A Study of Gender-Separate Human Capital Effects on Economic Growth Across 14 OECD Countries

By

Sylvie Marchand
(451817)

Major Paper presented to the Department of Economics
University of Ottawa
As part of the requirements for the Masters Degree
Supervisor: Professor Serge Coulombe
ECO 7997

Ottawa, Ontario

December 2003

Acknowledgements

I would like to thank Serge Coulombe, my supervisor, for proposing the extremely interesting subject of this major paper, and for generously sharing his experience, time and infectious enthusiasm throughout this project. I also thank Jean-François Tremblay for his help, collaboration and enthusiasm.

I am grateful to Scott Murray, from Statistics Canada, for sponsorship and helpful comments. Doug Willms kindly provided cross-country data on literacy scores.

I finally thank Matthew and Loïc Bramley, my spouse and son, for the time and encouragement they provided throughout the last year.

Contents

List of Tables

Chapter 1: Introduction

The rise of a naturalistic science of society, with all its magnificent promise of fruitful action and of intellectual light; the abdication of the Christian Churches from departments of economic conduct and social theory long claimed as their province; the general acceptance by thinkers of a scale of ethical values, which turned the desire for pecuniary gain from a perilous, if natural, frailty into the idol of philosophers and the mainspring of society - such movements are written large over the history of the tempestuous age which lies between the Reformation and the full light of the eighteenth century.

R.H. Tawney, *Religion and the Rise of Capitalism*

The concept of economic growth, first a theme of François Quesnay's Physiocrats, dominated Adam Smith's *Wealth of Nations* and subsequently found its way through the works of Thomas Malthus, David Ricardo and John Stuart Mill, to name a few (Rima 2001). And it is in the spirit of Newton's approach to physical sciences that economic growth came to be studied, that economists started looking for the laws under which wealth was created and distributed.

Once a sin of avarice, economic growth has become no less than a central preoccupation for macroeconomists and for governments that devote much of their resources in designing policies that aim at increasing the long-term rate of economic growth. While this is true for industrialized and industrializing countries, many countries still suffer today from extreme poverty due, among other things, to corruption, political instability, cultural constraints or religious influence. Why this is so, and why what worked for some countries did not for others remains puzzling and is the subject of ongoing research.

According to the early neoclassical model of Robert Solow (1956), economic growth was driven by the improvement of productivity *via* technological advances determined outside the model (exogenous). Although appealing, Solow's model could not be tested due to the lack of reliable data. Hence, growth issues had to wait until the late 1980s to be revived by the availability of internationally comparable data on income and price levels (Summers and Heston, 1988). At the same time that testing became a conceivable issue with Baumol's (1986) pioneering empirical results, another model – the endogenous growth model – was developed by Romer (1986) and Lucas (1988) where the long-term growth rate of productivity emerged endogenously from the model variables. Yet, empirical studies conducted through the 1990s to understand wealth differences between countries appeared to be best supported by models belonging to Solow's school. These models, however, had to be refined to fit the respective shares of capital and labour in output. The concept of capital had to be extended in order to account for *human* capital.

Human capital, recognized by Adam Smith as *skills*, acquired its denomination with Schultz (1961), Becker (1964) and Kiker (1966) and its definition was refined since then. Although there is no unanimity on its definition, human capital refers to an individual's competence in the fields of education, health, immigration and social capital (e.g., networks, norms and relationships), which endows him or her to work efficiently with other forms of capital.

Although theoretically appealing, the concept of human capital is empirically a very tricky subject. It is tricky to define and even more so to measure. Despite the foreseeable practical difficulties, economists have nonetheless made a fair amount of work to understand how changes in human capital influence economic growth. Expecting to find an empirical positive relationship between the two - justifying legitimate investments in health and education - there was however no such positive evidence until de la Fuente and Doménech's paper in 2002.[1]

The subject of the present paper is therefore to further investigate the empirical relationship between economic growth and the *accumulation* of human capital of men and women taken together and separately. Despite the many facets of human capital, we

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[1] Although other researchers have previously investigated the subject – see the literature review below – there was however no clear positive evidence of the relationship between *investments* in education and economic growth.

only consider education. We conduct panel data analysis to observe how the accumulation of education, in the population as a whole and for men and women taken separately, modulates economic growth for OECD countries.

