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Educational Attainment, Growth and Poverty Reduction within the MDG Framework: Simulations and Costing for the Peruvian Case

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Educational Attainment, Growth and Poverty Reduction within the MDG Framework: Simulations and Costing for the Peruvian Case

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Resumen

We propose a model that accounts for the potential feedback between schooling performance, human capital accumulation and long run GDP growth, and links these results with poverty incidence. Our simulation exercise takes into account targets for education indicators and GDP growth itself (as arguments in our planner's loss function) and provides two conclusions: (i) with additional funds which amount to 1% of GDP each year, public intervention could add, by year 2015, an extra 0.89 and 1.80 percentage points in terms of long-run GDP growth and permanent reduction in poverty incidence, respectively; and (ii) in order to engineer an intervention in the educational sector so as to transfer households the necessary assets to attain a larger income generation potential in the long run, we need to extend the original set of MDG indicators to account for access to higher educational levels besides primary..

Key words: Millennium Development Goals, education, human capital, GDP growth, poverty, Peru.

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1 Introduction and motivation

This project's main objective is to approximate the potential impact of different scenarios regarding public investment in education over economic growth and poverty incidence. Our analysis is based on the existence of interrelations and synergies between MDG indicators for poverty and education achievement. In this regard, we propose a model that accounts for the potential feedback between schooling performance, the accumulation of human capital and long run GDP growth, and link these results with poverty incidence. Within this framework, we address the issue whether MDG indicators related to education should be restated for the Peruvian case in order to maximize their effect over economic growth and poverty reduction in the long term.

In September 2000, all country members of the United Nations (UN) signed the Millennium Declaration, where they recognized the need to promote a multidimensional vision of development centered in the fulfillment of basic needs with an environmentally sustainable basis. Specifically, they committed to achieve, by the year 2015, a set of goals and targets related to the reduction of poverty, hunger, disease, mortality, illiteracy, environmental degradation and discrimination against women. These are known as the Millennium Development Goals (MDGs).

The wide range of aspects involved in the MDGs, ranging from education to environment and gender equality, reflects the shift towards a broadened concept of poverty (which includes short run poverty symptoms and long run poverty determinants) and, the fact that all these issues must be taken care of simultaneously, points out the relevance of promoting a comprehensive approach and a coordinated strategy for reducing poverty around the world.

Thus, MDGs can be viewed as an important step towards a consensus regarding the minimum set of arguments that a social planner's loss function must include, specially when considering inter-temporal difficult choices between short term poverty alleviation and long term poverty reduction. They have contributed to the debate regarding the multidimensional aspects of poverty and, in terms of policy analysis and design, made explicit the need for a systemic approach.

MDG assessment has been usually conducted on a sectorial basis, estimating the future path of each indicator as a function of its past evolution, or via structural models that account for a limited set of determinants, typically taking other MDG indicators as given. Thus, MDG prediction and costing can be biased because of the failure to consider the interactions among policy interventions and indicators.

The rest of the document is organized as follows. Section 2 provides a detailed description of the methodology undertaken for this study. The third section describes empirical results related to a simulation exercise which takes into account targets for education indicators or GDP growth itself (as arguments in our planner's loss function) and assesses the potential impact of reaching these targets in terms of the accumulation of human capital, aggregate GDP growth and poverty incidence. The fourth and final section summarizes our conclusions.

2 Methodology

The model proposed involves four different blocks: (i) a macro block (which connects aggregate GDP growth with educational attainment via the accumulation of human capital); (ii) an education block (which involves specific functional forms relating educational attainment with public investment in education and household expenditure, based on results that stem from micro-econometric estimations using Peruvian household data); (iii) a poverty block (which links GDP growth and changes in the Gini coefficient with the incidence of monetary poverty); and (iv) a costing and resource constraint block (which specifies cost functions for specific policy interventions identified in (ii), and links these to a planner budget constraint).

These four blocks are integrated in order to provide the system of constraints faced by the planner when trying to minimize her loss function. This loss function, in turn, will depend on the distance between exogenous targets and the level attained by education indicators or aggregate GDP growth at the end of the planning period (year 2015). In what follows, we present a detailed description of the analytical derivation of functional forms related to each of the four blocks involved in the aggregate model.

2.1 The Macro Block

2.1.1 The general framework

One of the main objectives of this paper is to build a model that accounts for the feedback between schooling performance, the accumulation of human capital and long run GDP growth. Following Lucas (1988), our analytical framework is based on a model where date t aggregate production (Y_t) is given by the combination of physical (K_t) and human (H_{Yt}) capital via a Cobb-Douglas technology:

$$Y_t = A_t K_t^\beta H_{Yt}^{(1-\beta)} \quad (1.)$$

In the expression above, H_Y is the stock of human capital devoted to production (labor force adjusted for productivity), and this is assumed to be equal to a proportion (μ_Y) of the total stock of human capital (H). The remaining proportion ($H_H = \mu_H H$) is devoted to the accumulation of more human capital according to:

$$\begin{aligned} \dot{H} &= B H_H - \delta H \\ &= B \mu_H H - \delta H \end{aligned} \quad (2.)$$

where B is the parameter describing the technology of the educational sector (the rate at which human capital is transformed into more human capital) and δ is the depreciation rate of human capital. Thus, human capital growth (γ_H) is given by:

$$\gamma_H = B \mu_H - \delta \quad (3.)$$

It is worth mentioning the Lucas' model only considers one "type" of education and that his representative agent seeks to maximize the discounted path of consumption with preferences defined by a constant relative risk aversion function. There is only one proportion of human capital devoted to education (μ_H) and this is one of the control variables available for the optimization problem. Lucas' steady state solution implies a value for μ_H given by:

$$\mu_H = 1 - [(1 - \theta)(\delta - B) + \rho] / [B\theta] \quad (4.)$$

where θ and ρ refer to the risk aversion parameter and inter-temporal discount rate, respectively. Given this steady state solution for the proportion of human capital devoted to the education sector, and a balanced growth path where $\gamma_K^{SS} = \gamma_H^{SS}$, GDP steady state growth rate is given by $\gamma_Y^{SS} = \gamma_A^{SS} + \gamma_H^{SS}$ ². In this way, long run GDP growth depends on the rate of growth of technology (γ_A^{SS} ; which can be assumed as exogenous) and the rate of growth of human capital (γ_H^{SS} ; which depends on the parameter governing the technology of the educational sector (B), the depreciation rate of human capital and parameters defining consumer preferences --the inter-temporal discount rate and risk aversion-).

2.1.2 Our specification

Given the above, our objective is to link long run GDP growth rate with observed enrollment and graduation rates in the different educational levels. In particular, these rates will influence the technology of the education sector (B) and affect long run GDP growth (γ_Y^{SS}) via γ_H^{SS} . In turn, and if enrollment and graduation rates can be affected by the provision of educational services, our model will capture the planner's potential ability to influence long run GDP growth by fostering the accumulation of human capital.

To accomplish this, we will consider three different educational levels (primary, secondary and tertiary) and assume the existence of three different "types" of agent which face choice. The first agent, with no education, must decide between enrolling and finishing primary education or entering the labor market. The second agent, with completed primary education, must decide between enrolling and finishing secondary education or entering the labor force. Finally, the third "type" of agent, with completed secondary, must decide between enrolling and finishing the next educational cycle (tertiary) or entering the labor market. This defines the existence of three different stocks

² Taking logs, differentiating with respect to time, and imposing $\gamma_K^{SS} = \gamma_H^{SS}$ in (1.) suffices to arrive to this solution.

of human capital (H_1 , H_2 and H_3 , respectively). Using a Barro-Lee (2000) type of human capital aggregation, we assume each stock is given by the number of individuals in each category (either enrolled in the corresponding educational cycle or in the labor force), adjusted by their corresponding productivity. Formally:

$$\begin{aligned}
 H_{1,t} &= \lambda_{Y0} H_{Y0,t} + \lambda_{H1} H_{H1,t} \\
 H_{2,t} &= \lambda_{Y1} H_{Y1,t} + \lambda_{H2} H_{H2,t} \\
 H_{3,t} &= \lambda_{Y2} H_{Y2,t} + \lambda_{H3} H_{H3,t}
 \end{aligned} \tag{5.}$$

where $H_{Yi,t}; i=0,1,2$ correspond to the number of individuals in the labor force with no education, completed primary and completed secondary, respectively. $H_{Hi,t}; i=1,2,3$, on the other hand, correspond to the number of individuals with no education, completed primary and completed secondary, respectively, that are enrolled in the corresponding educational cycle (primary, secondary and tertiary). Parameters $\lambda_{Yi}; i=0,1,2$ and $\lambda_{Hi}; i=1,2,3$ define the productivity of individuals in each category.

