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What Changes Gini Coefficients of Education? On the dynamic interaction between education, its distribution and growth

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What Changes Gini Coefficients of Education?
On the dynamic interaction between education, its distribution and growth

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Abstract.
We are interested in the relation between Gini coefficients of education, educational variables, and growth. We specify a system of 14 difference equations with lagged dependent variables in education variables, as well as a growth regression, auxiliary equations for savings and investment ratios, and the growth of the labour force and estimate all of them simultaneously. Having a closed system of 18 equations we run simulations, which show that for the panel average enrolment in tertiary education will go beyond 90%, and therefore drive transitional growth rates and average years of schooling to high levels and reduce inequality over time. This will be achieved by reductions in gender gaps, higher enrolment rates, and lower dropout rates, lower pupil-teacher ratios and higher public expenditure on education. There are no simple one-way causalities. Policies enhancing savings ratios and enrolment in tertiary education have the largest effects through the whole system.

Keywords: Gini coefficients, education, growth, simultaneous equation system.
JEL-code: E24, H52, O11, 15, 40.

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Summary
We are interested in the relation between Gini coefficients of education – as provided by Thomas et al. (2000a, b) and Castelló and Doménech (2002) – as well as average years of schooling, other educational variables, and growth.

We specify a system of 14 difference equations with lagged dependent variables in these education variables and estimate them simultaneously with a GMM-HAC generalization of non-linear 3SLS. Average years of schooling and Gini coefficients of education are changed by enrolment in primary, secondary and tertiary education and the changes in illiteracy. The enrolment rates and the success of the education depend themselves directly or indirectly on public expenditure on education, pupil-teacher ratios, dropout rates and gender gaps for illiteracy and enrolments. As savings ratios and GDP per capita growth rates are exogenous in this system, we specify a growth regression, and auxiliary equations for savings and investment ratios and the growth of the labour force. We estimate them separately as single equations using fixed effects estimators or the difference version of the system GMM estimator, and also as a simultaneous system of equations separately from and jointly with the fourteen education equations including each macro-equation as system GMM in the first difference variant. Having a closed system of 18 equations we can run simulations (after construction of initial values) in order to see the short-run, transitional and long-run trends. Simulations show that for the panel average enrolment in tertiary education will go beyond 90% and therefore drive transitional growth rates and average years of schooling to high levels and reduce inequality over time. This will be achieved by reductions in gender gaps, higher enrolment rates, and lower drop out rates, lower pupil teacher ratios and higher public expenditure on education. There are no simple one-way causalities. GDP per capita (growth) and savings ratios on the one hand and education variables on the other drive each other mutually. The education system produces tertiary education which improves growth. Growth encourages primary and secondary enrolment, investment and savings. Savings encourage public expenditure on education, which reduce primary pupil-teacher ratios and dropout rates. This latter effect improves the pass through to secondary and tertiary education, which improve growth again. Causality among educational variables also goes through many channels of indirect effects. As long as tertiary education can be improved accumulation and growth go together with a reduction of inequality in Gini coefficients of education and gender gaps. When growth of tertiary education slows down, transitional growth rates fall and inequality remains low. Policies enhancing the savings ratio improve primary, secondary and tertiary education and growth; they reduce Gini coefficients of education and gender gaps, with the exception of that for secondary enrolments. Policies modelled as a permanent shock to enrolment in tertiary education, enhance growth and savings, and from there improve the whole education system. Policies enhancing public expenditure on education per pupil as a share of GDP per capita without complementary measures have very limited effects on the panel average, because primary and secondary enrolments are already quite high when the policies start in 2015.

1. Introduction

Garcia-Penalosa (1995), Galor and Tsiddon (1997), Rehme (2007) and Viaene and Zilcha (2009) show theoretically that income inequality may be positively or negatively related to growth. The evidence has favoured the negative relation with some exceptions though (Ehrhart 2009, Galor 2009). In particular, educational inequality was seen to contribute to income inequality, which in turn has a negative impact on growth (Park 1998). However, Birdsall and Londono (1997) and Castello and Doménech (2002) show that income and education inequality may have different effects in growth regressions when they are included both. Birdsall and Londono (1997) find a significantly negative relation between human capital dispersion and growth using the standard deviation of human capital. Lopez et al. (1998) use the coefficient of variation and the standard deviation and find a significantly negative impact in their production function model with asset distribution; they also find an insignificantly positive impact of the coefficient of variation in the growth equation. In recent papers Thomas et al. (2000a,b) and Castelló and Doménech (2002) have provided data sets with Gini coefficients for years of education in the population at age above 15 calculated from the data in Barro and Lee (1997, 2001) for five-year intervals.[1] These data are highly relevant because Castello and Doménech (2002) show that growth is negatively related to inequality in education in the initial period in a cross-section regression. Reducing the inequality could therefore enhance future growth rates if the result could be generalized to a dynamic setting. However, Park (2006) finds a positive relation between dispersion and growth. There is no clear evidence for educational inequality so far. As the measures of dispersion capture dispersion by just one number they may not only reveal but possibly also hide some relevant information.

The crucial point in the model used by Garcia-Penalosa (1995) is whether human capital increases or decreases with income inequality, which is partly driven by educational inequality. Thomas et al. (2000b) regress the Gini coefficients on average years of schooling and the gender gap separately, but add no other variables. This leaves some risk for an omitted variable bias. Other empirical papers mentioned so far use inequality measures as exogenous variables. We make them endogenous because we want to get to know what changes them over time. We add many other variables and set up a dynamic system of interdependent difference equations in order to investigate, which variables change the Gini coefficients of education, average years of schooling and have an impact on growth either

[1] In Castelló and Doménech (2002) the last interval is one of four years: 1995, 1999. The new data from Barro and Lee (2010) have not yet been used to make Gini coefficients of education.

directly or indirectly. By implication, in this paper the focus is not on the indices of inequalities alone but rather on the forces driving them and the way of endogenous interactions of the changes of the variables that determine years of schooling, Gini coefficients of education and growth, including the issues of reversed and two-way causality between education and growth. This procedure provides more information in regard to the question how to change the (in)equality and to reap the potential benefits. In section 2 we explain the intuition behind our idea setting up an empirical simultaneous equation model. In section 3 we describe the data and the implications for the econometric methods. In section 4 we present estimation results. In section 5 simulations underpin the plausibility of our estimation results. Counterfactual policy simulations are presented in section 6. Section 7 summarizes and concludes.

See Scheme 1 (in appendix)

2. The model

Average and distribution of education

Scheme 1 shows a sketch of the Lorenz curve from which Gini coefficients can be calculated. We use it as a starting point for the explanation of the basic intuition in setting up the empirical framework. The first part of the Lorenz curve captures illiteracy in the population under the simplifying assumption that illiteracy stems only from not going to school. The other parts are completed or incomplete primary, secondary and tertiary schooling. In this section we explain our thoughts regarding the question how illiteracy and schooling change the Gini values and how they are changed themselves. This leads us to the specification of a dynamic system of equations for the development of education and the related macro economy.

A first step in changing the Gini coefficients would be enrolment in primary schooling, *sepri*, secondary schooling, *sesec*, and tertiary schooling, *seter*, which would change the percentages of schooling captured in the Lorenz curve of Scheme 1. Starting from some level of illiteracy, *ill*, and the Gini coefficient of education, denoted as *gh15* for the data of Castelló and Doménech (2002), enrolments would result in a new value after some years. What the effects are may depend on the initial situation of all regressors. If for example everybody is illiterate additional primary schooling will increase inequality, but if almost everybody is literate additional primary schooling will increase equality. By implication, somewhere half way to complete primary schooling there must be a point where additional primary schooling has no effect on the (in-)equality. Similarly, if everybody had secondary schooling completed and nobody had any tertiary education, enrolment in tertiary education would increase inequality, but once sufficiently many have tertiary education increases in enrolment to tertiary education would increase equality, and again somewhere in the middle there would be no effect.[2] Therefore we also employ the interaction variables of the enrolments with the neighbouring compartments, with average years of schooling, *ays*, and its own squared value. This is summarized in equation (1) dropping those, which turned out to be insignificant.[3]

$$gh15 = c_{11}+c_{12}gh15(-5) + c_{13}sesec(-5) + c_{14}sepri(-5)sesec(-5) + c_{15}sesec(-5)seter(-5) + c_{16}sesec(-5)ays(-5) + c_{17}seter(-5)ays(-5) + c_{18}ill(-5)^2 + c_{19}sepri(-5)^2 \quad (1)$$

Of course, not only the distribution of education may be important but also its average level in terms of years of schooling. This too can be changed by enrolments as captured by equation (2).

$$\log(ays) = c_{21} + c_{22}\log(ays(-5)) + c_{23}sepri(-5) + c_{24}sesec(-5) + c_{25}seter(-5) \quad (2)$$

The thorny road away from illiteracy: enrolment, gender gaps, drop outs, teachers and money

Illiteracy depends, in equation (3), on changing enrolment in primary schooling and the lag of the share of illiteracy in the population. Illiteracy is also enhanced by forgetting, but dropout rates with lags up to 15 years or their five-year differences do not capture this. We assume that forgetting develops parallel with illiteracy and is included in the lagged dependent variable.

$$ill - ill(-5) = c_{31} + c_{32}ill(-5) + c_{33}ill(-10) + c_{34}(sepri(-5)-sepri(-10)) \quad (3)$$

The gender gap in illiteracy, *gap*, may be reduced, according to equation (4), by reducing that of primary schooling enrolment, *gapsepri*. The drop-out rate from primary schooling, *drop*, though may increase it. Enrolment in primary schooling, *sepri*, is the most natural step to remove the literacy gap and therefore it is included here.

$$gap - gap(-5) = c_{41} + c_{42}gap(-5) + c_{43}gapsepri(-5) + c_{44}drop(-5) + c_{45}sepri(-5) \quad (4)$$

Enrolment in primary schooling is a major step in increasing the average of education, reducing illiteracy and its gender gap. Enrolment in primary schooling is enhanced, in equation (5), under higher five-year growth rates of the GDP per capita, *gdp*, which probably

[2] Knight and Sabot (1983) call this effect of first increasing and then decreasing variance or inequality the 'composition effect'. Rehme (2007) provides a clear theoretical formulation for this and other aspects and a good discussion of the related theoretical and empirical issues. Fig.1 in Park (2006) gives a flavor of the phenomenon empirically. Carnoy (2010) discusses the link with income distribution.

[3] Making joint variables from all possible combinations of two, three, four and five variables would lead to an extreme number of regressors. Practical use of the model may require an updated estimate as the coefficients of the interaction variables and by implication all other coefficients may be dependent on the situation of the countries.

make people more optimistic about the affordability and profitability of education, thus capturing the reversed causality argument of Bils and Klenow (2000) in regard to education and growth.[4] Public expenditure on education has turned out not to be significant here.

$$\text{sepri} = c_{51} + c_{52}\text{sepri}(-5) + c_{53}(\log(\text{gdp})-\log(\text{gdp}(-5))) \quad (5)$$

Enrolments in primary schooling have their own gender gap, *gapsepri*, a reduction of which can help reducing the gap in literacy as indicated in equation (4). The gap in primary enrolment is reduced, in equation (6), through enrolments in primary schooling. If the gap in illiteracy is larger, urgency is perhaps felt more and the gap in primary enrolments is reduced. Money variables, savings ratios or public expenditure on education, are again not significant.

$$\text{gapsepri} = c_{61} + c_{62}\text{gapsepri}(-5) + c_{63}\text{sepri} + c_{64}\text{gap} \quad (6)$$

The dropout rate depends on its own lag and on public expenditure spent per pupil in primary schooling relative to the GDP per capita, *shpupp*, as shown in equation (7). It is possible to reduce it through a lower pupil teacher ratio in primary schooling to an extent that is stronger the higher the drop out rate. This is captured through an interaction variable of a lag in the drop-out rate and the pupil-teacher ratio, *teapri*. We use an asymmetric lag here, because it takes time to recognize the drop out rate and then you need time and experienced teachers to reduce drop out rates successfully. The pupil/teacher ratio has been subject of much controversy. Our finding that it matters as an interaction variable with dropout rates does not appear in the literature so far to the best of our knowledge.[5]

$$\log(1 + \text{drop}) = $$
$$c_{71} + c_{72}\log(1 + \text{drop}(-5)) + c_{73}\log(\text{shpupp}(-5)) + c_{74}\,\text{shpupp}(-5) + c_{75}\log(1 + \text{drop}(-10))\log(\text{teapri}(-5)) \quad (7)$$

The pupil/teacher ratio is explained next. If public expenditure on education per pupil in primary schooling as a share of GDP per capita is high enough, it is reducing the pupil/teacher ratio in a non-linear way in equation (8). Money probably is first spent on elementary things like building and chairs and only at higher amounts the money goes into the reduction of pupil/teacher ratios. Moreover, a higher product of enrolment rates and lagged pupil/teacher ratios may lead to a reduction of the pupil/teacher ratio through institutional reactions of politicians. But a high product of drop-out rates and pupil/teacher ratios may go either way, because it signals a stronger requirement for teachers but also may be interpreted as a signal

[4] Reversed causality will be reconciled with the human-capital-growth link below in the growth regression.
[5] Similarly, we would expect micro-studies to find an effect of reduced class size only conditional on teachers choosing different methods.

of low ability of teachers for dealing with drop out rates. Dropout rates and enrolments signal some urgency, the effect of which depends though on the existing pupil/teacher ratio and on the expected achievements. In times of high growth of the GDP per capita more pupils leave school and enter the labour market but the same holds for teachers leaving the expected sign an open issue. Moreover, there are more financial means of families available for schooling when growth is higher.

$$\log(teapri) = c_{81} + c_{82}\log(teapri(-5)) + c_{83}\log(shpupp(-5)) + c_{84}\log(shpupp(-5))^2 + c_{85}sepri*\log(teapri(-5)) + c_{86}\log(1+drop(-5))\log(teapri(-5)) + c_{87}(\log(gdp(-1))-\log(gdp(-2))) \quad (8)$$

The thorny road away from illiteracy as described by equations (3)-(9) is completed with equation (9) for public expenditure per pupil on primary education as a share of GDP per capita. It is highly self-perpetuating as it depends on two five-year lags. But it gets higher when countries get richer as expressed in terms of a higher savings ratio, *savgni*, probably because it is itself a form of savings or investment in human capital, although the national accounts treat it as government consumption. Higher savings ratios allow for higher taxation and spending on schooling.

$$shpupp = c_{91} + c_{92}shpupp(-5) + c_{93}shpupp(-10) + c_{94}savgni(-5) \quad (9)$$

Secondary and tertiary schooling: Enrolment, gender gaps, teachers and money again

Enrolment in secondary schooling is a precondition to achieve partial or completed secondary schooling and for going into tertiary education. Its achievement formulated in equation (10) requires earlier enrolment in primary schooling and is diminished by drop outs from primary schooling in the same year. The higher the five year growth rate of the GDP per capita the more profitable schooling is, leading to more enrolments in secondary schooling (Schultz 1993) and again captures the reversed causality argument (Bils and Klenow 2000). We allow for the original causality below in the growth regression.

$$sesec = c_{101}+c_{102}sesec(-5)+ c_{103}sepri(-5) + c_{104}drop + c_{105}sesec(-5))^2 + c_{106}(\log(gdp) - \log(gdp(-5))) \quad (10)$$