Chapter 2 supplies the context in which growth models came to include human capital in their production function, and briefly surveys the principal growth models and the empirical specifications commonly used in the evaluation of the human capital-growth relationship. An overview of the major empirical results on the subject is also provided as well as literature on the gender educational gap and female labour force participation. The data and empirical methods are presented in Chapter 3. Results and discussion are provided in Chapter 4 and finally, Chapter 5 presents a brief conclusion and suggestions for further research.

Chapter 2: Literature Review

2.1 Growth theory and growth empirics

Growth theory and growth empirics can be compared to the theory and methods facets of the same subject. While growth theory settles the assumptions and mathematical formulation for a particular growth model, growth empirics relies on the different econometric approaches and available data used by researchers to test models and assumptions.

The early growth model developed by Solow (1956) and Swan (1956) is at the origin of today's neoclassical growth model that includes human capital. They stated a production function with characteristic features that are the essence of the neoclassical school. The output is a function of inputs that, taken together, contribute with constant returns to scale, and that, taken separately, contribute with diminishing returns to scale. Both inputs are linked by a positive elasticity of substitution. The saving rate and level of technology are determined exogenously to the production function and each fixed to a constant value. The commonly used Cobb-Douglas formulation is the following: $Y = AK^{\alpha}L^{(1-\alpha)}$ where Y is the output, A is the level of technology, K is the physical capital, L is the labour force and α is the share of capital in output.

The Solow-Swan model has simple equilibrium properties and predicts that a country will reach equilibrium where output, capital and consumption per worker-hour are constant, but where output, capital and consumption per worker grow at the constant and exogenous rate of technological progress. It is important to note that the model has no predictive power over the long-run growth rate of technology, as it is determined outside the model. Another important prediction from this model emerges from the diminishing returns of inputs to output: in the case where a set of countries have different starting capital intensities but exhibit the same saving rate, growth rates of population and technology, and preferences and level of technology, then one would expect the equilibrium levels of income per worker and growth rates of technology to be identical across countries. This is the absolute convergence feature of the Solow-Swan model: countries starting with a relatively low level of capital intensity will grow faster than those starting with a higher capital intensity, all heading towards the same level of income per capita.

As stated above, the availability in the late 1980s of international data on income and price levels spurred empirical testing of growth theory and developed in a discipline of its own – growth empirics. A pioneering work in this field is that of Baumol (1986) who used data on a group of countries belonging to Maddison's (1982) sample, and who appeared to confirm absolute convergence across countries. However, because countries included in the sample belonged to a group of very similarly industrialized – and rich - countries, definitive conclusions could not be put forward.

Summers and Heston's (1988) international data set provided a larger sample of countries, including poor as well as rich countries. This allowed macroeconomists such as Romer (1989) to further testing and conclude that absolute convergence did not hold over a larger and heterogeneous sample of countries. More precisely, Romer found that there was no significant correlation between initial income levels and subsequent growth rates.

Two avenues developed out of Baumol and Romer's empirical findings. The first avenue is the concept of conditional convergence, in the more general context of growth empirics. In their influential paper, Mankiw, Romer and Weil (1992) modified the early neoclassical Solow-Swan model to allow for the accumulation of human capital. Cross-country regressions led them to conclude that, instead of reaching a common steady state, each country reached its own steady state, due to differences in savings, the growth rate of population and human capital stock that condition a country's steady state. As our project is closer to the concept of conditional convergence and growth empirics, we will leave the in depth literature review on the subject for the following chapter.

The second avenue that developed is that of endogenous growth models by Romer (1986) and Lucas (1988). These models had the appealing feature of allowing for the endogenous determination of the growth rate long-run value. Instead of constant returns to scale, as in the Solow-Swan model, the endogenous growth production function can exhibit increasing returns to scale due to the fact that capital represents all types of capital, including human capital, allowing for spillovers from knowledge, health, immigration, etc. to counter the diminishing returns to scale of physical capital. But the early versions of endogenous growth models did not predict the empirically observed conditional convergence. To retrieve conditional convergence, a theory of technological progress was incorporated to better describe how discoveries and spillovers diffused through economies. However, despite this refinement, these models remain not well suited for cross-country studies because they do not allow for the determination of relative rates of growth across countries.