Equations in (5.) describe the way in which each “type” of agent distributes itself between the labor market (production sector) and the corresponding education sector. Therefore, and following Lucas (1988), their choice variables (proportion of each “type” of human capital devoted to accumulate more human capital) will be defined as:

$$\mu_{Hi,t} = \frac{\lambda_{Hi} H_{Hi,t}}{H_{i,t}}, i = 1, 2, 3.$$

The total stock of human capital (H_t) is given by the aggregation of human capital associated to each “type” of agent, plus the number of individuals with completed tertiary ($H_{Y3,t}$) adjusted by their corresponding productivity (λ_{Y3}). We assume this fourth “type” of agent faces no choice and will, therefore, be in the labor market.

$$H_t = H_{1,t} + H_{2,t} + H_{3,t} + \lambda_{Y3} H_{Y3,t} \tag{6.}$$

In order to build accumulation rules for the number of individuals in the labor force and enrolled in each educational cycle, let us define:

- $E6_t \equiv$ number of 6 year-olds in period t
- $glentry_t \equiv$ period t probability of enrolling in primary education at normative age (6 year-olds).
- $grdprim_t \equiv$ period t probability of graduating within the primary education cycle.
- $grdcontsec_t \equiv$ period t probability of enrolling in secondary education, given that the primary cycle has been completed.
- $grdsec_t \equiv$ period t probability of graduating within the secondary education cycle.
- $grdcontsup_t \equiv$ period t probability of enrolling in tertiary education, given that the secondary cycle has been completed.
- $grdsup_t \equiv$ period t probability of graduating within the tertiary education cycle.
- $ni \equiv$ number of grades within educational cycle “i”, $i=prim$ (primary), sec (secondary), sup (tertiary). For simplicity, we will assume that students are evenly distributed among grades within each educational cycle.

Given the above, the following equations define the number of individuals in the labor force and enrolled in each educational level.

$$H_{Y0,t} = (1 - \delta)H_{Y0,t-1} + (1 - glentry_t)E6_t \quad (7.)$$

where the number of individuals with no education in the labor market ($H_{Y0,t}$) is equal to last period’s remaining stock (considering a depreciation rate of δ) plus year t six year-olds that do not enroll in primary education. Despite that the official working age in Peru is fourteen, this formulation not only guarantees simplicity but also accounts for the fact that those children who do not attend school are typically providing labor services to their households, specially in rural areas.

$$H_{H1,t} = (1 - \delta - \frac{\text{grdprim}_{t-1}}{\text{nprim}})H_{H1,t-1} + (\text{glentry}_t)E\delta_t \quad (8.)$$

where the number of individuals with no education enrolled in primary education is equal to the last period's remaining stock of children in primary school (those surviving minus those who graduated from primary cycle) plus period t six year-olds enrolling in primary. Following the assumption that students are evenly distributed among grades within each educational cycle, $\left[\frac{H_{H1,t-1}}{\text{nprim}} \right]$ denotes the number of students in the last grade of primary education.

The remaining equations in this group follow a similar logic.

$$H_{Y1,t} = H_{Y1,t-1}(1 - \delta) + H_{H1,t-1} \left[\frac{\text{grdprim}_{t-1}}{\text{nprim}} \right] (1 - \text{grdcont sec}_t)$$

$$H_{H2,t} = H_{H2,t-1} \left(1 - \delta - \frac{\text{grd sec}_{t-1}}{\text{n sec}} \right) + H_{H1,t-1} \left[\frac{\text{grdprim}_{t-1}}{\text{nprim}} \right] \text{grdcont sec}_t \quad (9.)$$

$$H_{Y2,t} = H_{Y2,t-1}(1 - \delta) + H_{H2,t-1} \left[\frac{\text{grd sec}_{t-1}}{\text{n sec}} \right] (1 - \text{grdcont sup}_t)$$

$$H_{H3,t} = H_{H3,t-1} \left(1 - \delta - \frac{\text{grd sup}_{t-1}}{\text{n sup}} \right) + H_{H2,t-1} \left[\frac{\text{grd sec}_{t-1}}{\text{n sec}} \right] \text{grdcont sup}_t$$

$$H_{Y3,t} = H_{Y3,t-1}(1 - \delta) + H_{H3,t-1} \left[\frac{\text{grd sup}_{t-1}}{\text{n sup}} \right]$$

If we replace (7.), (8.) and (9.) into (5.), aggregate according to (6.) and collect terms related to parameters that define the productivity of individuals in each category, we obtain:

$$\begin{aligned}
H_t = & (1 - \delta)(\lambda_{Y_0}H_{Y_0,t-1} + \lambda_{H_1}H_{H_1,t-1} + \lambda_{Y_1}H_{Y_1,t-1} + \lambda_{H_2}H_{H_2,t-1} + \lambda_{Y_2}H_{Y_2,t-1} + \lambda_{H_3}H_{H_3,t-1} + \lambda_{Y_3}H_{Y_3,t-1}) \\
& + \lambda_{Y_0}E6_t + (\lambda_{H_1} - \lambda_{Y_0})E6glentry_t + (\lambda_{Y_1} - \lambda_{H_1})H_{H_1,t-1} \frac{\text{grdprim}_{t-1}}{\text{nprim}} + \\
& + (\lambda_{H_2} - \lambda_{Y_1})H_{H_1,t-1} \frac{\text{grdprim}_{t-1}}{\text{nprim}} \text{grdcont sec}_t + (\lambda_{Y_2} - \lambda_{H_2})H_{H_2,t-1} \frac{\text{grd sec}_{t-1}}{\text{n sec}} + \\
& + (\lambda_{H_3} - \lambda_{Y_2})H_{H_2,t-1} \frac{\text{grd sec}_{t-1}}{\text{n sec}} \text{grdcont sup}_t + (\lambda_{Y_3} - \lambda_{H_3})H_{H_3,t-1} \frac{\text{grd sup}_{t-1}}{\text{n sup}}
\end{aligned} \tag{10.}$$

The expression above is our version (in discrete terms) of (2.). If we subtract and divide both sides of (10.) by H_{t-1} , we finally arrive to an expression for the growth rate of human capital $\gamma_{H,t} = (H_t - H_{t-1})/H_{t-1}$:

$$\gamma_{H,t} = \lambda_{Y_0} \frac{E6_t}{H_{t-1}} + \mu_{H_1,t-1} B_{H_1,t} \frac{H_{1,t-1}}{H_{t-1}} + \mu_{H_2,t-1} B_{H_2,t} \frac{H_{2,t-1}}{H_{t-1}} + \mu_{H_3,t-1} B_{H_3,t} \frac{H_{3,t-1}}{H_{t-1}} - \delta \tag{11.}$$

where the variables that account for the technology of each educational sector (the rate at which human capital is transformed into more human capital) are given by:

$$\begin{aligned}
B_{H_1,t} &= \frac{1}{\lambda_{H_1}} \left[\frac{E6_t \text{glentry}_t}{H_{H_1,t-1}} (\lambda_{H_1} - \lambda_{Y_0}) + \frac{\text{grdprim}_{t-1}}{\text{nprim}} (\lambda_{Y_1} - \lambda_{H_1}) \right] \\
B_{H_2,t} &= \frac{1}{\lambda_{H_2}} \left[\frac{H_{H_1,t-1}}{H_{H_2,t-1}} \frac{\text{grdprim}_{t-1}}{\text{nprim}} \text{grdcont sec}_t (\lambda_{H_2} - \lambda_{Y_1}) + \frac{\text{grd sec}_{t-1}}{\text{n sec}} (\lambda_{Y_2} - \lambda_{H_2}) \right] \\
B_{H_3,t} &= \frac{1}{\lambda_{H_3}} \left[\frac{H_{H_2,t-1}}{H_{H_3,t-1}} \frac{\text{grd sec}_{t-1}}{\text{n sec}} \text{grdcont sup}_t (\lambda_{H_3} - \lambda_{Y_2}) + \frac{\text{grd sup}_{t-1}}{\text{n sup}} (\lambda_{Y_3} - \lambda_{H_3}) \right]
\end{aligned} \tag{12.}$$

Clearly, the variable governing the technology of each educational sector captures the “promise” in terms of expected increased earnings associated to progressing to the corresponding cycle: the marginal productivity gain times the probability of accessing this gain. As such, each variable $B_{H_i,t}; i=1,2,3$ is the sum of two terms: (i) the marginal productivity gain associated to entering the corresponding educational cycle with respect to entering the labor force with the previous cycle completed $(\lambda_{H_i} - \lambda_{Y_{(i-1)}}; i=1,2,3)$,

times the probability of accessing this gain; and (ii) the marginal productivity gain associated to entering the labor force with the corresponding cycle completed with respect to that associated to entering the corresponding educational cycle ($\lambda_{Y_i} - \lambda_{H_i}$; $i = 1, 2, 3$), times the probability of accessing this gain.

Since the first productivity gain applies to individuals from the previous cycle entering the corresponding one, the probability of accessing this gain is equal to this entry flow divided by the number of individuals enrolled in the corresponding educational cycle ($H_{H_i,t-1}$; $i = 1, 2, 3$). For primary education, the entry flow equals the current number of six year-olds times the probability of enrolling in primary education ($E6_g1entry_t$). For secondary education, this entry flow equals the number of individuals that completed primary last year ($H_{H1,t-1} \frac{grdprim_{t-1}}{nprim}$) times the contemporaneous probability of progressing to secondary education ($grdcontsec_t$). A similar logic applies for the entry flow to tertiary education. The second “type” of productivity gain, on the other hand, applies to all individuals enrolled in the corresponding cycle and, thus, the probability of accessing this gain is simply given by the proportion of individuals enrolled in the last year of the cycle $\frac{1}{n_“i”}$; “i” = prim, sec, sup, times the probability of graduating within the corresponding cycle $grd_“i”_{t-1}$; “i” = prim, sec, sup.