The gap in secondary schooling enrolments, *gapsesec*, captured in equation (11), is partly a consequence of the gap in primary schooling enrolment. Public expenditure on secondary education per pupil as a percentage of GDP per capita, *shpups*, can work in both directions, depending on money being spent more on boys or on girls. Secondary school enrolment, if boys go first, may first increase and then decrease the gap and therefore is captured as a linear-quadratic variable.

$$\text{gapsesec} = c_{111}+c_{112}\text{gapsesec}(-5)+c_{113}\text{gapsepri}(-5) + c_{114}\log(\text{shpups}(-10)) +c_{115}\text{sesec} + c_{116}\text{sesec}^2 \tag{11}$$

The pupil/teacher ratio in secondary schooling, *teasec*, may be increased, according to equation (12), by more enrolment through a mere numerator effect or it may decrease if accompanied by other policy measures. Public expenditure on secondary education turned out to be significant in its inverted form, because expenditure affects the number of teachers, which is in the denominator of the dependent variable.[6]

$$\log(\text{teasec}) = c_{121} + c_{122}\log(\text{teasec}(-5)) + c_{123}\text{sesec} +c_{124}(1/\text{shpups}) \tag{12}$$

Equation (13) explains public expenditures per pupil in secondary education as a share of GDP per capita through enrolments requiring money, again in a non-linear way, because of a decreasing effect. It gets higher when countries get richer as expressed in terms of a higher savings ratio ten years later, *savgni(-10)*, probably because it is itself a form of savings or investment in human capital. Higher savings ratios allow for higher taxation and spending on schooling. Once it takes effect, it does so very strongly, as indicated by the quadratic effect. It is highly self-perpetuating as it depends on its own five-year lag.

$$\text{shpups} = c_{131} + c_{132}\text{shpups}(-5) + c_{133}\text{sesec} + c_{134}\text{sesec}^2 + c_{135}\text{savgni}(-10)^2 \tag{13}$$

Finally, enrolment in tertiary schooling, *seter*, determines the upper part of the Lorenz curve. In equation (14) they depend on enrolment in secondary schooling earlier, besides there own lagged value in cubic form. When countries get richer, again expressed by a higher savings ratio, they have a higher enrolment in tertiary education. A higher pupil/teacher ratio in secondary schooling has a negative impact, which is larger the larger the enrolment in secondary schooling was.[7] Again, the pupil/teacher ratio enters as an interaction variable and public expenditures on education have no impact on enrolment.

$$\text{seter} = c_{141}+c_{142}\text{sesec}(-5)+ c_{143}\text{savgni}+c_{144}\text{seter}(-5) + c_{145}\text{seter}(-5)^2 + c_{146}\text{seter}(-5)^3 + c_{147}\log(\text{teasec}(-5)\log(\text{sesec}(-5)) \tag{14}$$

The education system of equations (1)-(14) has some important properties. Gini coefficients of education and average years of schooling depend mainly on enrolments in the three levels of education. However, public expenditures, pupil/teacher ratios and dropout rates have an impact in regard to the speed of the stream from one level to the next, as well as into and out

[6] Moreover, the quadratic version of equation (8) for primary schooling did not yield significant results.
[7] This result can be related to the finding of Chowdry et al. (2010) that students from poorer backgrounds are much less likely to participate in tertiary education because of lower achievements in secondary schooling rather than due to causes in the beginning of tertiary education.

of illiteracy and gender gaps. Pupil/teacher ratios matter mainly in the form of interaction variables. For money and enrolment variables there are several economically non-linear relations for good economic reasons. Besides equations (1) and (2), in equations (3), (4) and (6) - for illiteracy and the gaps for literacy and primary enrolments - no macro or public expenditure variable plays a role. They are probably the most culturally determined variables. The most crucial step in order to get some change in education is primary enrolment, which is driven by the growth rate of GDP per capita and its own lag.

Education and growth

The growth equation (15) contains the standard growth variables gross fixed capital formation as share of GDP, growth of the labour force, *lf*, in quadratic form,[8] and a lagged dependent variable. In addition past tertiary school enrolment plays a role.[9] Secondary education is not significant once a time trend is introduced, which reflects the idea of exogenous technical change.[10] This equation captures the effects of the schooling system on growth through tertiary enrolments.[11]

$$\log(gdp) = c_{151}+c_{152}\log(gdp(-1))+ c_{153}\log(gfcfgdp) + c_{154}d(\log(lf))^2 + c_{155}\,seter(-5) + c_{156}trend \qquad (15)$$

In order to have a system that is complete in the sense that it has only endogenous variables we need equations for savings, gross fixed capital formation and labour force growth. For savings and investment we make very simple assumptions. As in stochastic dynamic general equilibrium models we assume that they depend on their own past values and add the lagged GDP per capita growth rate in equations (16) and (17).

$$savgni = c_{161} + c_{162}savgni(-1) + c_{163}(\log(gdp)-\log(gdp(-1))) + c_{164}savgni(-2) + c_{165}savgni(-3) \qquad (16)$$

$$gfcfgdp = c_{171} + c_{172}gfcfgdp(-1) + c_{173}(\log(gdp(-1))-\log(gdp(-2))) \qquad (17)$$

[8] In a Solow growth model the labour variable appears in a linear form only in case of a Cobb-Douglas function and in case of linearizations.
[9] Interesting alternative variables could be the cognitive skills of Hanushek and Woessmann (2010) and the number of researchers in R&D. However, both variables cover much less countries than our sample. Therefore it cannot be tested whether or not they work as well for our dynamic panel data model as it does in their cross-section approach.
[10] An interaction term of the trend and tertiary education turned out to be insignificant. The potential impact of human capital on technical change in the long run is therefore not captured by this model. Cross-section approaches to growth cannot include a time trend and therefore get different coefficients for the other variables.
[11] A simultaneous equation system for the interaction between three macro-level variables - human and physical capital and growth - can be found in Oketch (2006).

Labour force growth is known to depend on education via past population growth.[12] Also, if more people stay in school this should reduce labour force growth. In many countries a crucial point is whether pupils leave school after primary schooling and enter the labour force, or go to secondary schooling. In equation (18) we tried to capture these arguments by including the gender gap in illiteracy. This variable is the only one that is robust in regard to both variants of the system GMM estimation method discussed below. In the time-series dimension the gender gap enhances the labour force growth because of an earlier labour market access, and in the longer run as well as in the cross-section dimension also through higher fertility. However, simulations results are implausible because of too early zero growth in the labour force. The cross-section effect seemingly dominates the time-series effect in the estimated coefficients. Therefore we leave only the income variable in this regression.

$$d(\log(lf)) = c_{181} + c_{182}\, d(\log(lf(-1))) + c_{183} d(\log(lf(-2))) + c_{184}(\log(gdp(-2))) \tag{18}$$

The education system, consisting of equations (1) - (14), leads to tertiary enrolments. Illiteracy and gender gaps indicate some of the losses on this way, partly driven by dropout rates and pupil/teacher ratios. Gini coefficients of education and gender gaps indicate the distribution. Average years of schooling are a result that does not feed back into the system because the arguments that drive them, mainly enrolments, have a stronger role. Equations (1)-(4), (6), and (11) do not feed back into the system. The major impact of education on growth is the tertiary education in the growth regression. (16) - (18) depend indirectly on the education system (1) - (14) via the growth rate. Savings then have an impact, via equations (9), (13), (14) on public expenditure for primary and secondary education and tertiary enrolment. The growth rate affects equations (5), (8) and (10) for primary and secondary schooling enrolment and the pupil/teacher ratio in primary education. Equations (8), (9), (12), (13) for pupil/teacher ratios and public expenditure on education are policy reaction functions. Public expenditure on education has an impact on dropout rates and pupil/teacher ratios, which in turn determine how many pupil go up or down towards tertiary education or towards illiteracy and gender gaps.

[12] This is explained in greater detail in Becker et al. (1990), Galor and Weil (1999), and Galor (2009). Of course, there are also more traditional effects of human capital like the effect of literacy on the understanding of the working of anti-conception means.

3. Data and econometric method

The data for the Gini coefficients range from 1960 to 1990 in the data of Thomas et al. (2000b) and 1960 to 1999 in the data by Castelló and Doménech (2002). As data are available for five year intervals this gives us a maximum of eight observations, because the last interval has only four years in the larger data set. As this number of observations is too low for a time series analysis for single countries we use pooled data. The data set of Thomas et al. has Gini coefficients for 85 countries and that of Castelló and Doménech has 108 countries. The major difference in the way of constructing the indices is in the number of categories of education used. Barro and Lee (2001) and Thomas et al. (2000b) use seven classes: illiteracy, partial and completed primary, partial and completed secondary, and partial and completed tertiary education. Castelló and Doménech (2002) put together the partial and completed education in each class. 79 countries are present in both data sets with seven observations for the five year intervals during the period 1960-1990. The correlation between the two sets of Gini coefficients – denoting the set of Thomas, Wang, Fan by 'egini' and that of Castelló and Doménech by 'gh15' in a fixed effects regression – is quite strong:

$$\underset{}{Egini} = \underset{(50.2)}{0.12} + \underset{(100.7)}{0.92gh15} - \underset{(-8.82)}{0.057gh15^2}$$

t-values are put in parentheses. If the quadratic term is dropped the linear coefficient is 0.86, and the adjusted R-squared is 0.999 in both cases. By implication, adding the highly significant quadratic term brings the linear coefficient closer to unity.

Data for the policy and control variables are taken either from the World Development Indicators or from Barro and Lee (1997, 2001) (see Appendix 1 for the means, standard deviations, countries and years of availability). [13] The sample is unbalanced, which means that in the time dimension the data availability is not the same for all countries.

For each variable we set up an equation containing its own lag in the previous section. Then we add variables, which should explain it either in terms of levels or changes. As this implies that endogenous, left-hand variables of one equation appear as right-hand variables of other equations, we may have an endogeneity problem whenever the left-hand side variable appears without lag on the right-hand side provided there is contemporaneous correlation. This has to be taken into account when estimating equations simultaneously.

In the recent past progress in econometric methods has been made mainly in the sphere of single equation estimation. For dynamic panel data and models with fixed effects this is

[13] In the last phase of this research Barro and Lee (2010) has appeared. This does not include Gini coefficients of education.

mainly associated with the names of Arellano and Bover (1995). The advantage of their method is that it captures some heterogeneity via fixed effects. Its dis-advantage is that unlike simultaneous equation methods it cannot capture the contemporaneous correlation of residuals of several economic equations as it is a single equation method. On the other hand the simultaneous equation methods do not capture and discuss fixed effects. Both methods can deal with endogeneity. A combination of these methods has not yet been investigated by econometricians. A scheme for the choice of methods summarizes this in Appendix 2. In this paper we will use the approaches first separately estimating the education equations as a simultaneous equation system and the macroeconomic equations single wise. In a second approach we will estimate the education part and the macro part each as a system but separately so. In a third approach we put them together into one simultaneous equation system.

Fixed effects methods have become the standard in growth regressions. Therefore we use fixed effects methods for the macroeconomic equations (15)-(18). Their time dimension is about 4, 30, 41 and 38 respectively. In case of lagged dependent variables fixed effects estimates are biased of order $1/T$, where T is the number of periods. As a general rule, when T is 30 or larger the bias is small enough and fixed effects or least-squares dummy variables can be used (Judson and Owen 1999). When T is small, fixed effects can be eliminated by first differencing as in the Anderson-Hsiao estimator. However, it is inefficient. An efficient estimator has been developed by Arellano and Bond which suffers from weak instruments though when samples are small. According to Monte-Carlo studies by Bond and Blundell (see Baltagi 2008, ch.8) and Soto (2009) a system GMM estimator with two equations works best: one equation takes first differences and uses lagged levels of regressors as instruments and the other equation uses levels and takes lagged first differences of the regressors as instruments. Coefficients are constrained to be the same in both equations for the respective regressors. Arellano and Bover (1995) have also replaced the first differences part by so-called orthogonal deviations, which is preferable when many observations are missing and first differences would make the problem worse (Roodman 2006).

In our first approach, we use the first differences approach to system GMM for equation (15) where $T = 4$ and simple fixed effects for (16), (17) and (18) where T is about 30 or higher when we estimate the macroeconomic equations separately. For the education equations there is also a great variation in the number of observations ranging from 166 to 940 (see Appendix 3). But common shocks can be assumed to be important for all parts of the education system. Therefore we use simultaneous equation estimation for the education equations (1)-(14)

assuming absence of fixed effects. To deal with that, we use the GMM-HAC[14] method using right-hand side variables with lags of the regressors as instruments, because eleven of the regressors are from the current period. In principle we handle the conventional significance level of 10%, but if dropping of a variable leads to strong downward jumps of the adjusted R-squared, we tolerate higher levels and attribute the low significance to collinearity or a potential non-normal distribution of the residuals, which is allowed by GMM methods. All results are tested in regard to their plausibility later by way of simulation of the whole system of 18 equations a suggested by econometricians (see Nakamura and Nakamura 1998). [15]

In our second approach we estimate the education system as in the first approach; we estimate the macroeconomic equations simultaneously (but separate from the education system) representing each of them as a system GMM set of two equations. In order to capture the fixed effects we combine for each macroeconomic equation the first-difference equation where the fixed effects drop out with an equation of the standard within estimator that subtracts the mean from all variables. This way fixed effects also drop out. Both equations then are constrained to have the same coefficients. Of course, fixed effects then could be calculated separately in a second step. This way of entering system GMM into a simultaneous equation approach has not been investigated by econometricians to the best of our knowledge. In the current setting its major weakness may be that the implied contemporaneous correlation works somewhat asymmetrically when equations have greater differences in the number of observations in the time dimension, some observations being under impact of residuals of other equations whereas other are not. As a first attempt of combining simultaneous equations systems with system GMM it may be interesting though and it also can serve as an additional intuitive robustness check.

In our third approach we integrate the education equations as in the first two approaches and the macroeconomic equations as in the second approach to one simultaneous equations system. There we use again the first difference approach to system GMM for all macroeconomic equations. The complete system is written down in its implemented form in Appendix 3.

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[14] General method of moments with Newey-West heteroscedasticity and autocorrelation correction.

[15] In terms of Appendix 2 we are in the lower right cell for the education system, in the upper right cell for the equations for growth and the labour force, and the upper left cell for the equations for savings and investment, which contain only lagged regressors. We proceed in principle in a stepwise regression mode, which means that we eliminate insignificant variables after having tried different lags, logs and squares and their differences instead of a level of a variable. In particular squared variables or higher exponents are important if one wants to take into account decreasing returns to policy measures rather than discussing only linear effects.

4. Estimation results and economic interpretation

All approaches give very similar results as can be seen from Appendix 4, where the estimated coefficients and their marginal significance levels (p-values) are collected. We will discuss them selectively as section 2 was partly based on the regression outcome already. The driving forces of GDP per capita growth are – see column 1, coefficients 153-156 - investment, past enrolment in tertiary education, and a time trend;[16] labour force growth squared has a negative impact and so does the lagged dependent variable indicating a convergence rate to the steady state of less than 3%. Gini coefficients of education are never significant in the growth equation if care is taken of the Hansen-Sargan statistic and second-order serial correlation.[17] Roodman (2009) had suggested that the p-value of the Hansen-Sargan J-statistic should be not too far outside the range of 0.05 and 0.25. If it is much lower, the minimized quadratic form gets too large in the chi-square test because of the overidentifying constraints – indicating invalid instruments or mis-specification - , and if it is much higher the instruments have only minor effects leaving us close to OLS estimates, which are known to be too high for the lagged dependent variable. For our growth equation the p-value is 0.013 (see the last part of Appendix 4), passing the chi-square test at the one-percent level, but not at the five- percent level.[18]

For investment and savings as a share of GNI and GDP respectively we find significantly positive lagged dependent variables and lagged growth rates of GDP per capita, and for investment also for labour force growth. Both equations serve only as auxiliary equations and therefore are kept simple.[19] The growth of the labour force decreases with GDP per capita.