Since the work of MRW, the concept of conditional convergence has been many times confirmed by cross-country and panel data analysis. Growth empirics has seen many improvements to allow for better and more reliable testing of growth theory and also became a discipline of its own. Including human capital in growth regressions presents many interesting challenges. First, one has to select the best available proxy for human capital - usually data related to education. Then, there is the question of how to model the relation between growth and education in a regression function. As stated in Temple (2000), there are two classes of specifications used when modelling growth and education. The first class refers to specifications where growth is regressed on control variables, and the initial level of the chosen education measure. There is usually a large and significant effect on growth found in the studies that include explicitly the initial level of output per worker as an explanatory variable, but as Temple (2000) states, the validity of those results is uncertain for OECD countries.

The second class of specifications is that where growth is regressed on the *change* of educational attainment as a measure of human capital investment. There are several possibilities arising when setting up the details of the actual testing, and even so for econometric problems that actually prevented many researchers from observing a positive and significant effect. This, until de la Fuente and Doménech (2002) solved some of the problems – improved data and solved for measurement error - and found a positive correlation between changes in output and educational attainment for OECD countries. But there is still room for more work and confirmation.

2.2 Human capital and growth empirics: cross-country estimation by Mankiw, Romer and Weil[2]

This literature review starts with Mankiw, Romer & Weil's work (1992). As mentioned above, their work aimed at verifying the ability of the Solow growth model to "explain international variation in the standards of living." They assume a basic Cobb-Douglas production function with constant returns to scale and decreasing returns to capital, augmented with the exogenous level of technology progress and stock of human capital. The principal assumptions of their model includes country specific constant rates of investment in human and physical capital. Both types of capital share a common and constant rate of depreciation. All countries share the same rate of growth of technological progress, but differ in their respective growth rate of labour force and starting level of technical efficiency. In other words, the cross-country differences in the steady states of income per capita emerge because of the differences in the accumulation of human and physical capital, and in the growth rate of population. Hence, each country will converge to its own steady state instead of reaching a common one because the convergence process is conditional on the existing differences between countries.

In their empirical implementation of the model, MRW[3] test for the impact of human capital in income per capita for three sets of countries for which non-convergence has been well documented. All countries in each set share the same production function, i.e., the same coefficients and intercepts. In doing so, they postulate a regression function for a set of countries of the following form:

$$\begin{aligned}\ln y(t_1) &= \lambda'\beta_1 \ln s_k + \lambda'\beta_2 \ln s_h + \lambda'\beta_3 \ln\left[n+g+\delta\right] - e^{-\lambda t}\ln y(t_0) \\ &\quad + \lambda'\ln A(0) + g\left(t_1 - e^{-\lambda t}t_0\right) + \varepsilon\end{aligned}$$

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[2] This literature survey is partly based on Jonathan Temple's (1999, 2000) reviews on growth empirics.

[3] MRW is the abbreviation for Mankiw, Romer and Weil that will be used in the rest of the text.

where $y(t_1)$ and $y(t_0)$ are respectively the current and initial levels of income per capita; $A(0)$ is the unobservable initial level of technology; n, g and δ are respectively the steady state growth rate of population and technological progress, and the depreciation rate of capital; s_k and s_h are respectively the fraction of income invested in physical and human capital; $\lambda' = \left(1-e^{-\lambda t}\right)$ where $\lambda = (n+g+\delta)(1-\alpha-\eta)$ is the linearized speed of convergence[4] and $t = (t_1 - t_0)$; $\beta_1 = \alpha/(1-\alpha-\eta)$, $\beta_2 = \eta/(1-\alpha-\eta)$ and $\beta_3 = (\alpha+\eta)/(1-\alpha-\eta)$, where α and η represent respectively physical and human capital's share in income; ε represents a set of countries' specific disturbances.