In order to explicitly account for the behavioral assumptions that stem from Lucas (1988) steady state solution, we will explain the evolution of those ratios that are a direct result of the choice of each “type” of agent, following:

$$\begin{aligned}
 \mu_{H1,t} &= 1 - [(1 - \theta_1)(\delta - B_{H1,t}) + \rho] / [B_{H1,t} \theta_1] \\
 \mu_{H2,t} &= 1 - [(1 - \theta_2)(\delta - B_{H2,t}) + \rho] / [B_{H2,t} \theta_2] \\
 \mu_{H3,t} &= 1 - [(1 - \theta_3)(\delta - B_{H3,t}) + \rho] / [B_{H3,t} \theta_3]
 \end{aligned} \tag{13.}$$

Thus, by using the result provided by Lucas to solve for three different μ_H 's (following expression (13.) above) we are implicitly assuming that the optimization problem is

solved by the three different “types” of agent described above³. In fact, each “type” of agent decides the proportion of its human capital that will be devoted to further human capital accumulation ($\mu_{Hi,t}; i = 1, 2, 3$) on the basis of the expected productivity gain associated to the corresponding educational cycle. As explained above, this expected productivity gain is captured in variables $B_{Hi,t}; i = 1, 2, 3$ which (as a simple inspection of expressions given in (13.) will reveal) have a positive effect on their corresponding $\mu_{Hi,t}; i = 1, 2, 3$.

Thus, and by using equations given in (11.), (12.) and (13.), our model seeks to explain the way in which public interventions aimed at increasing enrollment and graduation rates will exert a positive impact on the rate of growth of human capital. Following equations given in (12.), this positive impact will be engineered by increasing the expected productivity gain associated to each educational cycle. This, in turn, will transpire on the rate of growth of human capital both directly (as accounted for by the presence of variables $B_{Hi,t}; i = 1, 2, 3$ in equation (11.)) and indirectly, by affecting agents’ decisions regarding the proportion of human capital devoted to further human capital accumulation (as accounted for in equations given in (13.)).

2.2 The Education Block

In this block our interest focuses on describing enrollment and graduation rates in the three cycles considered (MDG indicators related to education) as a function of public investment in education and GDP growth. In this way, we will be able to connect the “promise” in terms of expected increased earnings associated to the decision of entering and continuing within the education sector (captured in variables $B_{Hi,t}; i = 1, 2, 3$ described above) with public intervention and GDP growth itself. The latter, in turn, will allow for feedback between education indicators and aggregate GDP growth.

Our approach for this will be empirical, in the sense that we will propose functional forms and parameter estimates that stem, directly, from an econometric exercise. Since the aim

³ These choices are consistent with the conditional nature of the probabilities considered in `grdcontsec` and `grdcontsup` (which define the proportion of individuals who progress to the next cycle provided that they have finished the previous one).

of our analysis is to approximate the behavior of these enrollment and graduation rates through time, one would expect that the preferred database should explicitly include a time dimension. However, the availability of information typically imposes a trade-off: we usually encounter too few observations for a time series analysis, while household survey data (which substantially increases the number of observations and the variability of covariates through space) typically lack a panel structure. Thus, and if the scarcity of time series information imposes almost no degrees of freedom for estimation, the only practical solution is to rely on cross-sectional household surveys. Obviously, this implies assuming that behavioral patterns captured in year 0 cross-section will not vary significantly through time.

Under this scenario, enrollment and graduation for a particular individual (i) with characteristics (X_i) can be viewed as a discrete realization for a binary dependant variable ($y_i = 1$ if successful in enrolling or graduating; 0 otherwise). Thus, the expected value of this dependant variable conditioned on individual's characteristics is the probability of occurrence of the event under analysis, and the specific functional form for this probability will be given by the type of distribution assumed for the error term. For example, if we assume a logistic distribution, the above will imply:

$$E[y_i | X_i; \psi] = \Pr[y_i = 1 | X_i; \psi] = \frac{\exp(X_i' \psi)}{1 + \exp(X_i' \psi)} \quad (14.)$$

The parameters involved (ψ) can be estimated with cross-sectional household survey data, and equation (14.) can be used to approximate the probability that an individual with characteristics X_i will exhibit the discrete characteristic identified in the dependant variable (y_i).

In order to estimate the behavior of education indicators through time, and under the assumption that behavioral patters will remain relatively constant in this dimension, we can rely on the estimated values of ψ and the functional form described in (14.) to predict the probability that an average individual will exhibit the characteristic under study in period (t). The probability associated to this "average individual" can be, in turn,

directly associated to the proportion of individuals who exhibit the characteristic. For this, we need to evaluate (14.) using the mean values (across space) of the set of determinants in period (t) (\bar{X}_t). In this way, and for a given set of these mean values, we will be able to predict the indicator's value in period (t).

$$\text{MDG2}_{i,t} = \Pr[y_t = 1 | \bar{X}_t; \psi] = \frac{\exp(\bar{X}_t' \psi)}{1 + \exp(\bar{X}_t' \psi)} \quad (15.)$$

In accordance to the objective of this block, we will evaluate the role of specific policy variables related to public investment in education and household per-capita expenditure among the set of determinants (\bar{X}_t). In particular, this last variable will allow to control for families' socio-economic characteristics and to connect enrollment and graduation rates with GDP growth provided by the macro block (by assuming that mean household per-capita expenditure grows at the same rate and per-capita GDP)⁴. In addition, and due to the nature of functional forms relating these determinants to indicators, both policy variables and per capita expenditures will exhibit a diminishing marginal impact over the indicator. This is a desirable property since it reflects the fact that improvements are harder to achieve once the indicators have reached an acceptable level.

Equations in (12.) reveal that we require functional forms and parameter estimates for six different rates: (i) the probability of enrolling in primary education at normative age (6 year-olds) (g1entry); (ii) the probability of graduating within the primary education cycle (grdprim); (iii) the probability of enrolling in secondary education, given that the primary cycle has been completed (grdcontsec); (iv) the probability of graduating within the secondary education cycle (grdsec); (v) the probability of enrolling in tertiary education, given that the secondary cycle has been completed (grdcontsup); and (vi) the probability of graduating within the tertiary education cycle (grdsup). Following the discussion

⁴ We acknowledge that success in graduating from lower education levels can also be among the determinants of the probability of enrolling and graduating in higher levels and that all rates, in general, can also depend on other variables related to education. In this paper, however, we decided to explicitly model the impact of public investment in education and household per-capita expenditure due to data availability and to focus our attention on the feedback between educational attainment and GDP growth, without introducing further second round effects. Depending on data availability at the household level, the connection between probabilities of enrollment and graduation at higher and lower levels of education could be addressed in an extension to our model.

above, all our estimates were based on binary logit models. These were applied using cross-sectional information captured in the ENAHO 2003 household survey and administrative records.

Regarding the results presented in Appendix 1, it is worth mentioning that the models that present better fit and more significant year-0 elasticities are those that determine the probability of entering the first and third educational cycle: *g1entry* and *grdcontsup*. As argued in Castro and Yamada (2006), this is due to the fact that initial values of these probabilities are low enough (0.89, 0.15, respectively) to allow sufficient variability in the dependant variable. Therefore, these probabilities are still in a point of the logistic function where proposed determinants can be effective in terms of causing changes in the indicator under study.

As mentioned above, the variable that summarizes families' socio-economic characteristics is the household per-capita expenditure level. It is highly significant and exhibits the largest elasticity for the probability of accessing primary and tertiary education. In fact, richer families will be in a better position to face the costs related to the decision of sending their children to school and, more importantly, of sending them to pursue higher education.

The variable that reflects public investment in education was built using an interaction between the number of teachers and the number of schools per student in the corresponding cycle⁵. We proposed this variable due to the high degree of complementarity between physical (classrooms) and human capital (teachers) in the provision of educational services. The results show that this variable is significant when explaining the two probabilities described above, although its year-0 elasticity is below that associated to per-capita household expenditure.

The models that explain the probability of enrolling in secondary education (*grdcontsec*) and graduating within each cycle (*grdprim*, *grdsec* and *grdsup*⁶), on the other hand,

⁵ Except for the case of *grdcontsec* where public intervention was captured via the number of teachers per student.

⁶ Table 4 in Appendix 1 presents the results of a model built to explain graduation in primary and secondary education (*grdprim* and *grdsec*). We were unable to obtain significant results for a model explaining

exhibit a lower fit and weaker elasticities. In fact, and due to the existence of decreasing marginal returns to intervention (captured in our logistic functions), the initial level of these probabilities (between 0.93 and 0.95) are sufficiently high to prevent public intervention from causing a large effect.

At this point, we would like to stress that this work does not pretend to replace proper impact evaluation at the project level when assessing specific interventions in public education. Our intention is to shed light on the detailed mechanics involved throughout the full cycle of educational attainment and, with this, try to uncover the potential priorities to look at for policy guidance from a MDG perspective, and the aggregate cost for the society in embarking in an active campaign for MDG achievement in education and poverty reduction.

2.3 The Poverty Block

In order to account for the impact of economic growth on individuals' income and the incidence of monetary poverty (MDG indicator 1), we will rely on the accounting model proposed in ECLAC-IPEA-UNDP (2002). According to their specification, individual (h) income in period (t) can be expressed as:

$$y_{h,t}^* = (1 + \gamma_y)^t \left[(1 - \alpha)y_{h,0} + \alpha\bar{y}_0 \right]; \quad t = 0, \dots, T \quad (16.)$$

where γ_y refers to the annual rate of (distribution-neutral⁷) per-capita GDP growth, α is the percentage change in the Gini coefficient, while $y_{h,0}$ and \bar{y}_0 refer to year 0 income of individual (h) and year 0 mean income, respectively.

graduation in tertiary education (grdsup). Therefore, results obtained for the model presented in Table 4 were also used to explain grdsup.