Columns 1 to 6 of Appendix 4 reflect the results for use of the data for Gini coefficients of education by Castello and Domenech (2002) and columns 7 and 8 for those by Thomas et al. (2000b). Only for the first equation we get slightly different results in size and significance,

[16] Enrolments in primary and secondary education are not significant. Similarly, Barro and Lee (2010) estimate a production function and primary education is not significant. Higher education has been found to be a good regressor in several papers using different indicators (see Gyimah-Brempong et al. 2006). Petrakis and Stamatakis (2002) emphasize the relation between enrolments as investment, completion rates and changes in human capital stock indicators.

[17] Halter et al. (2010) find a positive impact of inequality on GDP per capita in first differences and a negative one in levels in a bi-variate regression. For Gini coefficients of education we find the same for levels but no relation in first differences.

[18] A related test for the validity of the instruments is that for second-order serial correlation. It is more powerful than the Hansen-Sargan tests only if the serial correlation is above 0.2 (see Roodman 2006). Appendix 4, the second continuation, shows that for all applications of system GMM the coefficient is below 0.2, making the Hansen-Sargan test the relevant one.

[19] For investment we have also tried the use of gender gap and other education variables. Unlike Klasen and Lamanna (2009) they are not robust. They are either insignificant or have the opposite sign together with highly implausible simulation results. This seems to be a case where the use of cross-section results and dynamic panels may lead to different results, perhaps also due to different collinearity effects.

but not in the signs and orders of magnitude.[20] For all other coefficients the difference is less than one percent. The impact of the residuals of the first equation on the other equations is therefore very weak. The columns 5 to 8 of Appendix 4 stem from joint estimation of the education and the macroeconomic part. Again the signs are the same and the significance is mostly improved. Gini coefficients of education do not come back in any of these regressions and are just the results of the development of their single components. Enrolment rates essentially drive Gini coefficients, average years of schooling, and growth. Our simultaneous equation approach avoids a problem formulated by Rehme (2007, p.506): "… linear, empirical models (e.g. simple growth regressions with human capital and Gini coefficients as regressors) may miss the richness that may underlie the nonlinear relationship between economic growth and income inequality, when both are jointly determined by the level of human capital (or, ultimately, by the political economy consideration that lead to a particular level of human capital)." Of course this does not mean that distribution is irrelevant but rather that there are better determinants of growth, which are the regressors driving the Gini coefficients of education. In particular, behind tertiary enrolment there are primary and secondary enrolments.[21] Besides Gini coefficients, gender gaps are a second dimension of distribution. The gender gaps, the Gini coefficients, and average years of schooling are mainly driven by enrolments. Three of the four negative signs in equation (1) for Gini coefficients come from secondary schooling enrolments, indicating that this is the major equalizing force during the period under consideration. The three gender gap variables (in literacy, primary and secondary enrolment) and the Gini coefficients of education are driven by the other variables of primary and secondary schooling but they do not feed back into the other equations[22]. This does not mean that gender gaps have no effects in general but rather that the reason is that they are already included in the numbers for illiteracy and primary and secondary enrolments, which determine the completion rates and are the broader indicator for the problem of non-enrolment. In particular, gender gaps codetermine the initial values of their base variables and whether pupils go into illiteracy or to higher education enrolment both of which have an impact on Gini's and via tertiary enrolment on growth. But they can be removed only by enrolment and lower dropout rates, which therefore are the significant variables in several equations. The gender gap in secondary schooling is increased according

[20] For the first equation we have 366 and 239 observations in the two data sets respectively.
[21] A related but slightly different approach is taken in the literature searching for transmission channels from inequality to growth (see Neves and Silva 2010).
[22] This is complementary to Galor's (2009) summary saying that gender inequality declines with human capital accumulation.

to equation (11) through public expenditure per pupil as a share of GDP per capita; and boy's access to secondary schooling through enrolment is supported more than that of girls as indicated by the inverted u-shape of the enrolment variable. Secondary enrolments therefore play a double role in regard to inequality: They increase the secondary gender gap, but they decrease Gini coefficients of education unless primary enrolments are very high and all other interaction variables – other enrolment and average years of schooling - are very low.

The major driver of growth, enrolment in tertiary education, is driven itself by private savings to finance tertiary schooling according to equation (14), and by enrolment in secondary schooling, the previous stage. But the success there also depends on the reduction of the pupil/teacher ratio. Secondary enrolments in turn depend on enrolment and drop out rates for primary education in equation (10). Enrolment rates reduce the secondary pupil/teacher ratios according to equation (12), indicating that the effect on the numerator is overcompensated by other measures like hiring more teachers. This effect is also present in primary pupil/teacher ratios of equation (8). The secondary pupil/teacher ratio and the drop out rates are reduced by having more public expenditure in equation (12) and (7). Public expenditure in primary education is driven just by the savings ratio in equation (9). In addition, in equation (13) for secondary schooling there is more pressure on public expenditure per pupil when enrolments are higher, which dampens the positive effect of savings. Dropout rates and pupil-teacher ratios in primary schooling exhibit two-way causality in equations (7) and (8) with public expenditure helping to reduce the dropout rate and decreasing the number of pupils more than the number of teachers and thereby the pupil/teacher ratio if the expenditure share is large enough.[23] Expenditures have to be higher than 11.6% when using the coefficients of Appendix 4, to reduce the pupil/teacher ratio. As the panel average is 13%, a linear regression may yield insignificant results because in that neighbourhood the marginal effect is close to zero. Money does also matter in the reduction of dropout rates in equation (7), but with decreasing returns.[24] The positive coefficient of the interaction variable of dropout rates and pupil/teacher ratios in equation (8) indicates that dropout rates have a stronger effect on pupil/teacher ratios if the pupil teacher ratio is higher and higher pupil/teacher ratios are more self-perpetuating if the drop out ratios are higher. This suggests little confidence of politics in the signal from drop out rates and that they could

[23] The net effect can be caused by putting the money into buildings and allowing for more growth of the number of pupils than the number of teachers.

[24] Holmlund et al. (2010) find positive effects of a school's public expenditure per pupil on pupils' test attainment in the UK 2002-2007, which are larger for the disadvantaged. This micro panel result is in line with our macro panel effects on dropout rates if better attainment goes together with lower dropout rates and is not only achieved at the higher end of the attainment distribution.

be reduced through less pupils per teacher although equation (7) indicates that drop out rates are less self-perpetuating if pupil/teacher ratios are smaller. The positive sign of the GDP per capita growth rate in equation (8) indicates that more teachers than pupils are leaving school when the economies grow more strongly. Equations (7) and (8) also indicate a partial vicious circle: More drop outs lead to less hiring of teachers and a higher pupil/teacher ratio leads to more drop outs.[25]

The impact of long-term (five-yearly) GDP per capita growth rates is positive for primary and secondary enrolments in equations (5) and (10), probably because it indicates future revenues opportunities. The short-term growth rates enhance the pupil/teacher ratio in primary schooling in equation (8), either because teachers leave when the economy is working better or because more pupils than teachers are added.

Much literature has de-emphasized the role of public expenditure on education. Its positive effects are in reducing primary dropout rates in equation (7) and secondary pupil/teacher ratios in equation (12). As a consequence both help pupils getting into the enrolment of the next level. The negative effects are an increase of primary pupil/teacher ratios and secondary gender gap. These effects hamper the enrolment into the next stage or have a gender bias. Public expenditures thus have the potential to improve education pass through to the next higher level but they do not do this automatically. They would do it better if the pupil/teacher ratio and the secondary gender gap would be reduced, requiring structural breaks in equations (8) and (11). How does this relate to economic theorizing? In economic theory continuous choice models are used, which determine inputs and outputs of education (see for example Speciale 2011 for a recent contribution). In reality pupils and students do not have in the first instance continuous choices but rather choose discrete intervals of four to six years. This would be more adequately modelled by use of activity analysis with its linear segments and corners in the isoquants. However, once a student is enrolled in the next higher stage of education and perhaps is among the small percentage not doing well there, the timing of dropping out or investing additional money is indeed a continuous choice. Therefore it is quite plausible that public expenditure on education that can help not to drop out is appearing as a significant variable in regression equations for dropout rates, but not for enrolments, where the variation may be too small to get around the next corner of isoquant.

[25] Oppedisano and Turati (2010) find from PISA data that for educational inequality not only parental background but also schools' characteristics matter. This is captured by fixed effects and therefore called a black box. Pupil/teacher ratios may turn out to be one aspect of it in future research.

The overall structure of the estimated equations is that growth, savings and investment are driven by tertiary education, which in turn is based on the secondary education and behind that all other education variables. The other education variables in turn are driven by savings - equations (9), (13) and (14) for the public expenditure variables and tertiary enrolment - and growth rates of GDP per capita – equations (5), (8) and (10) for primary and secondary enrolments and primary pupil/teacher ratios.

All equations with the exception of (3), (5) and (9), have at least two other regressors besides the lagged dependent variable. In equation (3) illiteracy depends only on primary school enrolment. In (5) primary enrolments depend only on growth. Equation (9) indicates that public money for primary education is only available in proportion with private savings ratios with a coefficient of about 0.11.[26] These three equations as well as the three macroeconomic equations can be seen as being driven by savings and GDP per capita growth: growth increases primary enrolments and reduces illiteracy and both their gender gaps; savings drive money for education in (9), but depend themselves on growth. From there the effect of public expenditure on primary education goes to drop out rates and pupil teacher ratios in primary education. Lower dropout rates increase secondary enrolment, which in turn have an impact of tertiary enrolments and from there close the circle to growth. Other causalities are more complex and will be discussed below in connection with simulations and policy changes.

5. Simulation results

The next question is where the estimated system goes to numerically when it is solved simultaneously. We use the estimates of column 5 in Appendix 4 and estimates of linear – quadratic time trends to construct initial values. The estimated coefficients of the lagged dependent variables are either smaller than unity or they are accompanied by a negative quadratic term. This ensures partial stability. But effects from other equations may endanger stability. In particular, partial vicious circles as that between drop out rates and pupil/teacher ratios in equations (7) and (8) may cause instability in principle. Our numerical simulations in Figures 1 to 5 show that this is not the case; they are just forces dampening the stabilizing ones. More importantly, even if we have stability it is not a priori clear whether the variables go to low or high levels. Our explanation will focus on that.

SEE FIGURE 1 *(in appendix)*

[26] In our simulations below the value of public expenditure on primary education per pupil divided by the GDP per capita starts at 12% and then is driven up by the increase in savings ratios.

We present simulations until 2060, when labour force growth becomes negative, because it enters the growth rate equation as a squared term and therefore does not make sense under negative values. Gini coefficients of education (after multiplication by 100 in Figure 1, solid line) go from about 50.5 down to 17.3 in 2050 and then increase again. This improvement in equality is supported by the fall in illiteracy from above 50 to 5.7. Enrolment percentages in tertiary education move from 2.3 to 94. Almost all people then have tertiary education and therefore inequality is very low. Average years of schooling go from 2.6 to 17.5, a number which today is only obtained by those who have 12 years of school plus 5 years of university or other additional education.[27]

SEE FIGURE 2 *(in appendix)*

With more than 90% in tertiary education gender gaps go down or even become negative as is already the case in some developed countries, where girls often have a better learning performance (see Figure 2).[28] To achieve all this, gross enrolment in primary education goes beyond 100% (including older people for some time and recidivists permanently) after 1980, whereas gross secondary enrolment does so around 2020.[29] Dropout rates from primary schooling go from 19% to 1.9% in 2060 (see Figure 3).

SEE FIGURE 3 *(in appendix)*

Government money and pupil/teacher ratios must be very favourable to get dropout rates down according to equation (7). Government money will support this with public expenditure per pupil as a share of GDP per capita going from 12.7 to 17.9% for primary education (see Figure 4). In secondary schooling it first goes from the luxury value of 63% down to 15.6% and then up to 38% following the increase in enrolment rates once the quadratic term in (13) dominates. Pupil-teacher ratios in primary schooling go from 35 to 12%. For secondary schooling the number of pupils per teacher goes from more than 18 to 6 until 2060. This final situation exists already in developed countries in a small part of the private market that is complementary to the public schooling.

SEE FIGURE 4 *(in appendix)*

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[27] A model in which a low starting value of 2 to 3 years of schooling can lead to stagnation because of low life expectancy caused by an unequal distribution of parent education and the implied high share of low education families has been provided by Castello-Climent and Domenech (2008). Our regression approach looks at the average of the sample. Results for very poor sub-samples may be different, but data availability is also more modest for these countries. An important open question is whether or not life expectancy can also be tackled by private and public health expenditures at low levels of education.

[28] Reversed gender gaps of secondary school enrolment in some regions of Bangladesh in recent data are found by Asadullah and Chaudury (2009).

[29] The highest enrolment rate in primary education in our sample is that of Brazil in 1999: 165; the highest in secondary schooling are Sweden in 1998 and Australia in 2000: 160. The UK has values above 150 for 1998-2000.

The macroeconomic development is summarized in Figure 5. In the first phase, after a post-colonial start in 1960, the labour force growth rate is increasing. While GDP per capita growth rates increase labour force growth rates start falling and GDP per capita growth rates increase strongly because of this and because tertiary education grows. When enrolment for tertiary education stabilizes on a high level, growth convergence to a lower long-run growth rate sets in, which is not a steady-state rate though, because labour growth rates keep falling. Growth rates of the labour force go to zero around 2060 when that of the GDP per capita is 8.9 percent. Such high values are currently observable for the average of lower-middle income countries. For longer simulation horizons the growth rate would go to a value of about 1.86 percent. Then gross fixed capital formation as a share of GDP and savings as a share of GNI follow growth rates and go to values of 24.4 and 23.5 percent respectively.

SEE FIGURE 5 *(in appendix)*

The values in simulations for a longer period remain in the order of magnitude where they are at the end of Figures 1-5, with the exception of the labour force growth rate that goes to (-6%) , implying that the model has no stability problems within any reasonable horizon. Although the long-term perspective looks very positive it should be clear that this takes a very long time, which can be seen from Figures 1-5 again. Also we have only about 100 countries in the sample because of data limitations which compares to 209 countries in the World Development Indicators which may have data in the future, but are likely to lag behind the ones in our sample because poorer countries typically lag behind in the delivery of data.