To avoid the need for using instrumental variables and to be able to proceed with an OLS estimation of the regression function, MRW had to rely on a few more assumptions. As noted above, they postulate that g, the rate of technological progress is the same for all countries, while the initial level of technology $A(0)$ is a constant that varies randomly across countries. In practice, MRW include this term as a disturbance that they postulate independent[5] of all other explanatory variables. But in reality, $A(0)$ is likely to be correlated with the initial level of income per capita and the other explanatory variables, therefore inducing a bias in the estimation of the coefficients. Their final regression function can be rewritten as follow:

$$\ln y(t_1) - \ln y(t_0) = \lambda'\beta_1 \ln s_k + \lambda'\beta_2 \ln s_h - \lambda'\beta_3 \ln[n+g+\delta] - \lambda' \ln y(t_0) + \varepsilon,$$

where ε includes this time all country-specific disturbances. In summary, imposing a regression function with the same parameter values for all countries[6] and an initial level of technology correlated with the initial level of income per capita and the explanatory variables – s_k, s_h, n – will result in a set of biased coefficients.

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[4] Linearized around the steady state

[5] This is the crucial assumption that allows OLS estimation without the need for instrumental variables.

[6] Of a group of similar countries for which only differences in the variables are allowed.

MRW implement their model for the period between 1960 and 1985 and carry out single cross-country regressions ($t_0 = 1960$ and $t_1 = 1985$) for three samples of countries: the NONOIL sample includes 98 countries for which data were available, except for countries where the oil industry is dominant; the INTER sample excludes poor countries and countries whose data received a "D" grade by Summers and Heston; it includes 75 countries; finally, the OECD sample consists in 22 countries with population greater than a million. MRW consider investment in secondary education as a proxy for human capital accumulation. Specifically, their variable SCHOOL is computed as the percentage of the working age population in secondary school, thus ignoring higher education, arguing that if this variable is proportional to s_h, then the factor of proportionality will only affect the constant term. The s_k variable is measured as the average share of real investment over the period, and the growth rate of population, n, is also the average value observed for the 1960-1985 period.

Despite the econometric problems noted above, MRW conclude that their results strongly support the augmented Solow model. Specifically, their human capital variable enters significantly in the three country samples and adding human capital improves the overall fit of each of the three regressions. It also has the effect of reducing the importance of the physical capital investment coefficient that becomes insignificant in the OECD sample regression. Their estimation of the α and η – the elasticities of physical and human capital to output – is around 0.33 and highly significant for the NONOIL and INTER samples, but less so for OECD countries alone.

These results lead them to state that differences in population growth and investments in physical and human capital should explain about 80 percent of the cross-country differences in income per capita. Yet, as we will see below, their methodology and results were not without shortcomings, which unfortunately casts shadow on their conclusions.

2.3 Panel estimation by Islam

After MRW's attempt and apparent success in explaining changes in income per capita in terms of accumulation in human capital, many researchers turned their efforts to panel data analysis. The main reason for this change was to rule out the assumption imposing an identical production function for all countries as this gave rise to the omitted variable bias cited above. In his 1995 paper, Islam implements a panel data formulation of the human capital augmented Solow production function. Instead of a single cross-country estimation, he uses the data covering the same 1960-1985 period and splits it into five sub periods to benefit from five data point for each country. Moreover, Islam allows for country-specific level (fixed) effects to correct for the omitted variable bias. The restricted form of the regression equation is:

$$\ln y(t_1)-\ln y(t_0)=\lambda'\beta_1 \ln s_k+\lambda'\beta_2 \ln h^*-\lambda'\beta_3 \ln[n+g+\delta]-\lambda'\ln y(t_0)$$
$$+\lambda'\ln A(0)+g\left(t_1-e^{-\lambda t}t_0\right)+\varepsilon$$

In Islam's formulation, the rate of accumulation of human capital, s_k, is replaced by h^*, the steady state level, or stock, of human capital. Therefore, the beta coefficients are modified as follow: $\beta_1=\beta_3=\alpha/(1-\alpha)$ and $\beta_2=\eta/(1-\alpha)$.