⁷ Regarding the role and nature of economic growth, the recent literature proposes several definitions related to the impact of growth on poverty. Less restrictive definitions suggest that we can talk about pro-poor growth as long as we observe an improvement in the poverty indicator under analysis, even if it implies a deterioration in income distribution (Kraay (2003)). More restrictive definitions, on the other hand, propose that growth can only be regarded as pro-poor if it provokes an improvement in income distribution (Kakwani and Pernia (1999)). The "type" of growth implied in equation (16.) stands on an intermediate ground. In particular, it assumes that everyone's income grows at the same rate so we can regard this "type" of growth as distribution-neutral.

Since our intention is to endogenize GDP growth as a function of the rate of accumulation of human capital, we will extend (16.) in order to allow for a different per-capita GDP growth each period and to accumulate the distributional implications of introducing changes in the Gini coefficient. Formally:

$$y_{h,t}^* = (1 + \gamma_{y,t}) \left[(1 - \alpha) y_{h,t-1}^* + \alpha \bar{y}_{t-1}^* \right]; \quad t = 1, \dots, T \quad (17.)$$

With the above formula, and for a given percentage change in the Gini coefficient and a poverty line (y_{crit}), it will be possible to compute poverty incidence as:

$$I_{1,t} = \left[\sum_{h=1}^{Pop_t} 1(y_{h,t}^* < y_{crit}) \right] / Pop \quad (18.)$$

where Pop refers to the total population as accounted for in the ENAHO 2004 household survey. In this way, and by using the results provided by the macro block to account for the evolution of aggregate GDP, our model will be able to account for the potential impact that improvements in educational attainment have on the income generation capability of the population and the incidence of monetary poverty.

2.4 The Costing and Resource Constraint Block

We present the specific functional forms of cost functions for policy interventions related to the education sector. We also discuss the assumptions that will govern the behavior of the planner's budget constraint.

In particular, micro-econometric results that stem from the education block imply the existence of five potential policy variables: the number of teachers in each educational cycle and the number of schools in primary and tertiary education. In accordance with the complementary nature of these variables, the total cost of intervention (TC_t) was estimated as follows.

Intervention implies choosing a final value (in year T) for the ratios of teachers and schools per student in each educational level ($\text{eduqual}_{i,t}; i=1,2,3$). In particular, and according to the results discussed in the education block, variable eduqual refers to the product between the number of teachers and schools per student for primary and tertiary education, while it only refers to the number of teachers per student for the case of secondary education. Once the planner has chosen these three final values, we compute the annual growth rate of each $\text{eduqual}_{i,t}$ following: $\gamma_i = (\text{eduqual}_{i,T} / \text{eduqual}_{i,0})^{1/T}$ ⁸. The latter implies an annual growth factor for the number of teachers $\gamma_{i(\text{tea}),t}$ and schools $\gamma_{i(\text{sch}),t}$ in each educational level, which will depend on: (i) the endogenous evolution of the number of students enrolled in each educational level; and (ii) a fixed assumed ratio between the number of teachers and schools in each educational level⁹.

Given these endogenous growth rates, and unit costs for teachers and schools in each educational level, we can finally compute the total cost of intervention (TC_t) in education following:

$$\begin{aligned} \text{CTea}_{i,t} &= (\text{Tea}_{i,t} - \text{Tea}_{i,0}) \text{UCTea}_i = \text{Tea}_{i,0} \left(\prod_{s=0}^t \gamma_{i(\text{tea}),s} - 1 \right) \text{UCTea}_i \\ \text{CSch}_{i,t} &= (\text{Sch}_{i,t} - \text{Sch}_{i,t-1}) \text{UCSch}_i = \text{Sch}_{i,0} \prod_{s=0}^{t-1} \gamma_{i(\text{sch}),s} (\gamma_{i(\text{sch}),t} - 1) \text{UCSch}_i \\ \text{TC}_t &= \sum_{i=1}^3 \text{CTea}_{i,t} + \sum_{i=1}^3 \text{CSch}_{i,t} \end{aligned} \quad (19.)$$

where:

$\text{CTea}_{i,t}$ = Cost of additional teachers for educational level i in period t

$\text{Tea}_{i,t}$ = Number of teachers in educational level i in period t

UCTea_i = Unit cost per teacher in educational level i

$\text{CSch}_{i,t}$ = Cost of additional schools for educational level i in period t

⁸ This implies that variable eduqual exhibits a constant growth rate throughout the simulation exercise. In the absence of short term shocks affecting the expenditure profile, we believe this a reasonable assumption. In fact, we are attempting to capture the mean evolution of additional expenditures in the education sector.

⁹ For the case of primary and tertiary education, the planner can provoke an increase in eduqual by raising either the number of teachers or schools. In the absence of further restrictions, the planner will typically choose to raise eduqual via the number of teachers since this is a less expensive input for the provision of educational services. Thus, during the simulation exercise we impose the restriction that the ratio of teachers to schools remains fixed and equal to its initial level. In this way, we guarantee that improvements in the provision of educational services can not be achieved by raising only one of the required inputs.

$Sch_{i,t}$ = Number of schools in educational level i in period t

$UCSch_i$ = Unit cost per school in educational level i

Finally, and regarding the planner's budget constraint, we will impose the following condition:

$$\begin{aligned} TC_t &\leq \lambda Y_t \\ Y_t &= Y_{t-1}(1 + \gamma_{Y,t}) \end{aligned} \quad (20.)$$

In fact, the planner's budget constraint implies that, each period, total intervention costs must be such that the fiscal deficit (equivalent to the difference in the stock of public debt, $D_t - D_{t-1}$) does not exceed a percentage (λ) of aggregate GDP, for a given interest rate (r) and given levels of recurrent fiscal expenditure (G_t) and revenues (R_t).

$$D_t - D_{t-1} = rD_{t-1} + G_t + TC_t - R_t \leq \lambda Y_t \quad (21.)$$

Moreover, and since official projections¹⁰ contemplate a sustained reduction of the fiscal deficit (0.3% of GDP in year 2005) and the possibility of a surplus (of around 0.5% of GDP) by year 2009, our simulation exercise will assume fiscal equilibrium as the average situation for the period 2005-2015 under a no intervention scenario. The latter implies that $rD_{t-1} + G_t - R_t = 0$, and combining this result with the expression above yields:

$$D_t - D_{t-1} = TC_t \leq \lambda Y_t \quad (22.)$$

According to the current Fiscal Discipline Law $\lambda = 0.01$. Therefore, the above simply means that the planner has access to additional resources that amount to 1 percent of GDP each year to finance further intervention and comply with the fiscal rule.

¹⁰ Ministry of Finance of Peru (2006).

3 Education, long-run growth and poverty

3.1 The integrated model

As already mentioned, our intention is to build a model that accounts for the potential feedback between education indicators and aggregate GDP growth which will, in turn, lead to further improvements in education and poverty MDG indicators. Given this, simulations were carried out considering that our planner seeks to achieve particular targets for selected education indicators or GDP growth itself, subject to the budget constraint explained in the previous section.

The macro block provided the rate of growth of human capital ($\gamma_{H,t}$) by using equations (11.), (12.) and (13.) explained above. In order to focus on the behavioral implications that stem from the use of Lucas' steady state solution, during the simulation exercise we further assumed that all ratios that do not directly pertain to the choice of the three agents considered remain constant and equal to their year-0 values¹¹. Parameter estimates for productivity ($\lambda_{Y_i}; i = 0,1,2,3$ and $\lambda_{H_i}; i = 1,2,3$) were defined in terms of market-based returns for each educational cycle instead of using the number of schooling years as originally proposed by Barro and Lee. These were estimated via a Mincer equation detailed in Appendix 2¹². Following Dancourt *et al.* (2004), the inter-temporal discount rate (δ) was fixed in 0.02 (2%). Risk aversion parameters ($\theta_1, \theta_2, \theta_3$), on the other hand, were calibrated to fit (following equations in (13.)) year-0 values for the proportion of each type human capital enrolled in the corresponding educational level, obtained from household survey data (ENAH0 2004)¹³. Finally, the rate of growth of aggregate GDP was computed following: $\gamma_{Y,t} = \bar{\gamma}_A + \gamma_{H,t}$, where the exogenous rate of growth of

¹¹ These ratios are: $E6_t/H_{t-1}$; $H_{i,t-1}/H_{t-1}$, $i = 1,2,3$; $E6_t/H_{H1,t-1}$; and $H_{H(i-1),t-1}/H_{H,t}$, $i = 2,3$.

¹² This paper assumes that productivity remains constant in order to focus on the implications (in terms of GDP growth and poverty incidence) of increasing graduation and enrollment rates, since these are the indicators explicitly addressed within the MDG framework. However, we believe endogenizing productivity could be addressed as an extension to our model by, for example, developing and estimating functional forms connecting returns to education to the provision of educational services. In this way, public intervention would not only foster human capital accumulation by increasing the probability of accessing productivity gains in each cycle, but also by increasing productivity gains *per se*.