Figure 1 shows that tertiary enrolments are linearly related to time from 2010 to 2030 and so are growth rates in Figure 5. Then growth rates start falling after 2035 but inequality remains falling too (see Figure 1 and 2), because secondary and tertiary enrolments keep growing although at a decreasing pace (see Figure 3). There is no simple stylized relation between growth and Gini coefficients though except for the period 1980-2025 when growth rate go up and Gini coefficients of education go down. The increase in the labour force growth rate in the first two decennia of our simulation according to Figure 5 that decreases growth rates of GDP per capita strongly is not reflected in the time path of Gini coefficients. When enrolment is stagnant at a high level, growth rates go down and Gini coefficients are constant. The overall trend according to our simulation of the panel average results from our estimations is that human capital variables improve, inequality in terms of Gini's and gender gaps go down and growth is permanently positive. The relation between equality on the one hand and human capital and growth on the other comes mainly from the reduction of gender gaps in primary schooling and literacy. However, they themselves are driven down by primary enrolments and falling dropout rates; the driving forces behind the latter two is growth and public expenditure on education, where the latter in turn is driven by savings indicating the share of taxable income. According to our estimates Gini coefficients of education, average years of schooling and gaps for secondary enrolment do not feed back into the system of equations, but the components driving them with the support of the whole educational and macroeconomic system do.

6. Some policy scenarios

For the model consisting of equations (1)-(18) policy can be analyzed as a shift in the initial values of a variable or in the intercept of an equations. There are many possibilities for education variables to apply this approach. As this takes much space we limit ourselves to a change in the intercept of the savings equation (16) and some education policies.

SEE FIGURE 6A-C *(in appendix)*

The impact of saving policy on education and growth

In line with Chami et al. (2009) we assume that there exists a tax policy of increasing the taxation of consumption, perhaps with exceptions for subsistence goods or compensating transfers to the poor or reduction of other tax rates, such that savings ratios would be increased. We re-run the simulation with an initial value of the savings equation increased by 0.5 in 1963. The initial value for the baseline simulation has been obtained from estimation of the savings ratio on a time trend for the first ten periods available; the result is s= 14.99+0.305t, which is used for the simulation of the first five periods. For the policy simulation we increase this value by 0.5. It has an impact on its own next periods according to equation (17). The results are summarized in Figure 6a-c. In Figure 6, we have divided the results for the enhanced initial value by those of the baseline simulations of Figures 1 to 5.[30] The savings ratio is shown to be 9-11% higher through the increase of the intercept and all feedback effects. The enhancement of savings has an effect on tertiary enrolment in the same period according to equation (14). With a lag of five years it has an impact on public expenditure on education in primary schooling according to equation (9) and with a ten year lag on those for secondary schooling according to equation (13). These four effects then work through the whole system. The largest effect is that on public expenditure on primary schooling per pupil divided by the GDP per capita. It runs up to 15% above the baseline value as shown in Figure 6a. These increases in money help reducing the pupil/teacher ratio

[30] The method of building ratios avoids the choice of discount rates and the use of absolute numbers.

according to equation (8) and the dropout rate according to equation (9). Both effects are almost identical according to Figure 6a. Both run down by up to 9.5% of the baseline value. According to Figure 6b public expenditure on secondary education per pupil as a share of GDP goes up to 4.5% above the baseline value. Pupil/teacher ratios in secondary schooling fall by 0.85% of the baseline value and the gender gap is larger before it changes sign and smaller afterwards. These effects are weaker than those on variables for primary schooling in Figure 6a. Enrolment effects are worth reporting only for tertiary enrolment where they increase by up to 1.94% above baseline according to Figure 6c. As a consequence of increased tertiary enrolments, the log of the level of the GDP per capita is for some time up to 0.4% above the baseline level following the peak in tertiary enrolment with a 20 years lag. All effects together make Gini coefficients go down marginally until 2040 but then they increase by up to 0.35%. The decrease is due to improvements in primary and secondary enrolments, but when they are passed through to tertiary enrolments inequality increases. The relation between education and growth is clearly positive, but that with education inequality is far from monotonous. Finally, the gender gap in literacy is quickly and strongly reduced and turns into a boy's gap, which returns to baseline in the long run, probably calling for worldwide pedagogic progress. The overall impression from this policy is that savings policies have an effect that is equally strong for savings ratios and public expenditure on education in primary schooling, but weaker for all other variables.[31]

SEE FIGURE 7A-C *(in appendix)*

A permanent budget neutral shock to tertiary education

We simulate a permanent shock to tertiary education by adding a value of two to the intercept of equation (14) from 2015 onwards. This induces an immediate jump from 53.5 to 55.5 in tertiary enrolment. The effects are shown in Figure 7a-c. Tertiary enrolment goes beyond 8% above baseline and then falls back to 2.5% above baseline at the end of the simulation period in 2060 in Figure 7a. Growth follows tertiary enrolment with a five year lag, goes to a maximum of 9% above baseline in 2030 and then falls to baseline values. The level of the GDP per capita remains 1.4% above baseline. Savings and investment both as a share of GDP are more than two percent above baseline as long as the growth rates are. Effects on basic education are shown in Figure 7b. Growth directly encourages primary enrolments according to equation (5) and increases pupil-teacher ratios in equation (8). Primary enrolments reduce

[31] As effects on investment/GDP ratios can be shown to be no more than 0.025% there is also a contribution of savings policies to decreasing global imbalances on the current accounts, which is the mirror image of the difference between savings and investment (Inv-Sav= imp-exp).

their own gap in (6), illiteracy in (3) and its gap in (4). A higher pupil-teacher ratio increases dropout rates, which in turn increase the pupil-teacher ratio in (8) and the gender gap in illiteracy in (3). Savings encourage public expenditure on education in (9), which increase pupil/teacher ratios in (8) and reduce dropout rates in (7). From there all effects go through the whole system. The net effects in Figure 7b show – going from the lowest to the highest effects - that relative to baseline, illiteracy is lower, but dropout rates and pupil/teacher ratios are higher, enrolments and public expenditure are higher, but also the gender gaps in illiteracy and primary enrolment are larger, both of which are in the phase of being boy gaps since 2011 and 2024 respectively. For secondary schooling, favourable effects are obtained except for the distribution; see Figure 7c. Higher growth encourages enrolment in (10) and higher savings encourage public expenditure in (13). The latter reduces the pupil/teacher ratio in (12). According to (11) these effects would increase the gender gap, which is a boy gap though in the relevant phase, and is enhanced predominantly by the boy gap in primary education. The net results according to Figure 7c is an increase in the secondary boy gap. The Gini coefficients of education are also driven up, although all enrolments are going up. Overall, the permanent shock to tertiary enrolment is good for human capital accumulation and growth but not for distribution as boy gaps are enlarged.[32] Also Gini coefficients are increased because average years of schooling are mainly driven up by tertiary enrolment and their interaction effects dominates the effect on Gini coefficients. Through its relatively quick effect on growth and savings it has quick returns and positive effects on the other parts of education. This raises the question whether or not we should worry much about the distribution if the growth effect is good for enrolments at all levels and illiteracy is reduced. For gender gaps and dropout rates complementary policies could be used.

The modest effects of 'more money only'

Since decennia much research has been done on the question whether or not public expenditure on education has a positive and significant effect on growth and other variables. We find several significantly positive effects. However, the effect of an increase is shown to be disappointing in Figure 8a. A permanent shock of 0.1 to the intercept from 2015 onwards raises public expenditure per pupil in primary education as a share of GDP per capita to 4% above baseline within forty years. The only noticeable effects are a reduction of the

[32] Similarly, a low ability person may be willing to subsidize a high ability person with higher income if he knows that the qualification of the other person is also good for his own income (see Creedy and Francois 1989). Conversely, results that human capital formation should be taxed can be derived if education has no or a sufficiently low effect on growth or other persons. The model by Speciale (2011) provides the logic of this case.

pupil/teacher ratio and dropout rates. All other effects are close to zero and therefore not shown. Similarly, an increase of public expenditure on secondary education shows only reductions in pupil/teacher ratios and boy gaps in Figure 8b.[33] Effects of 'more money' may be larger if combined with other measures of course.

Speciale (2011) finds that public expenditure on secondary education per unit of GDP reduces inequality measured by the Gini coefficients of education in a cross-section regression in the neighbourhood of the median income of the sample. The results can easily be reconciled. First, note that we use expenditure per pupil (and GDP per capita), which is reduced by more enrolments. Second, for our equation (1) we found that secondary enrolments reduce inequality. In a cross-section of countries those with higher enrolment will have higher expenditure. By implication in a cross-section one would indeed expect to have a negative impact for the panel average. Over time and taken causally though, public expenditures drive mainly pupil-teacher ratios and dropout rates. These effects are too small to affect other variables than those shown in Figure 8b.

Modern times: Budget neutral reductions of dropout rates

Dropout rates are not only caused by the well-known social problems. In recent years there is a growing awareness at least in developed countries that they stem from pupils being bilingual or dyslectic, having dyscalculia or hyperactivity, or gifted underachievement and related reasons (see Renzulli and Park 2004, and Reis 2004). Of course, quite a few pupils have both of these problems. All these require special treatment and some additional education for teachers. Similarly, in developing countries there are developments of targeting specific problems and groups that may bring down dropout rates (see Rodriguez et al. 2010). We assume – probably somewhat optimistically - that innovation in the curricula for teachers can solve this in a budget neutral way.[34] A permanent shock of -0.01 on the intercept of equation (7) from 2015 onwards reduces dropout rates from one to ten percent below baseline during 45 years and generates other results shown in Figure 8c. Pupil/teacher ratios fall in primary and secondary schooling. Gini coefficients improve and secondary enrolment and public spending increase. Other effects are negligible because the secondary enrolment effects are too small.

SEE FIGURE 8A-C *(in appendix)*

[33] These results for public expenditure also hold if the shock is five times as large.
[34] In the experimental phase evaluated by Rodriguez et al. (2010) subsidies from the World Bank and others were involved. After the experimental phase budget neutrality seems more realistic.

Of all the policies considered increasing savings ratios and tertiary enrolments both have rich indirect effects as captured by Figures 6a-c and 7a-c. In contrast increasing only public expenditure on education per pupil as a share of GDP per capita has fairly small effects, but is more favourable in regard to the gender gaps. The weak effects are probably due to the fact that primary and secondary enrolments are already quite high in 2015 when these policies set in. For countries which are below average in primary and secondary enrolments the effects may be larger. Aiming at good combinations of these policies together with addressing gender gaps directly rather than only via money therefore seems preferable.

7. Conclusion and policy: How to increase human capital without increasing inequality?

The results obtained above may of course differ by continent, country or income-group of countries. Therefore policy recommendations can only be illustrative for a hypothetical ‘average country’. Economic theory shows that inequality and growth may be positively or negatively related. In our model the education sector produces tertiary education which enhances transitional growth of the GDP per capita. Growth encourages primary and secondary enrolments, investment and savings ratios. Savings encourage governments to increase public expenditure on education. The major effect how this money matters is in decreasing primary pupil/teacher ratios and decreasing dropout rates and thereby allowing for a better pass-through to tertiary education. During the improvement of all enrolments average years of schooling are increasing, Gini coefficients of education and gender gaps are falling. For politicians who want to carry out an education policy, which does not increase education inequality, it may be interesting to see that in equation (1) average years of schooling do increase inequality in our panel average estimation if secondary enrolments are low and tertiary enrolments are sufficiently high, but not if it is the other way around. Once the ratio of tertiary to secondary enrolment is above 9/16 average years of schooling are increasing Gini coefficients of education. In the simulation of the estimated system average years of schooling are increasing from 1960-2060 and Gini coefficients of education are falling until 2050. A similar result based on bi-variate panel regression was also shown by Thomas et al. (2000a, b). Moreover, enhancing enrolment in secondary schooling will decrease inequality directly according to equation (1). When investing in ways of schooling that do increase inequality it is possible to find measures that work in the opposite direction as well. In many countries it is a major task to expand secondary schooling. When all types of schooling are growing simultaneously, as is the case in most countries, the growth in education can be equalizing as it is in our simulations, but when secondary schooling has its effects on tertiary enrolments the effects favouring equality become weaker. In order to preserve equality, politicians can also strive for more complete primary schooling by bringing net enrolments rates to 100% more quickly (as suggested by the last term of equation (1)), by reducing dropout rates, and thereby erasing illiteracy, and by continuing to decrease the pupil-teacher ratios. This will improve the stream from secondary to tertiary education, increase average years of schooling and erase gender gaps. According to the equations estimated above, this will require a higher share of spending per pupil as a percent of GDP per capita, which finances the change in some of the variables, in particular pupil/teacher ratios and dropout rates. If human capital expansion can be done in this way without increasing inequality, as suggested by T.W. Schultz (1956) more than fifty years ago with some more emphasis on primary education, this may also be good for future growth as indicated by Castelló and Doménench (2002). Our model supports this view for the simulation period when tertiary education is increasing, but may change thereafter, when growth rates and inequality go both down but enrolment rates are close to their maximum. A change to endogenous technical change, which is not in our model, will hardly change this because our long-run growth rate is as high as that of the OECD countries. Our model is capable of running counterfactual analyses that can quantify the effects of certain policies and compare them to the baseline simulations presented above. We have provided the example of increasing savings ratios, which is in line with a reduction of decreasing global imbalances for many countries with current account deficits equal to the difference between investment and savings. Increases in savings enhance enrolments at all levels, reduce primary pupil/teacher ratios and dropout rates, enhance average years of schooling, reduce Gini coefficients of education and all gender gaps but those for secondary schooling; this latter one requires a more specific targeting. Whereas in the 1950s T.W. Schultz' emphasis was duly on primary schooling our analysis of a permanent shock to tertiary education in the previous section shows that much can be achieved here. Tertiary enrolments enhance growth, which feeds back into the education system where it improves most variables. The two policies of enhancing savings ratios and tertiary enrolments are the most effective also because primary and secondary schooling are quite well advanced in the panel average already and there is less to be done here. As estimation reveals only an average result it is possible that in the less advanced countries investment in primary and secondary schooling may have a stronger role in speeding up the growth process.[35]

[35] The discussion of the reasons behind the slow speed is beyond the scope of this paper. Interesting contributions are Schultz (1964), Ziesemer (1990), Ehrhart (2009) and Galor (2011).