As a proxy for the steady state level of human capital, Islam (1995) uses Barro and Lee's (1993) HUMAN variable which provides information about the average schooling years, including primary, secondary and higher levels, in the total population over 25 years of age. Countries are divided in the same three NONOIL, INTER and OECD samples. Results from Islam's estimations allowing for country effects imply values of the annual speed of conditional convergence λ (OECD: 0.0913) that are higher than those obtained by MRW (OECD: 0.0203). Moreover, the estimated values of the elasticities of output with respect to physical and human capital, α and η, for the three country samples (α = 0.5224, 0.4947, 0.2074; η = -0.20, -0.007, -0.045) are lower than those obtained by MRW without fixed effects (α = 0.69, 0.70, 0.28; η = 0.66, 0.73, 0.76), but otherwise similar to those obtained with panel estimation excluding the human capital variable. This is not surprising because the coefficient of HUMAN is not significant for the INTER and OECD samples and has the wrong sign for all samples. As Islam notes in his discussion: ...*such "anomalous" results...are not new. Whenever researchers have attempted to incorporate the temporal dimension of human capital variables into growth regressions, outcomes of either statistical insignificance or negative sign have surfaced.*[7]

Obviously, although correcting for the omitted variable bias has an undisputable value, what comes out of these results is that some econometric and data problems still remains. Of these, we note the fact that the growth rates g and n, and the speed of convergence were still considered the same for all countries. This aspect was examined by Lee, Pesaran and Smith (1998) in a paper in which they point out that panel estimations should also allow for heterogeneity in the growth rates of technology and population (and therefore in the speed of convergence) as well as for starting levels of technology (intercepts). However, as concluded in their own paper and in Islam's reply on their *Comment*, allowing and testing for such heterogeneity in countries' steady state growth rate involves difficulties that are not easily circumvented. For example, Islam notes in his *Reply* that the data available provides information on the *actual* growth rates whereas what would be required are the steady state growth rates.

Another problem to note in Islam's panel estimations is that the explanatory variables might be serially correlated.[8] This results in serial correlation problems in the disturbances and so the average effects evaluated are inconsistent (Temple, 1999). More concretely, the consequence of not correcting for serial correlation of that type is that the estimated speed of convergence will be biased upwards, which is probably the case in Islam (1995). Since then, this problem has been highlighted and corrected for in many panel data analysis such as Coulombe and Day (1996), and de la Fuente (1998), and Coulombe (2000). However, Coulombe (2000, and 2003) show that serial correlation is a serious problem only when annual data are used in panel estimation. Coulombe does not

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[7] Islam (1995), p. 1153.

[8] Temple (1999), p. 126-127.

detect any significant serial correlation when pooling information in periods of five or ten years.

Another point to note is that including the initial level of technology and the initial level of income per capita on the same side of the regression equation leads to correlation problems in the disturbances. Correlation between those initial levels and other explanatory variables, and among explanatory variables is also an issue to address when doing growth panel estimations. Also of interest is the possibility that some of the countries belonging to each of the NONOIL, INTER and OECD samples will be outliers and will therefore lead to results that are less robust than they could otherwise be. Another potential source of error is the specification of the regression equation used to represent a particular economic model. Relying on a sole model cannot result in robust results because it ignores the uncertainty related to all the different possible specifications. Measurement error in the data can lead to violations in the fundamental assumptions of the classical linear regression model, namely the assumptions about the normality and independence of the error distributions. Finally, it should not be forgotten that the use of proxy variables for human capital might only capture certain aspects of the "real" variable. It might also capture the effect of other variables that were not initially desired. This could lead to unexpected results.

2.4 Refinement of methods by Barro (1997)

On the subject of proxy variables and data quality, Barro & Lee (1997) refined their previous 1993 human capital data set. This improved data set provides estimates of school attainment over five year intervals between 1960 and 1999 for the population aged 15 years and over because in many countries, a large proportion of the labour force is between 15 and 25 years of age. They use estimates of net enrolment ratio, i.e. the ratio of students at a given level of schooling in the designated age group to the total population of the same age group. To construct a complete data set, they use a fill in procedure where missing cells are filled in by using school enrolment ratios by sex at various levels of schooling. The enrolled population being the flow that adds over time to the prior stock of schooling, this allows them to determine subsequent stock. Overall, their data was complete for 121 of the 126 countries.