¹³ Values obtained were $\theta_1 = 0.876$, $\theta_2 = 1.249$, $\theta_3 = 2.079$. Since these parameters correspond to the inverse of the elasticity of intertemporal substitution, parameter values reflect the fact that, as agents grow older and progress through the education sector, they are more risk-averse in the sense that they are less eager to substitute present for future consumption.

technology ($\bar{\gamma}_A$) was obtained via the growth accounting exercise described in Appendix 2.

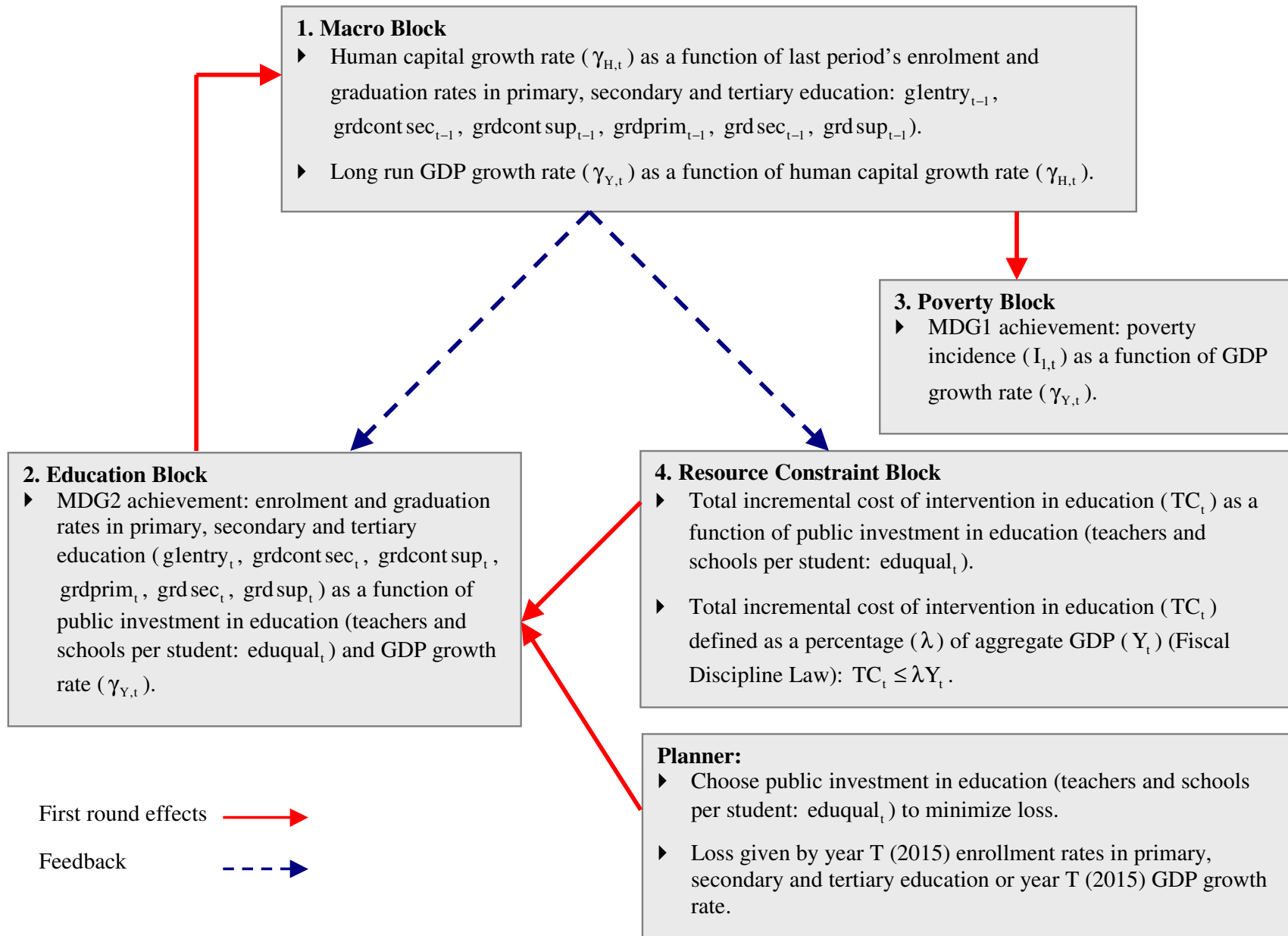
The education block, on the other hand, provided the evolution of enrollment and graduation rates according to the functional forms described in (15.), considering: (i) parameter estimates given in Appendix 1; (ii) the planner's choice for the rate of growth of policy variables (as described in the resource constraint block); and (iii) the rate of growth of per-capita GDP given by: $\gamma_{y,t} = \gamma_{Y,t} - \bar{\gamma}_N$ ¹⁴.

Finally, the poverty block provided the evolution of monetary poverty incidence following equations (17.) and (18.) above. For this, per-capita GDP growth was computed as explained in the previous paragraph and we assumed no distributional changes ($\alpha = 0$).

Figure 1 highlights the main interactions and feedbacks we intend to capture. Appendix 3, on the other hand, provides a complete list and description of the variables considered.

¹⁴ The exogenous rate of growth of the population ($\bar{\gamma}_N$) was set equal to 0.0135 (1.35%), following demographic projections for Peru.

Figure 1: Summary of the Model



3.2 The simulation exercise

In this section we present our simulation results¹⁵ based on the model described above. Our analysis is based on the comparison of five different scenarios: (i) BaU – a no-intervention (business as usual) scenario, where no additional fiscal effort is devoted to increase the provision of educational services; (ii) MDG2 – an intervention scenario where our planner expands the provision of educational services in order to minimize loss defined as a function of enrollment rates in primary education¹⁶; (iii) MDG2* – an intervention scenario where our planner expands the provision of educational services in order to minimize loss as a function of both primary and secondary enrollment rates; (iv) MDG2** – an intervention scenario where our planner expands the provision of educational services in order to minimize loss as a function of all enrollment rates¹⁷; and (v) MDG1 – an intervention scenario where our planner expands the provision of educational services in order to maximize GDP growth¹⁸. Thus, loss functions for the last four scenarios are given by¹⁹:

$$\begin{aligned}
 \text{LF_MDG2} &= (1 - \text{glentry}_T) \\
 \text{LF_MDG2}^* &= (1 - \text{glentry}_T) + (1 - \text{grdcont sec}_T) \\
 \text{LF_MDG2}^{**} &= (1 - \text{glentry}_T) + (1 - \text{grdcont sec}_T) + (1 - \text{grdcont sup}_T) \\
 \text{LF_MDG1} &= (10 - \gamma_{Y,T})
 \end{aligned} \tag{23.}$$

If we refer to the gains in terms of increased GDP growth, it is worth noticing that the model captures the effects of several driving forces. In particular, the main exogenous determinants of our results can be grouped in two: (i) those that affect the maximum attainable improvement in terms of GDP growth, which, according to equations (11.), (12.) and (13.), will basically depend on the productivity gains associated to individuals'

¹⁵ Simulations were carried out using the General Algebraic Modeling System (GAMS).

¹⁶ Following the indicators originally targeted as part of the second MDG.

¹⁷ Scenarios (iii) and (iv) introduce an extension in the set of indicators related to the second MDG in order to account for educational attainment in the secondary and tertiary levels.

¹⁸ According to our poverty block, and for a given percentage change in the Gini coefficient (captured via parameter α), poverty incidence will only depend on aggregate GDP growth. Therefore, in the context of our model, a planner concerned about maximizing GDP growth resembles a planner concerned about minimizing poverty incidence. This is why this scenario, where the loss depends on GDP growth itself, is referred as MDG1.

¹⁹ Targets for enrolment rates were fixed in 1 (100%). The target for aggregate GDP growth was fixed in 10%.

educational attainment ($\lambda_{Y_i}, \lambda_{H_i}; i=1,2,3$); and (ii) given (i), those that affect the proportion of this maximum attainable improvement that can be actually achieved under our BaU and intervention scenarios. Regarding the latter, the actual improvement under the BaU scenario will be mainly driven by the elasticity of enrollment and graduation rates with respect to per-capita expenditure. Given this, further improvements under the intervention scenarios will mainly depend on the elasticity of enrollment rates with respect to policy variables, the unit costs of intervention, the budget constraint, and the arguments included in our planner's loss function.

Figures 2 and 3 depict the evolution of the GDP growth rate and the moderate (or national) poverty headcount index, under each of the five scenarios considered (in Appendix 4 we present the evolution of each enrollment rate under these five scenarios). As revealed in Figure 2, the BaU scenario already predicts an increase of 0.51 percentage points in aggregate GDP growth if we compare year 0 (5.90%) and year 2015 (6.41%) values. As discussed above, this improvement depends on the elasticity of enrollment and graduation rates with respect to per-capita expenditure, which guarantees that enrollment and graduation rates do experience an improvement throughout the simulation period even if no specific additional policy interventions are in place.

If we simulate our model under the first intervention scenario (MDG2) results reveal an increase of 0.57 percentage points in aggregate GDP growth if we compare year 0 and year 2015 values. This implies that, despite the fact that the enrollment rate in primary education reaches its target by year 2015²⁰, there is only a marginal gain in terms of increased GDP growth with respect to the no intervention scenario.

²⁰ It must also be said that the probability of graduating within the primary cycle (grdprim) also reaches a value very close to 1 by year 2015. These results imply that the probability of entering grade 1 and finishing grade 6 at normative age is also close to 100%.