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Appendix 1: Description of Education Data

Data availability:	**Period**	**Countries**	**Mean**	**Std. dev.**
Barro & Lee (1997)				
DROP:	Drop-out rate at primary school in %			
	1970-90,	102	25.90101	23.81084
SHPUPP:	Real government current educational expenditure per pupil at primary school to real per capita GDP (in %)			
	1960-90	104	13.05429	8.848042
SHPUPS:	Real government current educational expenditure per pupil at secondary school to real per capita GDP (in %)			
	1960-90	105	39.66704	59.49412
TEAPRI:	Pupil-teacher ratio at primary school.			
	1960-90	111	32.74706	12.4304
TEASEC:	Pupil-teacher ratio at secondary school.			
	1960-90	111	19.61884	6.981591
Barro & Lee (2001)				
AYS:	Average schooling years in the total population (years 15+)			
	1960-2000	113	4.952851	2.865885
Casetlló&Doménech (2002)				
GH15:	Human capital Gini coefficient for the population aged 15 years and over			
	1960-1999	108	0.438413	0.239209
Thomas, Wang, Fan (2000)				
EGINI:	Education Gini		0.49095	0.213214
	1960-90	84		
World Development Indicators:				
GDP:	GDP per capita (constant 1995 US$)			
	1960-2001	105	6100.042	8959.947
ILL:	Illiteracy rate, adult total (% of people ages 15 and above)			
	1970-2001	88	33.68957	25.4306
SEPRI:	School enrollment, primary (%gross)			
	1970-2000	110	94.66596	22.08159
SESEC:	School enrollment, secondary (% gross)			
	1970-2000	110	58.28478	34.85153
SETER:	School enrollment, tertiary (% gross)			
	1970-2000	110	18.39594	18.33547
GAP:	The difference between Illiteracy rate, adult (female – male) (% aged 15 and above)			
	1970-2000	89	13.52941	11.86327
GAPSEPRI:	The difference of school enrollment, primary, (male – female) (% gross)			
	1970-2000	110	7.064617	12.18615
GAPSESEC:	The difference of School enrollment, secondary, (male – female) (% gross)			
	1970-2000	110	2.445418	9.880575

We have observations for 111 countries: Afghanistan, Argentina, Australia, Austria, Belgium, Benin, Bangladesh, Bulgaria, Bahrain, Bolivia, Brazil, Barbados, Botswana, Canada, Central African Rep., Switzerland, Chile, China, Cameroon, Congo Rep., Colombia, Costa Rica, Czech Rep./Czechoslovakia, Cuba, Cyprus, Germany, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Spain, Finland, Fiji, France, United Kingdom, Ghana, Gambia, Guinea-Bissau, Greece, Guatemala, Guyana, Hong Kong, Honduras, Haiti, Hungary, Indonesia, India, Ireland, Iran, Iraq, Iceland, Israel, Italy, Jamaica, Jordan, Japan, Kenya, Korea, Kuwait, Liberia, Sri Lanka, Lesotho, Mexico, Mali, Myanmar, Mozambique, Mauritania, Mauritius, Malawi, Malaysia, Niger, Nicaragua, Netherlands, Norway, Nepal, New Zealand, Pakistan, Panama, Peru, Philippines, Papua New Guinea, Poland, Portugal, Paraguay, Romania, Rwanda, Sudan, Senegal, Singapore, Sierra Leone, El Salvador, Sweden, Swaziland, Syrian Arab Republic, Togo, Thailand, Trinidad and Tobago, Tunisia, Turkey, Tanzania, Uganda, Uruguay, United States, Venezuela, Yemen, Yugoslavia, South Africa, Congo Dem. Rep., Zambia, Zimbabwe.

From the 113 for which we have data for average years of schooling from Barro and Lee (2000), Taiwan and East Germany drop out because there is no observation in any of the equations. We do not abandon any other countries, because the data situation is biased against poor countries anyway as they start delivering data later than rich countries.

Appendix 2: Estimation methods for systems of equations[36]

Endogeneity → (Un-)related regression ↓	No	Yes (instruments)
Cov(i,j) =0	Least squares (LS) → single equation, fixed effects methods[37]	IV, GMM → single equation, fixed effects methods
Cov(i,j)>(<)0	Seemingly unrelated regression (SUR)	3Stage LS (GMM-HAC)

[36] This follows from Davidson and McKinnon (2004), chapter 12.
[37] It may be an interesting task for econometricians to marry 3SLS or GMM for simultaneous equation systems with system GMM approach of Arellano-Bover (1995) for single equations.

Appendix 3: System specification and instruments

gh15 = c(11) + c(12)(gh15(-5)) + c(13)sesec(-5) + c(14)sepri(-5)sesec(-5) +c(15)sesec(-5)seter(-5) + c(16)sesec(-5)aysnew(-5) + c(17)seter(-5)aysnew(-5) + c(18)ill(-5)^2 + c(19)sepri(-5)^2. Instruments: c, gh15(-5), sesec(-5), sepri(-5)sesec(-5), sesec(-5)seter(-5), sesec(-5)aysnew(-5), seter(-5)aysnew(-5), ill(-5)^2, sepri(-5)^2 . Obs.:366; Adj.R^2=0.97

LOG(AYSNEW) = C(21) + c(22)LOG(AYSNEW(-5)) + c(23)SEPRI(-5) + c(24)SESEC(-5) + c(25)SETER(-5). Instruments: c, log(aysnew(-5)), sepri(-5), sesec(-5), seter(-5). Obs.:585; Adj.R^2=0.98

ill - ill(-5) = c(31) + c(32)ill(-5) + c(33)ill(-10) + c(34)(sepri(-5)-sepri(-10)).
Instruments: c, ill(-5). ill(-10), sepri(-5)-sepri(-10). Obs.: 445; Adj.R^2=0.95

gap-gap(-5) = c(41) + c(42)gap(-5) + c(43)gapsepri(-5) + c(44)drop(-5) + c(45)sepri(-5).
Instruments: c, gap(-5), gapsepri(-5), drop(-5), sepri(-5). Obs.: 370; Adj.R^2=0.69

SEPRI = C(51) + C(52)SEPRI(-5) + C(53)(LOG(GDP)-LOG(GDP(-5))).
Instruments: C, SEPRI(-5), (LOG(GDP(-1))-LOG(GDP(-6))). Obs.: 900; Adj.R^2=0.74

gapsepri = c(61) + c(62)gapsepri(-5) + c(63)sepri+c(64)gap(-5). Instruments: c, gapsepri(-5), sepri(-5), gap(-5). Obs.: 751; Adj.R^2=0.86

log(1+drop) = c(71) + c(72)log(1+drop(-5)) + c(73)log(shpupp(-5)) + c(74)shpupp(-5) + c(75)log(1+drop(-10))log(teapri(-5)). Instruments: c, log(1+drop(-5)), log(shpupp(-5)), shpupp(-5), log(1+drop(-10))log(teapri(-5)). Obs.:239; Adj.R^2=0.94

log(teapri) = C(81) + c(82)log(teapri(-5)) + c(83)log(shpupp(-5)) + c(84)log(shpupp(-5))^2 + c(85)seprilog(teapri(-5)) + c(86)log(1+drop(-5))log(teapri(-5)) + c(87)(log(gdp(-1))-log(gdp(-2))). Instruments: c, log(teapri(-5)), log(shpupp(-5)), log(shpupp(-5))^2, sepri(-5)log(teapri(-5)), log(1+drop(-5))log(teapri(-5)), (log(gdp(-1))-log(gdp(-2))). Obs.: 294; Adj.R^2=0.89

SHPUPP = C(91) + c(92)shpupp(-5) + c(93)shpupp(-10) + c(94)savgni(-5).
Instruments: c, shpupp(-5), savgni(-5), shpupp(-10). Obs.: 241; Adj.R^2=0.76

sesec = c(101) + c(102)sesec(-5) + c(103)sepri(-5) + c(104)drop + c(105)sesec(-5)^2 + c(106)(log(gdp) - log(gdp(-5))). Instruments: c, sesec(-5), sepri(-5), drop(-5), sesec(-5)^2, log(gdp(-1)) - log(gdp(-6)). Obs.:334; Adj.R^2=0.95

gapsesec = c(111) + c(112)gapsesec(-5) + c(113)gapsepri(-5) + c(114)log(shpups(-10)) + c(115)(sesec(-0)) + c(116)sesec^2. Instruments: c, gapsesec(-10), gapsepri(-5), log(shpups(-10)), sesec(-5), sesec(-5)^2 . Obs.:325; Adj.R^2=0.83

LOG(TEASEC) = c(121) + C(122)LOG(TEASEC(-5))+c(123)sesec + c(124)(shpups)$^{(-1)}$.
Instruments: c, log(teasec(-5)), sesec(-5), (shpups(-5))$^{(-1)}$. Obs.:234; Adj.R^2 =0.77

SHPUPS = C(131) + c(132)shpups(-5) + c(133)sesec + c(134)sesec^2 + c(135)savgni(-10).
Instruments: c, shpups(-5), sesec(-5), (sesec(-5))^2, (savgni(-10))^2. Obs.:166; Adj.R^2=0.77

seter = c(141) + c(142)sesec(-5) + c(143)savgni + c(144)seter(-5) + c(145)seter(-5)^2+c(146)seter(-5)^3 + c(147)log(teasec(-5))log(sesec(-5)). Instruments: c, sesec(-5), savgni(-1), seter(-5), seter(-5)^2, seter(-5)^3, log(teasec(-5))log(sesec(-5)). Obs.:400; Adj.R^2=0.94

LOG(GDP) - LOG(GDP(-1)) = c(152)(LOG(GDP(-1))-LOG(GDP(-2))) + c(153)(LOG(GFCFGDP) - LOG(GFCFGDP(-1))) + c(154)(D(LOG(LF))^2 - D(LOG(LF(-1)))^2) + c(155)(SETER(-5) - SETER(-6)) + c(156). Instruments: c, LOG(GDP(-2)), LOG(GDP(-3)), LOG(GFCFGDP(-1)), LOG(GFCFGDP(-2)), D(LOG(LF(-1)))^2, SETER(-7), trend

LOG(GDP)-mean(LOG(GDP)) = c(152)(LOG(GDP(-1))-mean(LOG(GDP(-1)))) + c(153)(LOG(GFCFGDP)-mean(LOG(GFCFGDP))) + c(154)(D(LOG(LF))^2-mean(D(LOG(LF))^2)) +

c(155)(SETER(-5)-mean(SETER(-5))) + c(156)(trend-mean(trend)). Instruments: c, d(LOG(GDP(-2))), d(LOG(GDP(-3))), d(LOG(GFCFGDP(-1))), $D(LOG(LF(-1)))^2$-$D(LOG(LF(-2)))^2$, SETER(-7)-SETER(-8).
Obs.:320; Adj.R^2=0.999

d(SAVGNI) = c(162)d(SAVGNI(-1)) + c(163)d(LOG(GDP)-LOG(GDP(-1))) + c(164)d(SAVGNI(-2)) + c(165)d(SAVGNI(-3)). Instruments: c, SAVGNI(-2), LOG(GDP(-1))-LOG(GDP(-2)), SAVGNI(-3), SAVGNI(-4)

(SAVGNI-mean(savgni)) = c(162)(SAVGNI(-1)-mean(savgni(-1))) + c(163)(LOG(GDP)-LOG(GDP(-1))-mean(LOG(GDP)-LOG(GDP(-1)))) + c(164)(SAVGNI(-2)-mean(SAVGNI(-2))) +c(165)(SAVGNI(-3)-mean(SAVGNI(-3))). Instruments: c, d(SAVGNI(-2)), d(LOG(GDP(-1))-LOG(GDP(-2))), d(SAVGNI(-3)), d(SAVGNI(-4)). Obs.:2462; Adj.R^2=0.79

GFCFGDP-GFCFGDP(-1) = C(172)(GFCFGDP(-1) - GFCFGDP(-2)) + C(173)(LOG(GDP(-1))-LOG(GDP(-2))-(LOG(GDP(-2))-LOG(GDP(-3)))).
Instruments: c, GFCFGDP(-2), d(LOG(GDP(-2))).

GFCFGDP-mean(GFCFGDP) = C(172)(GFCFGDP(-1)-mean(GFCFGDP(-1))) + C(173)((LOG(GDP(-1))-LOG(GDP(-2))) - mean(LOG(GDP(-1))-LOG(GDP(-2)))).
Instruments: c, d(GFCFGDP(-2)), d(d(LOG(GDP(-2)))). Obs.:3067; Adj.R^2=0.83.

d(D(LOG(LF))) = c(182)d(D(LOG(LF(-1)))) + c(183)d(D(LOG(LF(-2)))) + c(184)d((LOG(GDP(-1)))).
Instruments: c, D(LOG(LF(-2))), D(LOG(LF(-3))), LOG(GDP(-2)).

(D(LOG(LF))-mean(D(LOG(LF)))) = c(182)(D(LOG(LF(-1)))-mean(D(LOG(LF(-1))))) + c(183)(D(LOG(LF(-2)))-mean(D(LOG(LF(-2))))) + c(184)((LOG(GDP(-1)))-mean((LOG(GDP(-1))))).
Instruments: c, d(D(LOG(LF(-2)))), d(D(LOG(LF(-3)))), d((LOG(GDP(-2)))). Obs.:3655; Adj.R^2=0.33

Our third approach estimates all equations as written down here simultaneously using GMM-HAC. Numbers of observations and adjusted R-squares are from this approach. In our second approach we estimate equations (1)-(14) as a simultaneous system and also, separately, the last eight macroeconomics equations (coefficients 151-184) as a simultaneous equation system again using GMM-HAC. In our first approach we estimate the macroeconomic equations using simple fixed effects estimators. More detailed information is given in the Table of Appendix 4.

Appendix 4 Estimated coefficients of the simultaneous equations

	Castelló/Doménech data						*Thomas/Wang/Fan data*	
	Separate estimation				*Complete System*			
	educ. sys., macro single		*educ.sys., macro sys.*		*Simultaneous education & macro system*			
Number	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
C(11)	0.107	0.000	0.107	0.000	0.109	0.000	0.116	0.000
C(12)	0.784	0.000	0.784	0.000	0.789	0.000	0.772	0.000
C(13)	-0.001	0.058	-0.001	0.058	-0.001	0.022	-0.001	**0.325**
C(14)	0.00002	0.005	0.00002	0.005	0.00002	0.001	0.00002	0.043
C(15)	-0.00002	0.118	-0.00002	0.118	-0.00002	0.086	-0.00004	0.023
C(16)	-0.00009	0.043	-0.00009	0.043	-0.00009	0.038	-0.00014	0.016
C(17)	0.00016	0.129	0.00016	0.129	0.00017	0.092	0.00039	0.015
C(18)	0.00001	0.001	0.00001	0.001	0.00001	0.003	0.00001	0.005
C(19)	-0.00001	0.000	-0.00001	0.000	-0.00001	0.000	-0.000004	0.003
C(21)	0.138	0.000	0.138	0.000	0.143	0.000	0.143	0.000
C(22)	0.833	0.000	0.833	0.000	0.821	0.000	0.821	0.000
C(23)	0.002	0.000	0.002	0.000	0.002	0.000	0.002	0.000
C(24)	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000
C(25)	0.001	0.026	0.001	0.026	0.001	0.009	0.001	0.009
C(31)	0.200	0.000	0.200	0.000	0.188	0.000	0.188	0.000
C(32)	0.859	0.000	0.859	0.000	0.856	0.000	0.855	0.000
C(33)	-0.874	0.000	-0.874	0.000	-0.870	0.000	-0.869	0.000
C(34)	-0.004	0.100	-0.004	0.100	-0.004	0.126	-0.003	0.129
C(41)	1.647	0.000	1.647	0.000	1.684	0.000	1.695	0.000
C(42)	-0.122	0.000	-0.122	0.000	-0.122	0.000	-0.122	0.000
C(43)	0.094	0.000	0.094	0.000	0.093	0.000	0.093	0.000
C(44)	0.010	0.006	0.010	0.006	0.008	0.017	0.008	0.017
C(45)	-0.024	0.000	-0.024	0.000	-0.024	0.000	-0.024	0.000
C(51)	23.047	0.000	23.047	0.000	23.373	0.000	23.350	0.000
C(52)	0.781	0.000	0.781	0.000	0.780	0.000	0.780	0.000
C(53)	11.797	0.020	11.797	0.020	11.835	0.025	11.801	0.026
C(61)	9.623	0.000	9.623	0.000	10.015	0.000	10.016	0.000
C(62)	0.837	0.000	0.837	0.000	0.847	0.000	0.848	0.000
C(63)	-0.088	0.000	-0.088	0.000	-0.091	0.000	-0.091	0.000
C(64)	-0.055	0.131	-0.055	0.131	-0.078	0.050	-0.079	0.047
C(71)	0.471	0.000	0.471	0.000	0.464	0.000	0.463	0.000
C(72)	0.819	0.000	0.819	0.000	0.811	0.000	0.811	0.000
C(73)	-0.276	0.000	-0.276	0.000	-0.265	0.000	-0.265	0.000
C(74)	0.017	0.000	0.017	0.000	0.016	0.000	0.016	0.000
C(75)	0.041	0.012	0.041	0.012	0.043	0.006	0.043	0.006
C(81)	-0.321	0.022	-0.321	0.022	-0.371	0.008	-0.371	0.008
C(82)	1.000	0.000	1.000	0.000	1.003	0.000	1.003	0.000
C(83)	0.263	0.015	0.263	0.015	0.285	0.008	0.283	0.008
C(84)	-0.054	0.021	-0.054	0.021	-0.058	0.012	-0.058	0.012
C(85)	-0.00034	0.014	-0.00034	0.014	-0.00033	0.011	-0.00033	0.011
C(86)	0.008	0.003	0.008	0.003	0.008	0.001	0.008	0.001
C(87)	0.288	0.025	0.288	0.025	0.315	0.010	0.321	0.009
C(91)	-1.340	0.149	-1.340	0.149	-1.656	0.060	-1.665	0.058
C(92)	0.723	0.000	0.723	0.000	0.735	0.000	0.735	0.000
C(93)	0.231	0.000	0.231	0.000	0.229	0.000	0.230	0.000
C(94)	0.107	0.002	0.107	0.002	0.116	0.001	0.116	0.001
C(101)	4.367	0.006	4.367	0.006	4.834	0.002	4.840	0.002
C(102)	0.982	0.000	0.982	0.000	0.986	0.000	0.984	0.000
C(103)	0.059	0.031	0.059	0.031	0.055	0.034	0.055	0.035
C(104)	-0.094	0.000	-0.094	0.000	-0.100	0.000	-0.100	0.000
C(105)	-0.001	0.344	-0.001	0.344	-0.001	0.245	-0.001	0.253
C(106)	5.539	0.057	5.539	0.057	6.811	0.010	6.875	0.009