In his following 1997 paper, Barro carries out panel estimations using his improved human capital data set for a panel of 100 countries over ten and five year periods between 1960 and 1990. His estimation method includes three equations where the dependent variables are the growth rates of real per capita GDP (henceforth GDP) for 1965-75, 1975-85, and 1985-90. The explanatory variables are the lagged GDP and male schooling[9] that refer to 1965, 1975, and 1985; life expectancy at birth for 1960-64, 1970-74, and 1980-84; the interaction variable log(GDP)*male schooling is the product of log(GDP) (expressed as a deviation from the sample mean) and the male upper-level schooling variable (also expressed as a deviation from the sample mean); a rule-of-law index that applies to the early 1980s; a terms-of trade variable taken as the growth rate over each period of the ratio of export to import prices; the inflation rate computed as the growth rate over each period of a consumer price index or as the GDP deflator. The other variables, measured as averages over each period are the log of the total fertility rate, the ratio of government consumption to GDP (exclusive of defence and education), and the democracy index.

In addressing the endogeneity problem that arises when many determinants of economic growth are considered in the estimation, Barro uses a three-stage least squares technique to solve for a model with three simultaneous equations. This method relies on the use of instrumental variables where each equation includes a different set of instrumental variables. As a result, the errors from the growth rate equations should not be correlated across periods, as was probably the case for Islam (1995). The instruments include the five-year earlier values of log(GDP), the actual values of the schooling, life-expectancy, rule-of-law, and terms-of-trade variables and three area dummy variables.[10] Additional instruments are earlier values of the other variables except the inflation rate. For example,

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[9] Years of attainment for the population aged 25 and over at the secondary and higher levels.

[10] For Sub Saharan Africa, Latin America and East Asia.

the 1965-75 equation uses the averages of the fertility rate and the government-spending ratio for 1960-64. The instrument list also includes the cross product of the lagged value of log(GDP) with the male schooling variable (both in terms of deviation from the mean).

Considering only the results relating to human capital, Barro finds that the years of schooling at the secondary and higher levels for males aged 25 and over have a significantly positive effect on growth for countries taken altogether. Female education appears to have no significant effect on growth at any level. He estimates that for males 25 an over, an extra year of higher-level schooling would raise the growth rate *on impact* by 1.2 percent per year. The life expectancy at birth also appears to have a significant impact on growth and is interpreted to proxy for the quality of the available human capital. However, and this is the point of interest for the purpose of the present research, Barro writes, somehow speculatively, that when considering OECD countries only, adding years of schooling in the form of increases in educational spending has no significant effect on the growth rate of the economy. Barro concludes in saying that " *a 2 percent growth rate for rich countries appears to be about as good as the long run growth rate will get* ".

2.5 The post 1997 literature

This period has been enriched by many more studies that aimed at estimating the effect of human capital on growth. In particular, many studies have focused on the effect of human capital at the intranational level because this circumvents most of the data heterogeneity problems encountered while working at the international level. Results along this line are reported below. But before doing so, it is relevant to note the apparent confusion found in the literature about the *actual* and the *steady state* growth rates of an economy. While working in a neoclassical context, some authors have reported results on the relationship between the initial level (or the accumulation) of schooling and the *long run* growth rate without referring to any different method but the neoclassical analysis framework. It is difficult to conceive how this is possible as the steady state growth rate of an economy is determined exogenously in this model.

In a paper published in 2000, Mauro studies the effect of human capital accumulation on the development of Italian regions for the past 30 years. When testing for different models, including those of Islam (1995) and Barro (1997), and controlling for the unemployment rates as well as accumulated job experience, Mauro specifically reports a positive and significant relationship between schooling investment and the *long run* growth rate. The logic of including unemployment being that it might reduce the productivity of those who cannot acquire job experience and use it to become more efficient. Moreover, Mauro nowhere raises the possibility of collinearity between his unemployment variable and his schooling investment proxy for human capital.

A difference between his and other studies is that he uses thirty and ten years averages, instead of five, to overcome the noise generated by the short-term fluctuations related to business cycles. Although encouraging, Mauro's results are difficult to assess, as he does not give much details about the data set he used and, as written below, the quality of the data set with which regressions are performed is clearly an important factor while analysing results.

Also in a paper published in 2000, Bils and Klenow develop a model to assess the causality between schooling and growth. Specifically, their model is built on finite-lived individuals where the growth rate appears to be enhanced, not only by one's actual accumulated schooling years, but also by its elders' accumulated human capital that appears to potentialize the imprints of the youngs' human capital on the growth rate of the economy. Based on a Mincerian (1974) wage equation, they however evaluate that schooling only explains less that one-third of the relationship found by many economists between the level of schooling and the growth rate of the economy.