Figure 2: GDP growth (BaU and intervention scenarios)

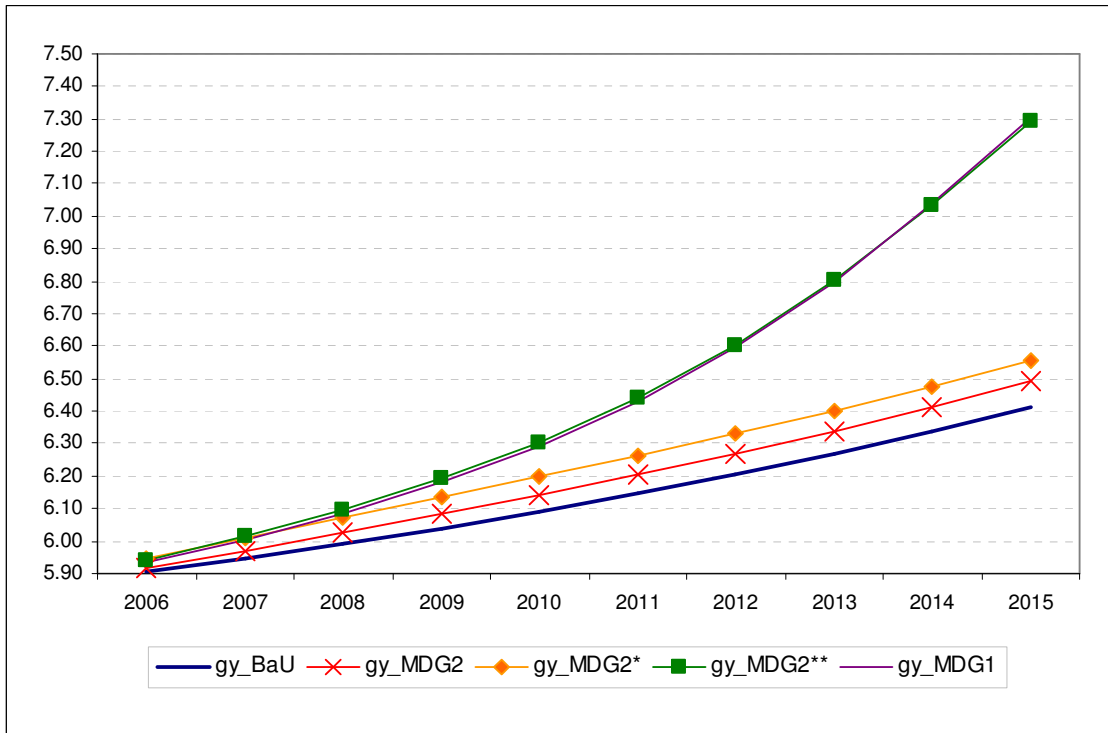
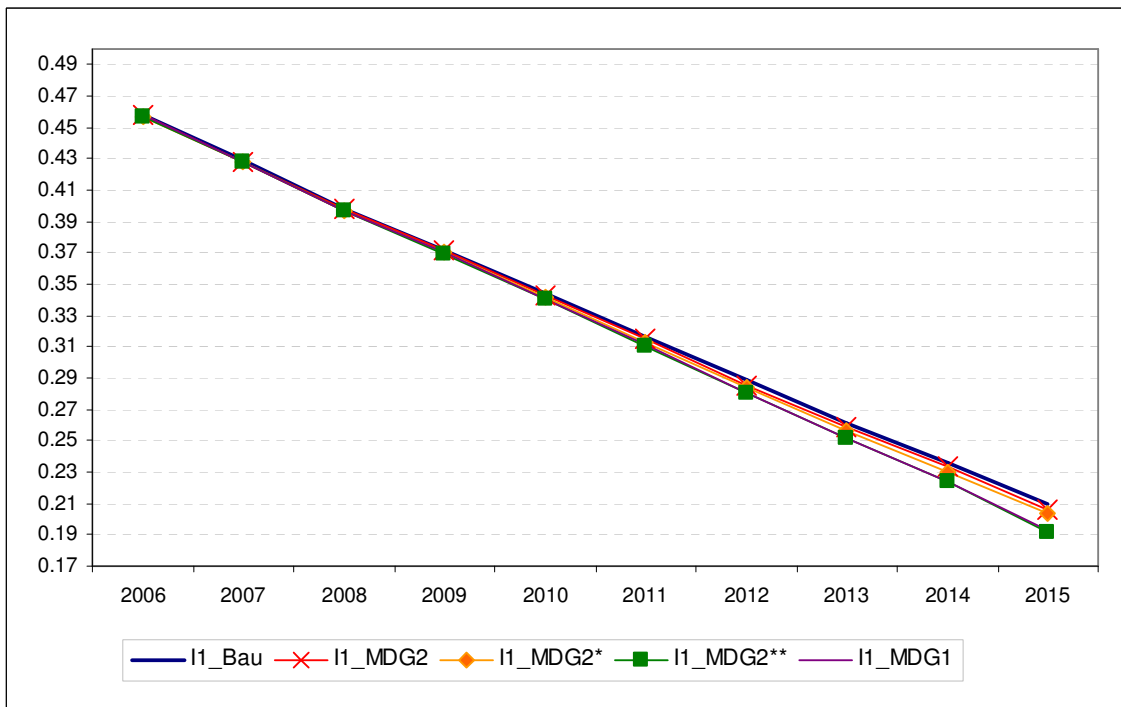


Figure 3: Poverty incidence (I1) (BaU and intervention scenarios)



Little further improvements are attained if we extend the set of arguments in the planner's loss function to include enrollment in secondary education (MDG2*). Actually, the growth rate by year 2015 is as little as 0.06 percentage points above that obtained in the previous scenario.

Under the MDG2** and the MDG1 scenarios, however, we do observe a significant increase with respect to the BaU scenario. In both cases, results reveal an increase of around 1.36 percentage points in aggregate GDP growth, which imply gains close to 0.89 percentage points with respect to the no intervention scenario by year 2015.

The main reason behind this is that under the MDG2** and MDG1 scenarios the planner is concerned about enrollment rates in tertiary education and, according to estimates provided in Appendix 2, productivity gains are substantially larger for this cycle. In fact, the last graph in Appendix 4 attempts to decompose the contributions to growth of each cycle by year 2015, as accounted for by the second, third and fourth term in equation (11.)²¹. This figure reveals that under the MDG2** and MDG1 scenarios growth is boosted, mainly, through an increase in the contribution of tertiary education --i.e. the technology of the tertiary education sector ($B_{H3,t}$) and the proportion of human capital devoted to accumulate more human capital in this cycle ($\mu_{H3,t-1}$)-.

To accomplish this, and given the budget constraint, the planner decides to sacrifice part of the resources devoted to expand educational services in primary and secondary to expand the provision of educational services in tertiary education. As a result, accomplishments in terms of enrollment rates in primary and secondary education are less promising under the MDG** and MDG1 scenarios, whereas the opposite occurs in terms of enrollment rates in tertiary education (please refer to the first three graphs in Appendix 4).

At this point it is worth highlighting that almost no difference can be observed if we compare GDP growth rates under the MDG1 and MDG2** scenarios. This means that, given the restrictions imposed in our model, the gains in terms of increased aggregate

²¹ These terms are: $\mu_{H1,t-1} B_{H1,t} \frac{H_{1,t-1}}{H_{t-1}} + \mu_{H2,t-1} B_{H2,t} \frac{H_{2,t-1}}{H_{t-1}} + \mu_{H3,t-1} B_{H3,t} \frac{H_{3,t-1}}{H_{t-1}}$.

growth do not depend on whether our planner is concerned about **all** enrollment rates *per se*, or concerned about growth (or poverty) itself. These restrictions are basically: (i) productivity gains associated to individuals' educational attainment ($\lambda_{Y_i}, \lambda_{H_i}; i=1,2,3$); (ii) the elasticity of enrollment rates in tertiary education with respect to policy variables related to this educational cycle; (iii) the unit costs of intervention²²; and (iv) the budget constraint²³.

Although results are similar, planner's motivations are different. In the first case (MDG2**) the planner is explicitly concerned about tertiary education (year 2015 enrollment rate in this cycle is an argument in her loss function) and growth is boosted as a by-product. Under the MDG1 scenario, on the other hand, the planner is concerned about growth itself and, acknowledging that productivity gains are larger for the case of tertiary education, she needs to expand enrollment rates at this level as an input.

Finally, a similar situation is observed if we analyze the behavior of the poverty headcount index. In particular, and as revealed in Figure 3, the marginal expansion in aggregate GDP growth gained via intervention under the MDG2 and MDG2* scenarios exhibit almost no effect in terms of poverty reduction with respect to the BaU scenario. A different situation is observed under the MDG1 and MDG2** scenarios, where the additional expansion in aggregate GDP growth gained via intervention provokes a further 1.8% permanent decline in poverty by year 2015: under the BaU scenario poverty incidence falls from 45.7% to 21.0%; under these intervention scenarios poverty falls to a figure close to 19.2%²⁴. Once again, these results are independent of our planner's preferences: given the available policy instruments (human resources and infrastructure in every educational level), their unit costs and the budget constraint, it would be almost

²² According to imputed unit costs (provided by the Ministry of Education), teachers in tertiary education cost twice as much as those in primary or secondary education. Infrastructure (schools), on the other hand, costs three times as much.

²³ The budget constraint is binding under all intervention scenarios.