App. 4 cont.	Castelló/Doménech data						Thomas/Wang/Fan data	
	Separate estimation				Complete System			
	educ. sys., macro single		educ.sys., macro sys.		Simultaneous education & macro system			
Number	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
C(111)	-4.983	0.014	-4.983	0.010	-6.523	0.000	-6.527	0.000
C(112)	0.700	0.000	0.700	0.000	0.696	0.000	0.697	0.000
C(113)	0.176	0.000	0.176	0.000	0.186	0.000	0.185	0.000
C(114)	0.823	0.019	0.823	0.014	1.104	0.001	1.107	0.001
C(115)	0.051	0.196	0.051	0.179	0.069	0.057	0.069	0.058
C(116)	-0.0004	0.186	-0.0004	0.172	-0.001	0.076	-0.001	0.078
C(121)	0.522	0.000	0.522	0.000	0.533	0.000	0.531	0.000
C(122)	0.857	0.000	0.857	0.000	0.857	0.000	0.857	0.000
C(123)	-0.003	0.000	-0.003	0.000	-0.003	0.000	-0.003	0.000
C(124)	0.432	0.042	0.432	0.050	0.472	0.030	0.459	0.034
C(131)	16.722	0.051	16.722	0.025	16.584	0.026	16.370	0.028
C(132)	0.574	0.000	0.574	0.000	0.577	0.000	0.579	0.000
C(133)	-0.374	0.112	-0.374	0.074	-0.375	0.072	-0.369	0.076
C(134)	0.003	0.086	0.003	0.056	0.003	0.056	0.003	0.059
C(135)	0.003	0.089	0.003	0.082	0.003	0.034	0.003	0.035
C(141)	1.150	0.128	1.150	0.144	1.385	0.065	1.391	0.064
C(142)	0.062	0.000	0.062	0.000	0.065	0.000	0.064	0.000
C(143)	0.039	0.022	0.039	0.018	0.040	0.009	0.041	0.008
C(144)	0.967	0.000	0.967	0.000	0.943	0.000	0.943	0.000
C(145)	0.006	0.128	0.006	0.092	0.007	0.031	0.007	0.030
C(146)	-0.00007	0.040	-0.00007	0.024	-0.00008	0.006	-0.00008	0.005
C(147)	-0.225	0.030	-0.225	0.032	-0.252	0.011	-0.253	0.011
C(152)	0.983	0.000	0.972	0.000	0.972	0.000	0.972	0.000
C(153)	0.066	0.020	0.058	0.006	0.054	0.008	0.055	0.007
C(154)	-3.006	0.000	-2.740	0.000	-2.639	0.000	-2.642	0.000
C(155)	0.002	0.117	0.002	0.030	0.002	0.005	0.002	0.006
C(156)	0.001	0.037	0.001	0.002	0.001	0.046	0.001	0.044
C(161)	5.753	0.000	-	-	-	-	-	-
C(162)	0.647	0.000	0.704	0.000	0.695	0.000	0.696	0.000
C(163)	5.795	0.005	18.786	0.000	17.552	0.000	17.656	0.000
C(164)	0.035	0.106	0.038	0.026	0.049	0.009	0.049	0.009
C(165)	0.020	0.161	0.024	0.073	0.026	0.073	0.026	0.072
C(171)	4.061	0.000	-	-	-	-	-	-
C(172)	0.802	0.000	0.814	0.000	0.828	0.000	0.826	0.000
C(173)	10.744	0.000	9.137	0.000	10.720	0.000	10.746	0.000
C(181)	0.015	0.000	-	-	-	-	-	-
C(182)	0.442	0.000	0.140	0.000	0.188	0.000	0.189	0.000
C(183)	0.296	(a) 0	0.315	0.000	0.316	0.000	0.316	0.000
C(184)	-0.001	0.000	-0.002	0.067	-0.002	0.041	-0.002	0.037

	Macro system		Education system(b)		Complete System			
			Castelló/Doménech data				*Thomas/Wang/Fan data*	
Observations	3781		1026		3859		3859	
J-statistic	0.006715		0E+00		0.009582		0.009548	
Instruments	38		74		112		112	
Parameters	17		74		91		91	
p(nJ)	0.23		-		0.0169		0.0175	
2nd order serial correlation in sys.GMM								
	Coeff.	p-val.	Coeff.	p-val.	Coeff.	p-val.	Coeff.	p-val.
Growth eq.	-0.156	0.013	-0.165	0.010	-0.153	0.014	-0.154	0.014
Savings eq.	0.033	0.075	-	-	0.026	0.157	0.026	0.159
Investment eq.	-0.121	0.000	-	-	-0.121	0.000	-0.121	0.000
lab.for.gr. Eq.	0.021	0.300	-	-	0.048	0.017	0.048	0.016

Estimation Method: Generalized Method of Moments
Kernel: Bartlett, Bandwidth: Variable Newey-West (183, 48, 59, 59), Prewhitening for complete systems only.
Linear estimation after one-step weighting matrix

Single equation information for separately estimated eqs. (15)-(18) in column 1.

Eq.(15) Sys.GMM, difference; Linear estimation after one-step weighting matrix
Kernel: Bartlett, Bandwidth: Variable Newey-West (10), Prewhitening
Obs.:421 J-stat.=0.0497 Instr.:14 p(nJ)=0.013

	Method	*Period*	*Observations*	*Adj. R-sq.*	*Durbin-Watson (c)*
Eq.(16)	Panel LS	1973-2002	2772	0.79	2.02
Eq.(17)	Panel LS	1962-2002	3277	0.83	1.80
Eq.(18)	Panel EGLS	1966-2003	3589	0.89	1.98

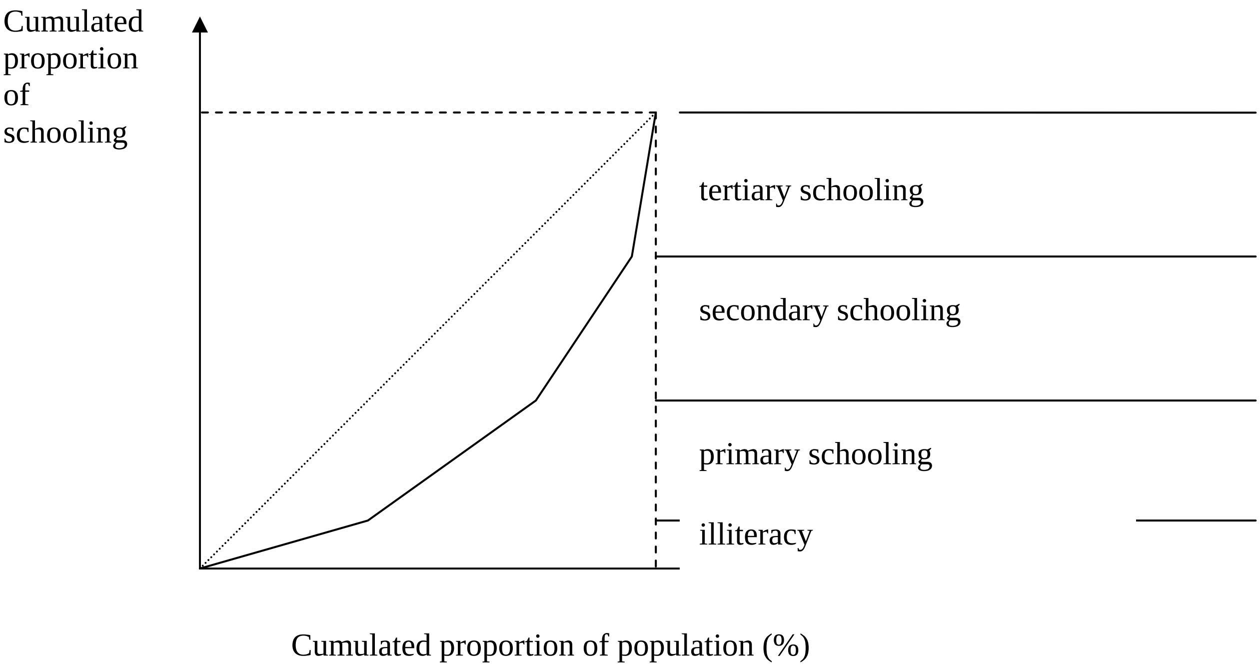
Notes

(a) There are three other significant lags in equation (18) with coefficients 0.076907, -0.034249, -0.033203.

(b) Adjusted R-square for the fourteen equations for education range from 0.69 to 0.978

(c) The Breusch-Godfrey test would be the rigorous variant under endogeneity;
a reasonable DW though indicates absence of serial correlation bias (Epple and McCallum 2006).

Scheme 1: The Lorenz curve for years of schooling



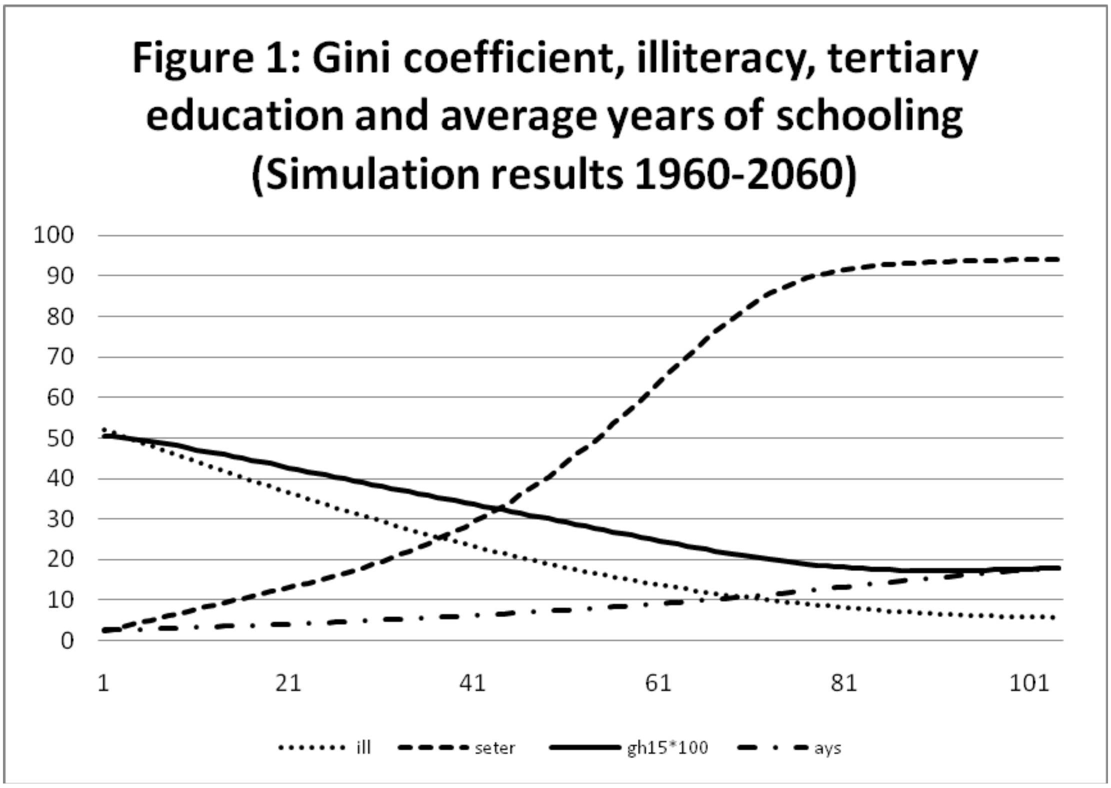


Figure 1: Gini coefficient, illiteracy, tertiary education and average years of schooling (Simulation results 1960-2060)

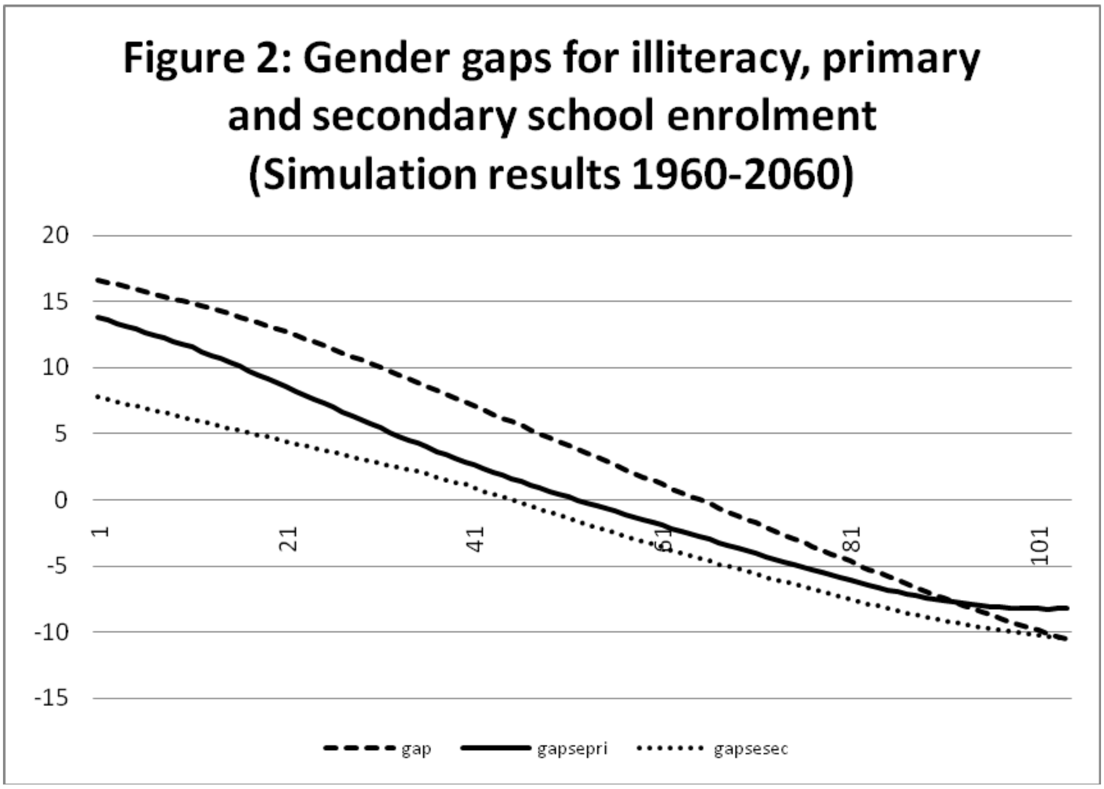


Figure 2: Gender gaps for illiteracy, primary and secondary school enrolment (Simulation results 1960-2060)
20
15
10
5
0
-5
-10
-15
1
21
41
61
81
101
gap
gapsepri
gapsesec

