\ time\ t \end{bmatrix} = f\left(\begin{matrix} Last\ \ year's\ \ population; other\ mortality; \\ maternal\ mortality;\ \ fertility\ rate\ by\ mother's\ age\ and \\ by\ baby's\ gender\ at\ t-1; net\ migration\ rate\ by\ age\ and\ \ gender \end{matrix}\right)$$

Migration is modeled here a fixed net migration rate (share of population group) per age and gender.

The disaggregate mortality data is fitted to the aggregate MDG4 (under-five mortality) and MDG5 (maternal mortality) information by a separate optimization procedure, which makes disaggregate population information to concur with the aggregate MDG production functions by minimizing adjustment factors MDG4ADJ and MDG5adj, when MDG4 and MDG5 values are given by the BASE run. In addition, the end-year total fertility is calibrated first as an aggregate number, which then is used in the calibration of the disaggregate fertility parameter values.