²⁴ It is important to stress that these results are consistent with a distribution-neutral growth. We decided to present our core results under this assumption since our model does not explain (endogenize) distributional changes due to improved educational attainment (it is an aggregate model that accounts for the effects of the latter on GDP growth). However, and if we follow historic trends regarding the evolution of the Gini coefficient, we could assume an exogenous annual growth of 1.1% for this coefficient. This implies a value of -0.011 for parameter α . Under this setting, poverty incidence would only fall down to 29% under the BaU scenario, thus making a stronger case for further intervention in the educational sector as discussed in this model.

equivalent in terms of its final effect on poverty to ask our planner to close the existing gaps in **all** enrollment rates or to ask her to minimize poverty.

If we believe education indicators are among those targeted as MDGs because the accumulation of human capital is closely related to households' long run income generation potential, then we should also believe that targeting education indicators is important to the extent in which they serve as proxies of future poverty. Our claim is that MDGs can serve as a basic template for the design and evaluation of social policy intervention because, together with the standard poverty measures, they also involve targets for a broader set of variables that, if attended, should grant intervention the ability of transferring the necessary assets to create more egalitarian opportunities of income generation in the future. In fact, and as argued in Yamada and Castro (2007) it should not be difficult to expand social assistance (such as cash or food transfers) while the economy is booming and observe a short run decline in poverty headcount indexes as a result of their combined effects. However, this improvement will only be temporary if social programs have failed to deliver those assets that guarantee that households can attain and secure a larger income generation potential²⁵.

We believe the results presented here lie at the core of this discussion. For policy intervention to be effectively transferring households the ability of securing a larger income generation potential, it should (in terms of our model and when compared to a BaU scenario) maximize the gain in terms of increased long run GDP growth and further permanent reduction in poverty incidence. Following the results discussed above, our simulation exercise has revealed that if we are to target education indicators so as to maximize this gain (given constraints), we need to extend the original set of MDGs in order to foster access to higher educational levels besides primary. In fact, asking our planner to minimize poverty (or maximize growth) using the set of policy variables considered in the model implies engineering intervention in the educational sector so as to transfer households the necessary assets to attain a larger income generation potential in the long run. Which enrollment rates should be considered, *per se*, in order to mimic this

²⁵ As accounted for in Yamada and Castro (2007), the economic recovery experienced between 1991 and 1997 was accompanied by a significant reduction in poverty incidence from 54.2% to 46.4%, while the moderate recession period experienced between 1998 and 2001 wiped away these achievements and poverty was again as high as 54.5% by the end of year 2001.

situation? Results discussed above show that, given restrictions, we also need to target enrollment rates in secondary and tertiary education²⁶.

4 Conclusions

The model developed has provided the necessary inputs to: (i) estimate the gains, in terms of potential increased long-run GDP growth and poverty reduction, that could stem from intervention leading to improvements in enrollment and graduation rates within the education sector; and (ii) discuss which type of educational services are to be considered if we seek improvements in enrollment rates *per se*, vs. improvements in households' income generation potential, being the latter a critical element to be taken into account when designing intervention in the educational sector.

Regarding the first of these two objectives, our simulations reveal that with additional funds which amount, on average, to 1% of GDP each year, expansions in the provision of educational services in all three levels could add, by year 2015, an extra 0.89 and 1.80 percentage points in terms of long-run GDP growth and permanent reduction in poverty incidence, respectively.

Regarding the second objective, our simulations reveal that in order to engineer intervention in the educational sector so as to transfer households the necessary assets to attain a larger income generation potential in the long run, we need to extend the original set of MDG indicators to account for access to higher educational levels besides primary. In fact, the gains (in terms of added GDP growth and poverty reduction) are only marginal if we limit ourselves to the provision of education services related to the primary cycle. On the other hand, if the planner is concerned about enrollment rates in all three cycles, final results in terms of long-run growth and poverty reduction mimic a situation where our planner is concerned about maximizing growth (or minimizing poverty).

²⁶ As already mentioned, one of the key elements behind this result are estimated productivity gains associated to individuals' educational attainment. In fact, results presented here assume that returns to each cycle are linear. It is worth mentioning that these results are confirmed if, following the more recent literature (Bourguignon *et al*, 2005), we consider that labor markets in Latin America exhibit non-linear returns to education. Please refer to Appendix 2 for a detailed explanation of the way in which linear and non-linear returns were estimated.

As discussed in other recent research efforts (Beltrán *et al*, 2004; Castro and Yamada, 2006), and confirmed in this one, a seven percent sustained and broad-based GDP growth rate proves to be an important pre-condition to cut national poverty by half by year 2015. This paper suggests an answer to the question of whether the MDG framework could provide, by itself, an engine to foster such a growth rate. The answer is yes: education, and this assessment has revealed that, in the Peruvian case, it should be understood as education in all three levels.

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Appendix 1: Econometric estimations for the education block - enrollment and graduation rates

Table 1: Probability of enrolling in primary education at normative age (g1entry)

Sample: population (6 year-olds) not enrolled in year 2002; y = 1 if enrolled in primary in year 2003.			
Prob > chi2 = 0 Pseudo R2 = 0.1470 Observations = 562			
Variable	Coefficient	P-value	Year 0 Elasticity ²⁷
Per-capita household expenditure	0.0014735	0.000	0.2346
Teachers per student in primary education times number of schools per student in primary education (provincial level)	1726.944	0.068	0.0689
Access to adequate water services (1 if access; 0 otherwise)	1.266016	0.009	0.0431
Constant	-1.084624	0.039	

Table 2 : Probability of enrolling in secondary education at normative age (grdcontsec)

Sample: 12 year-olds that were enrolled in primary and graduated in year 2002; y = 1 if enrolled in secondary in year 2003.			
Prob > chi2 = 0 Pseudo R2 = 0.048 Observations = 782			
Variable	Coefficient	P-value	Year 0 Elasticity
Teachers per student in secondary education (provincial level)	10.52603	0.300	0.0085
Place of residence (1 if urban; 0 otherwise)	0.8503937	0.0020	0.1369
Household head educational attainment (1 if at least completed primary; 0 otherwise)	0.6902159	0.0300	0.1216
Constant	-0.5673254	0.443	

²⁷ Due to the functional form relating determinants to enrolment rates in all models, any change in the level of a determinant will imply a change in all elasticities comprised in the same model. In fact, and as explained in the main text, all determinants exhibit decreasing marginal returns.

Table 3 : Probability of enrolling in tertiary education at normative age (grdcontsup)

Sample: 17 year-olds that were enrolled in secondary and graduated in year 2002; y = 1 if enrolled in tertiary in year 2003.

Prob > chi2 = 0 Pseudo R2 = 0.1217 Observations = 444			
Variable	Coefficient	P-value	Year 0 Elasticity
Per-capita household expenditure	0.0002639	0.0000	0.8902
Teachers per student in tertiary education times number of schools per student in tertiary education (regional level)	2.917545	0.0080	0.1161
Gender (1 if female; 0 otherwise)	0.7491251	0.0210	
Household head educational attainment (1 if tertiary; 0 otherwise)	0.6089362	0.1000	0.0953
Constant	-4.112534	0.0000	

Table 4 : Probability of graduating within primary or secondary education (grd)

Sample: children between 6 and 16 years of age that in year 2002 were enrolled in some grade in primary or secondary; y = 1 if approved grade.

Prob > chi2 = 0 Pseudo R2 = 0.0450 Observations = 24,970			
Variable	Coefficient	P-value	Year 0 Elasticity
Child mortality incidence (regional level)	-0.0106746	0.000	-0.0206
Wage gap: completed primary vs. no education (regional level)	0.4393046	0.026	0.0221
Per-capita household expenditure	0.0010663	0.200	0.0213
Teachers per student in primary education times number of schools per student in primary education (provincial level)	447.3088	0.027	0.0085
Access to adequate water services (1 if access; 0 otherwise)	0.355461	0.008	0.0075
Access to adequate sanitation services (1 if access; 0 otherwise)	0.3142476	0.042	0.0054
Constant	2.290515	0.000	

Appendix 2: Econometric estimations for the Macro block

1. Estimating the stock of human capital when returns matter

Typically, the stock of human capital is computed considering the number of individuals corrected by the number of completed years of schooling. In this way, a person with completed primary will contribute to the stock of human capital six times as much as a person with no education (see, for example, Barro and Lee (2000)).

For the purpose of our analysis, we will instead consider the returns (in terms of increased earnings in the labor market) associated to each educational level. To estimate these returns, we relied on a Mincerian earnings equation and data contained in the ENAHO 2004 household survey. The specific form considered for the earnings equation depended on whether we imposed the assumption of linearity for returns or allowed these to be non-linear, in the sense that they depend on the educational level considered. Thus, for linear returns we estimated:

$$\ln Y_i = \alpha + \beta E_i + X_i' \theta + \varepsilon_i \quad (2.1)$$

where $\ln Y_i$ refers to the logarithm of hourly earnings for individual “i”, E_i refers to schooling years for individual “i”, and X_i is a vector including relevant controls such as experience, gender, marital status, etc. For a given set of parameter estimates $(\hat{\alpha}, \hat{\beta}, \hat{\theta})$, hourly earnings were predicted following: $w_0 = \exp(\hat{\alpha} + \bar{X}'\hat{\theta})$ for no education; and $w_j = \exp(\hat{\alpha} + \hat{\beta}\bar{E}_j + \bar{X}'\hat{\theta})$ for educational level “j”, where \bar{E}_j is the average number of schooling years for educational level “j” encountered in the sample.