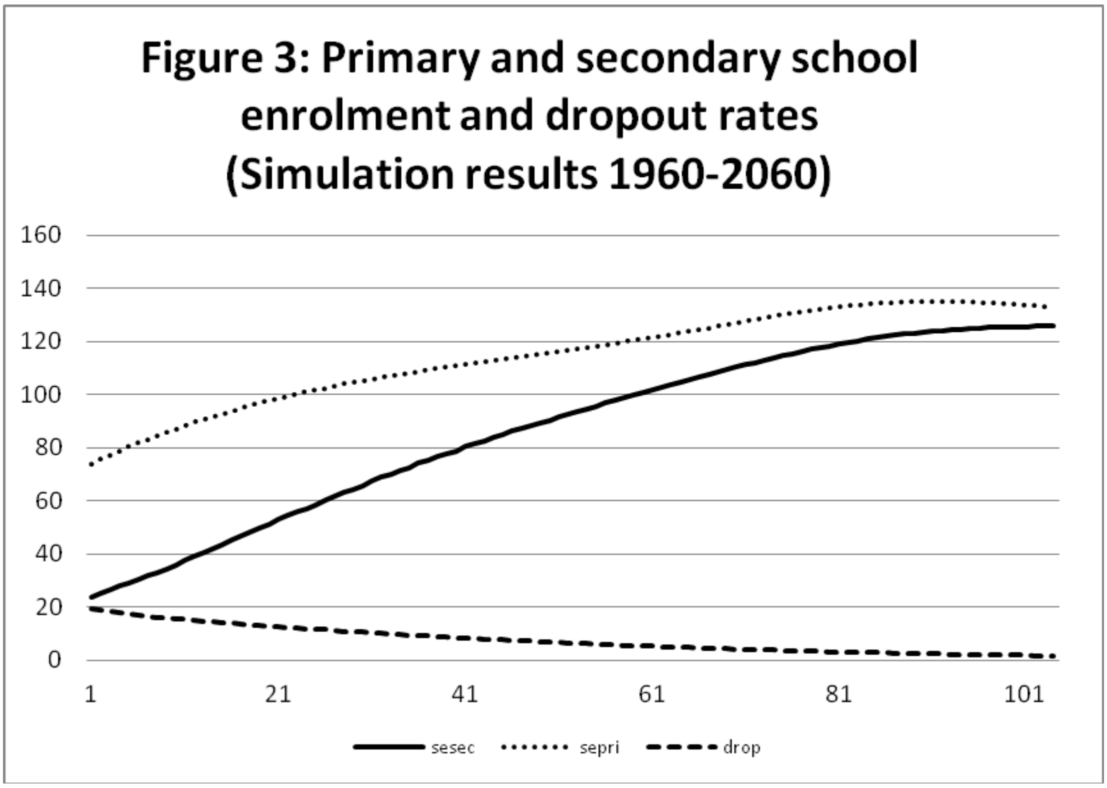


Figure 3: Primary and secondary school enrolment and dropout rates (Simulation results 1960-2060)
160
140
120
100
80
60
40
20
0
1
21
41
61
81
101
sesec
sepri
drop

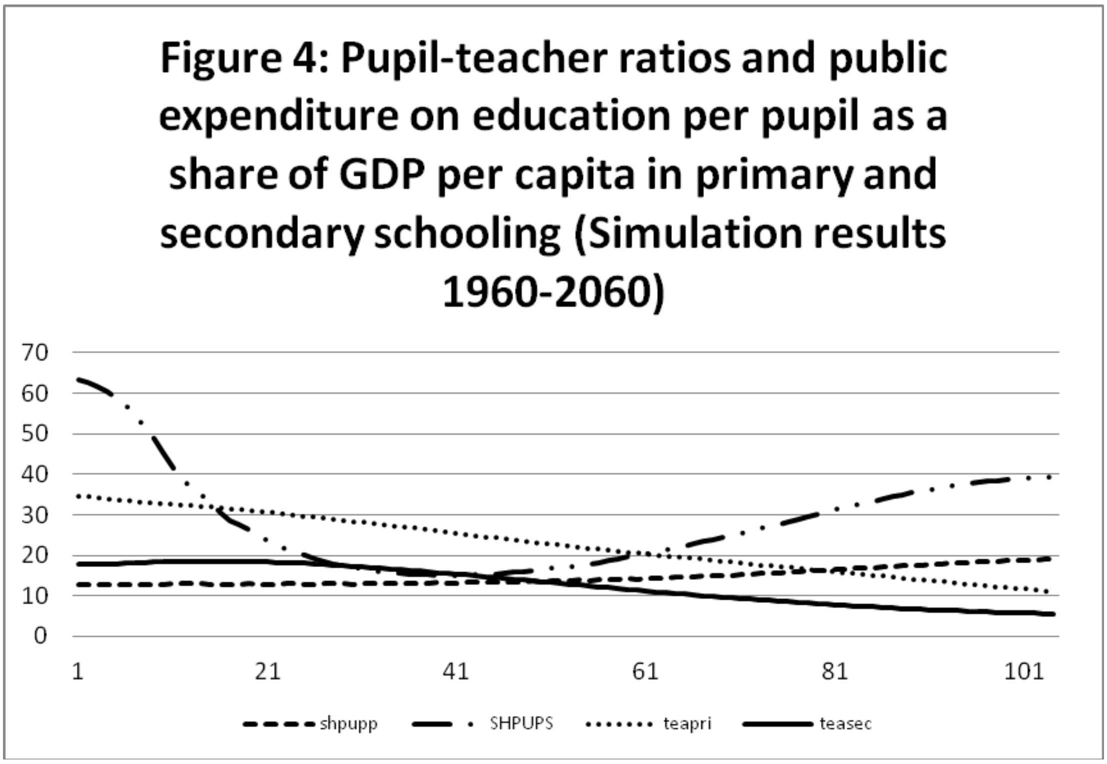


Figure 4: Pupil-teacher ratios and public expenditure on education per pupil as a share of GDP per capita in primary and secondary schooling (Simulation results 1960-2060)
70
60
50
40
30
20
10
0
1
21
41
61
81
101
shpupp
SHPUPS
teapri
teasec

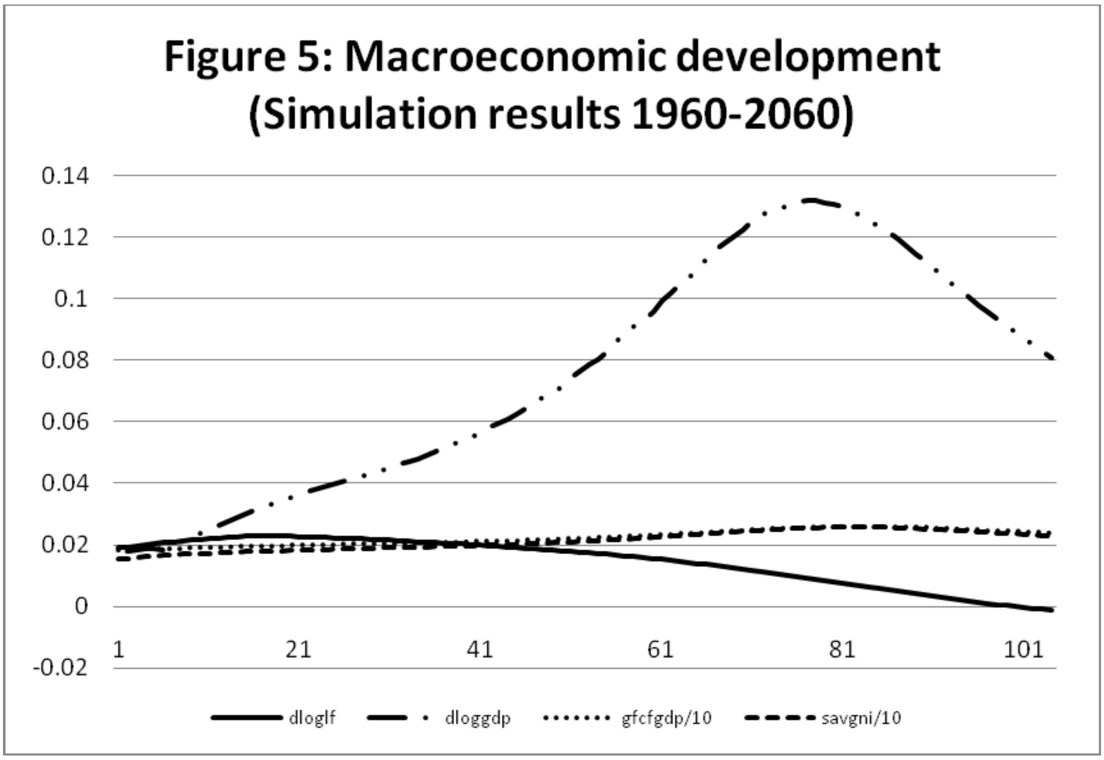


Figure 5: Macroeconomic development (Simulation results 1960-2060)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
1
21
41
61
81
101
dloglf
dloggdp
gfcfgdp/10
savgni/10

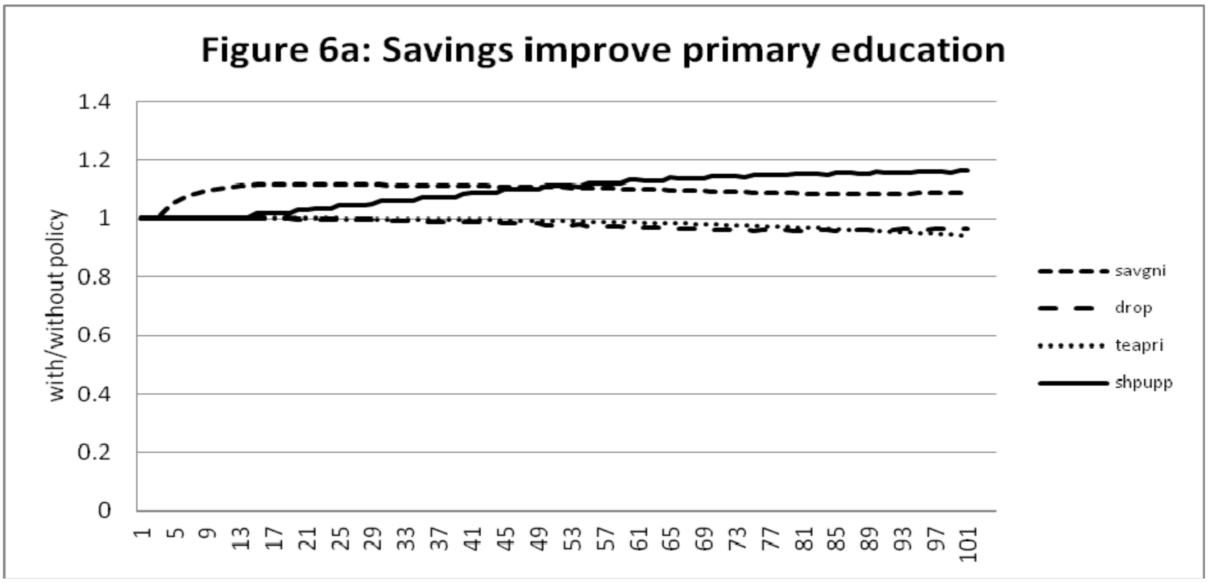


Figure 6a: Savings improve primary education
with/without policy
savgni
drop
teapri
shpupp

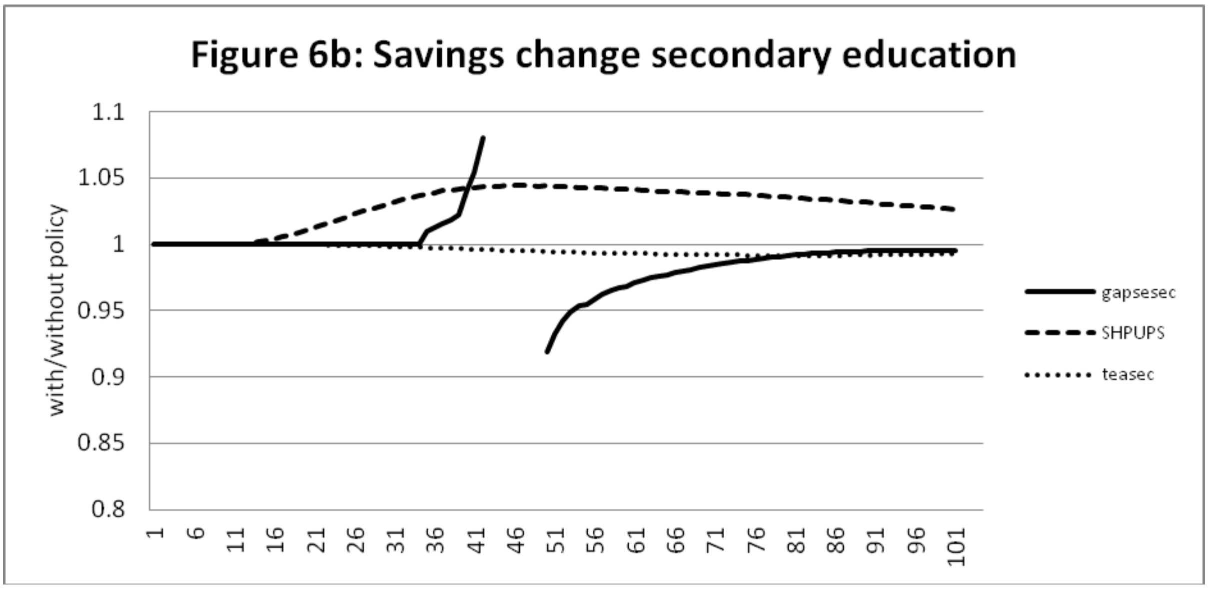


Figure 6b: Savings change secondary education
with/without policy
gapsesec
SHPUPS
teasec

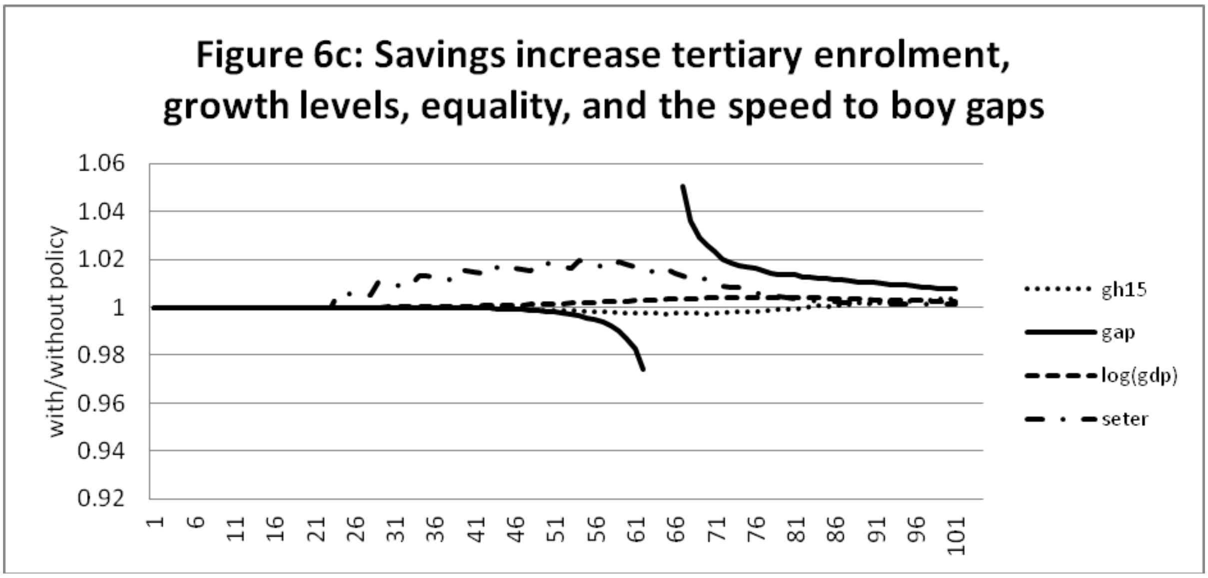


Figure 6c: Savings increase tertiary enrolment, growth levels, equality, and the speed to boy gaps
with/without policy
gh15
gap
log(gdp)
seter

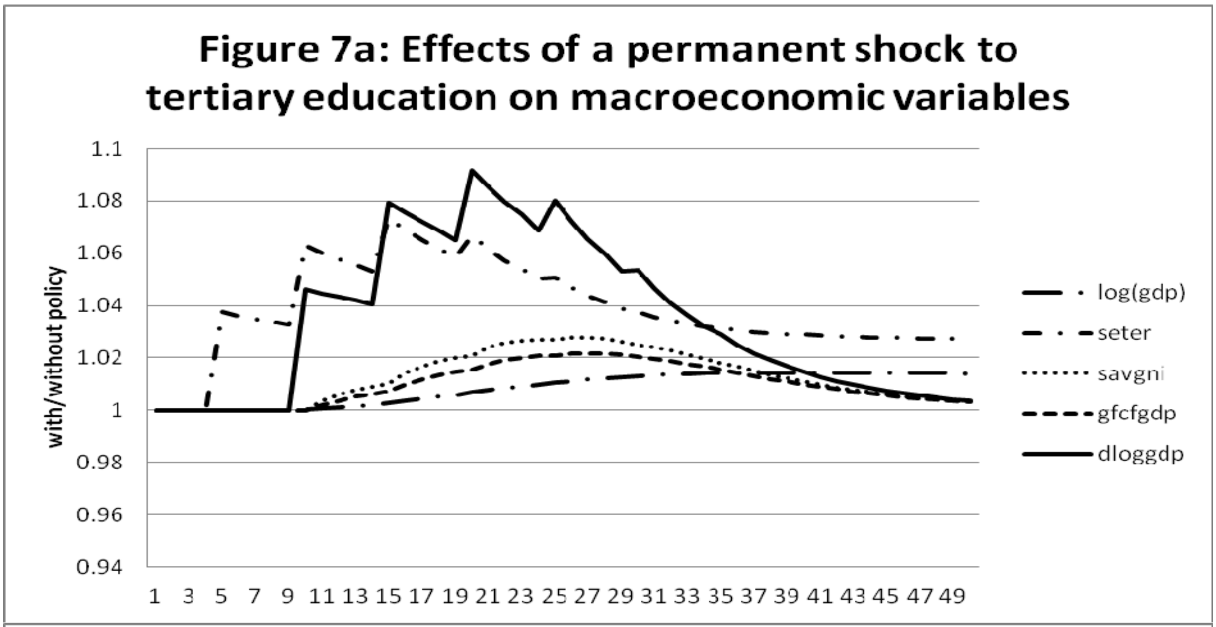


Figure 7a: Effects of a permanent shock to tertiary education on macroeconomic variables
with/without policy
log(gdp)
seter
savgni
gfcfgdp
dloggdp

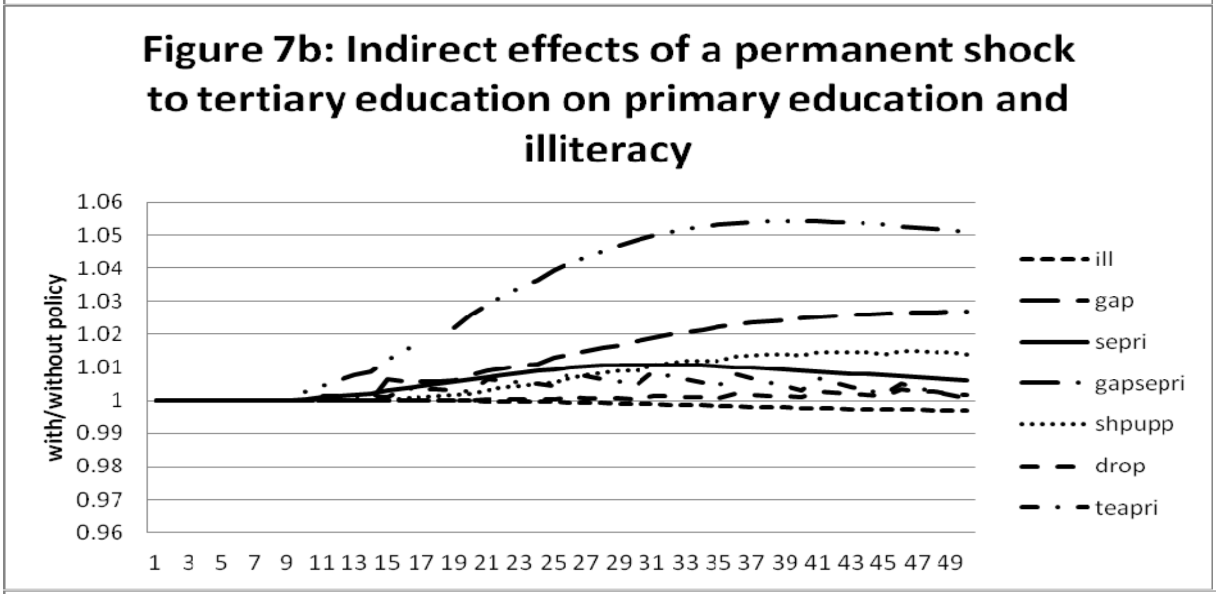


Figure 7b: Indirect effects of a permanent shock to tertiary education on primary education and illiteracy
with/without policy
ill
gap
sepri
gapsepri
shpupp
drop
teapri

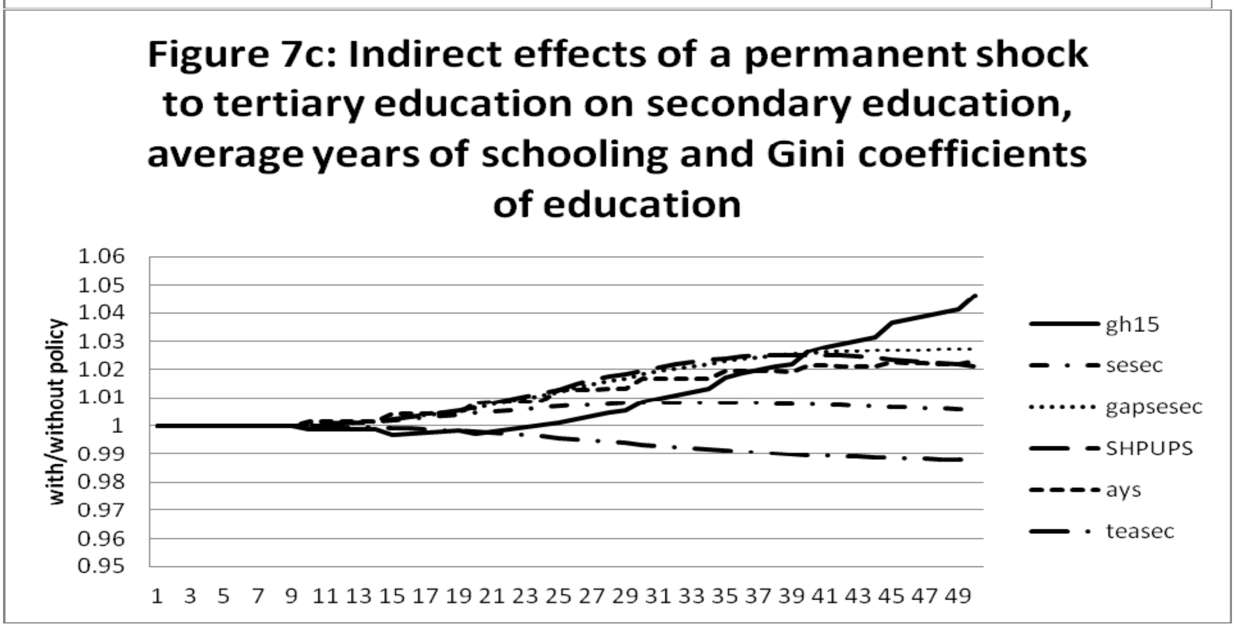


Figure 7c: Indirect effects of a permanent shock to tertiary education on secondary education, average years of schooling and Gini coefficients of education
with/without policy
gh15
sesec
gapsesec
SHPUPS
ays
teasec

Figure 8a: Public expenditure on primary education reduces primary pupil-teacher ratios and dropout rates

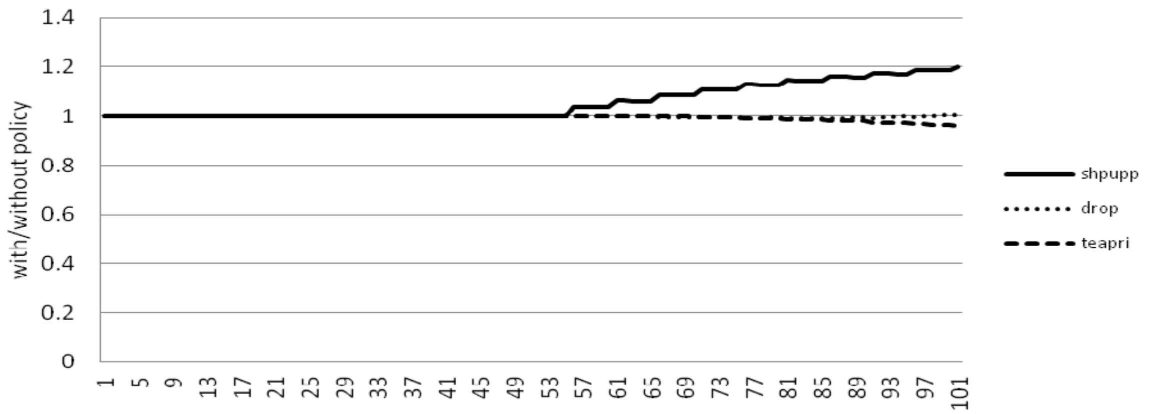


Figure 8b: Public expenditure on secondary education reduces the pupil-teacher ratio and the 'boys gap'.

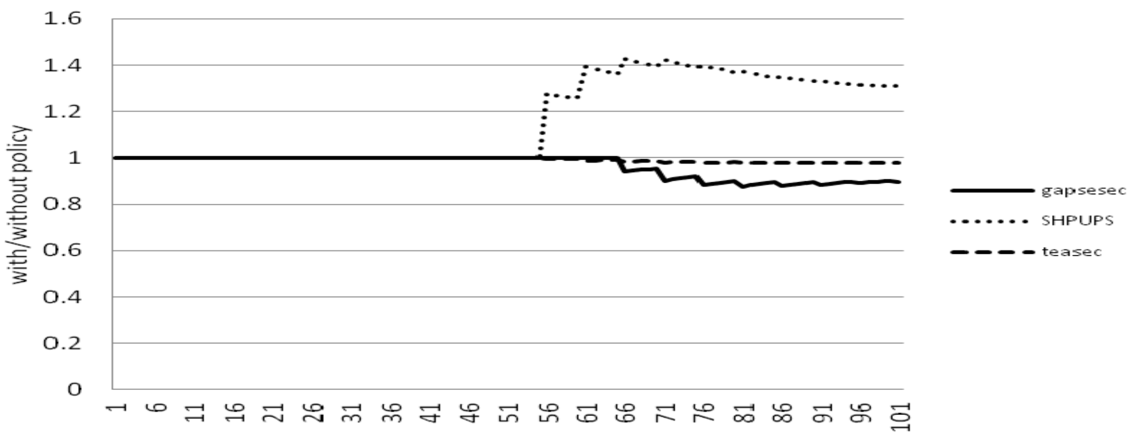
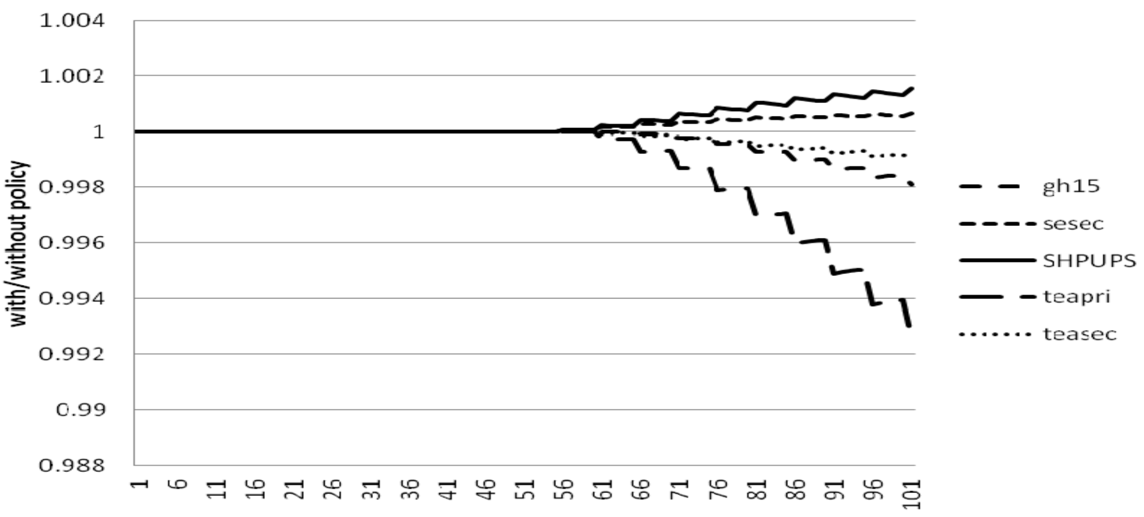


Figure 8c
Consequences of dropout rate reductions



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