For the case of non-linear returns we estimated:

$$\ln Y_i = \alpha + \sum_{j=1}^6 \beta_j D_j E_i + X_i' \theta + \mu_i \quad (2.2)$$

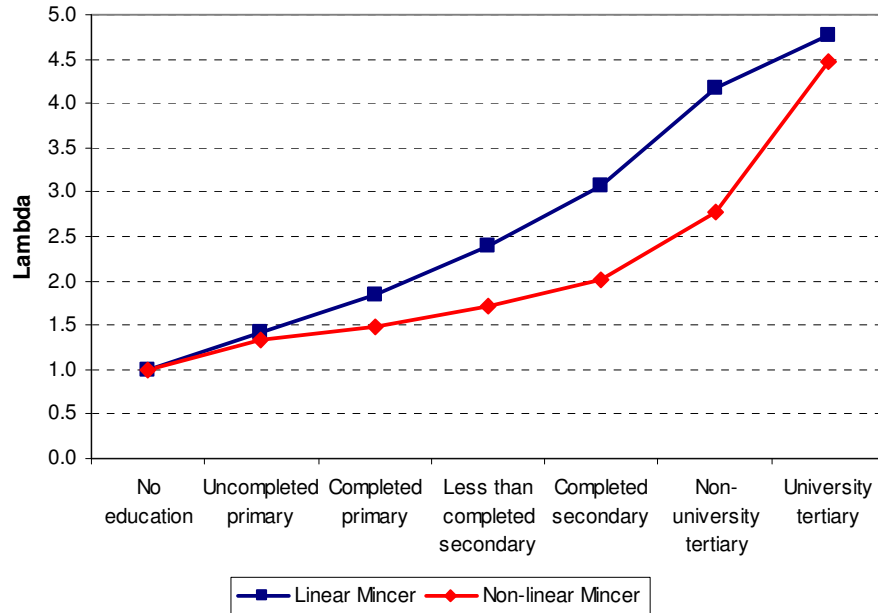
where D_j is a dummy variable that adopts the value of 1 if “j” (less than completed primary, primary, less than completed secondary, secondary, less than completed tertiary or tertiary) is the last level of education attained by individual “i”. Clearly, this specification allows for a different value of β depending on the educational cycle considered. Hourly earnings were predicted in a similar fashion as in the case of linear returns: $w_0 = \exp(\hat{\alpha} + \bar{X}'\hat{\theta})$ for no education; and $w_j = \exp(\hat{\alpha} + \hat{\beta}_j D_j \bar{E}_j + \bar{X}'\hat{\theta})$ for educational level “j”.

Based on these results, the values of λ_{Y_i} and λ_{H_i} $i = 1, 2, 3$ used to estimate the stock of human capital were computed following: $\lambda_j = w_j / w_0$. Results for the linear and non-linear case are reported in the table below. Simulation results presented in the main text correspond to the linear case.

Table 1: Productivity associated to each educational level

Educational level		Linear returns	Non-linear returns
No education	λ_{Y0}	1.0	1.0
Less than completed primary	λ_{H1}	1.4	1.3
Completed primary	λ_{Y1}	1.8	1.5
Less than completed secondary	λ_{H2}	2.4	1.7
Completed secondary	λ_{Y2}	3.1	2.0
Less than completed tertiary	λ_{H3}	4.2	2.8
Completed tertiary	λ_{Y3}	4.8	4.5

Graph 1: Linear and non-linear returns to education



2. Growth accounting exercise

In order to provide an estimate for the rate of growth of technology ($\bar{\gamma}_A$), we relied on an empirical version of (1.). Formally:

$$\gamma_{Y,t} = \beta\gamma_{K,t} + (1-\beta)\gamma_{HY,t} + \varepsilon_t$$

where the residual (ε_t) accounts for the rate of growth of technology. Data for aggregate GDP and the stock of physical capital were obtained from the statistical series provided by the Peruvian Central Bank for the period 1960-2000. A time series for the stock of human capital devoted to production, on the other hand, was built using the estimates of the number of people in the labor force with each educational level provided in Carranza *et al.* (2003), and our own estimates of the productivity of each type of human capital (λ_{Yi}) as described above. Finally, growth rates for each of these variables were computed using the trend component of each series estimated via a Hodrick-Prescott filter.

The table below presents our results for the estimation of parameter β and the historical value of γ_A used in the simulation exercise.

Table 2: Results of the growth accounting exercise

Estimation of parameter beta

R-squared = 0.45		
Variable	Coefficient	P-value
$\gamma_{K,t}$	0.41	0.00
$\gamma_{HY,t}$	0.59	0.00

Imputed growth rates for the simulation exercise

Variable	Growth rate
Residual (A)	1.55%

Appendix 3: Variable and parameter list

Description	Variable / Parameter	Ref. equation
1. Macro Block		
Exogenous variables and parameters used by this block:		
Productivity of individuals in the labor force.	$\lambda_{Yi}; i = 0, 1, 2, 3$	(12.)
Productivity of individuals enrolled in the education sector.	$\lambda_{Hi}; i = 1, 2, 3$	(12.)
Number of years (grades) in each educational cycle.	nprim, nsec, nsup	(12.)
Depreciation rate.	δ	(11.)
Ratio of six-year olds with respect to the total stock of human capital.	E6/H	(11.)
Ratio of each type of human capital with respect to the total stock of human capital.	$H_i/H; i = 1, 2, 3.$	(11.)
Ratio of six-year olds with respect to the number of individuals enrolled in primary education.	E6/H _{H1}	(12.)
Ratio of individuals enrolled in primary education with respect to the number of individual enrolled in secondary education.	H _{H1} /H _{H2}	(12.)
Ratio of individuals enrolled in secondary education with respect to the number of individual enrolled in tertiary education.	H _{H2} /H _{H3}	(12.)
Inter-temporal discount rate.	δ	(13.)
Risk aversion parameters.	$\theta_1, \theta_2, \theta_3$	(13.)
Technology growth rate.	$\bar{\gamma}_A$	-.-
Endogenous variables used by this block:		
Last period's probability of enrolling in primary education at normative age (6 year-olds).	glentry _{t-1}	(12.)
Last period's probability of graduating within the primary education cycle.	grdprim _{t-1}	(12.)
Last period's probability of enrolling in secondary education, given that the primary cycle has been completed.	grdcont sec _{t-1}	(12.)
Last period's probability of graduating within the secondary education cycle.	grd sec _{t-1}	(12.)
Last period's probability of enrolling in tertiary education, given that the secondary cycle has been completed.	grdcont sup _{t-1}	(12.)
Last period's probability of graduating within the tertiary education cycle.	grd sup _{t-1}	(12.)
Endogenous variables provided by this block:		
Period t human capital growth rate.	$\gamma_{H,t}$	(11.)
Technology of each educational sector.	$B_{Hi,t}; i = 1, 2, 3$	(12.)
Proportion of human capital devoted to further human capital accumulation in each cycle.	$\mu_{Hi,t}; i = 1, 2, 3$	(13.)
Period t GDP growth rate.	$\gamma_{Y,t}$	-.-

2. Education Block		
Exogenous variables and parameters used by this block:		
Parameters governing the impact of policy variable eduqual and mean per-capita household expenditure on enrollment and graduation rates	Ψ	(15.)
Population growth rate	$\bar{\gamma}_N$.-
Endogenous variables used by this block:		
Period t teachers and schools per student in each educational cycle	$\text{eduqual}_{i,t}; i = 1, 2, 3$	(15.)
Period t GDP growth rate.	$\gamma_{Y,t}$.-
Period t rate of growth of per-capita GDP	$\gamma_{y,t}$	(15.)
Endogenous variables provided by this block:		
Period t probability of enrolling in primary education at normative age (6 year-olds).	glentry_t	(15.)
Period t probability of graduating within the primary education cycle.	grdprim_t	(15.)
Period t probability of enrolling in secondary education, given that the primary cycle has been completed.	grdcont sec_t	(15.)
Period t probability of graduating within the secondary education cycle.	grd sec_t	(15.)
Period t probability of enrolling in tertiary education, given that the secondary cycle has been completed.	grdcont sup_t	(15.)
Period t probability of graduating within the tertiary education cycle.	grd sup_t	(15.)
3. Poverty Block		
Exogenous variables and parameters used by this block:		
Percentage change in the Gini coefficient	α	(17.)
Poverty line	ycrit	(18.)
Total population	Pop	(18.)
Endogenous variables used by this block:		
Period t rate of growth of per-capita GDP	$\gamma_{y,t}$	(17.)
Endogenous variables provided by this block:		
Period t poverty incidence	$I_{1,t}$	(18.)
4. Costing and resource constraint block		
Exogenous variables and parameters used by this block:		
Unit costs for teachers and schools in each educational level	$\text{UCTea}_i; \text{UCSch}_i; i = 1, 2, 3$	(19.)
Percent of annual GDP available for investment in educational services	λ	(20.)
Endogenous variables used by this block:		
Period t GDP growth rate.	$\gamma_{Y,t}$	(20.)
Endogenous variables provided by this block:		
Period t teachers and schools per student in each educational cycle.	$\text{eduqual}_{i,t}; i = 1, 2, 3$.-
Period t total cost of intervention.	TC_t	(19.) (20.)

Appendix 4: Enrollment rates under the five scenarios