We have exposed the results of influential papers in which the authors use methods belonging to both classes of specification mentioned above. At this stage of research development, conclusions were that the methods used for evaluating the impact of education accumulation on growth for OECD countries had yet to be improved to draw robust conclusions. After correcting for fixed effects with panel data methods, and for serial correlation (endogeneity problems) with the use of lagged (instrumental) variables with three-stage least squares methods, attention was turned to the nature and quality of the data used as proxies for education. As education systems vary among countries, it made sense at that point to try to normalize the data sets used in the estimations in order to take quality into account, and also minimize measurement errors related to data anomalies.

As Hanushek and Kimko (2000) observe, focussing only on the quantity of schooling to proxy for human capital appears to be too restrictive. In search of a better proxy, they assess a nation's labour force quality through scores obtained by students in science and mathematics international tests.[11] Starting from these test scores, they are able to construct a unique (normalized) labour force quality measure for 31 countries covering the 1960-1990 period. More explicitly, they compute a country's labour force quality measure as the weighted average over all harmonized test scores where each country's weight is calculated as the normalized inverse of its standard error. They then perform a single cross-country regression for the 31 countries over the 1960-1990 period. They regress the annual average growth rate on the initial (1960) per capita income, the quantity of schooling, the average rate of population growth, the quality of labour force and a constant. Their estimation reveals a negative and significant coefficient on the initial per capita income variable; a positive but insignificant coefficient on the quantity of schooling variable; a positive and highly significant coefficient on the labour force quality variable; and a negative but insignificant coefficient on the rate of population growth. After testing for causality, they sum up in writing that there is a significant and positive causal relationship between the quality of labour force (in other words better productivity) and the growth rate of the economy. They also specify that although the differences between countries are related to differences in the quality of schooling, their results do not allow them to state that this relation necessarily extends to a country's resources devoted in education. Despite these interesting findings, Hanushek and Kimko

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[11] Four tests were from the International Association for the Evaluation of Educational Achievement (IEA) and two were from the International Assessment of Educational Progress (IAEP).

do not appear to be concerned by the inclusion of both the quantity and quality of schooling on the right hand side of the same regression equation. It is possible that both variables be correlated: where there is poor education quality, the quantity of schooling is also likely to be low as there is little incentive to remain a student given the poor envisaged future rewards. Perhaps what their results tell is that schooling quality acts as such a better proxy for the contribution of education to growth that it eclipses the impact of the quantity of schooling. Although they report a R^2 as high as 0.73, there are no accompanying robustness tests to allow further analysis of their results.

Another study reporting the use of direct measures of schooling quality is that of Barro (2001). Data from the same source as Hanushek and Kimko (2000) are used to construct a single measure of test scores for each country, whether in science, mathematics, reading or overall. This single cross-section schooling quality data is then incorporated in the panel regression described above for Barro (1997), where the schooling quality data differs for each cross-country unit but remains the same for all the five or ten year sub-periods. The regression equation is defined by the real per capita economic growth rate as the dependent variable. The independent variables are those cited in Barro (1997). Barro's results suggest that the quality of education is much more important than the quantity as measured by secondary and university average levels of attainment. As for Hanushek and Kimko's results, Barro finds that the coefficient on the quantity of schooling variable is positive but insignificant, while that of the quality of schooling variable has a strong and significant predictive power. Information about the other variables' coefficient is not provided, as for robustness test to gauge the quality of the results.

A natural next step in growth empirics has been to turn attention towards the statistical properties of the data sets used when using panel estimation methods. In a 2000 important paper and a revised version in 2002, de la Fuente and Doménech settle the importance for OECD countries of correcting for inconsistencies and breaks in the data time profile attributable to the measurement methods and changes brought about, or the criteria used in classification. They study the performance of previously existing data sets and also construct what they consider improved credible time profiles for a new data bank on schooling attainment levels. After correcting for measurement errors, they evaluate a positive and significant relationship between the quality of data used and the size and significance of the growth regression coefficients on the human capital variables. In terms of performance, they conclude that their data sets are the most reliable, followed by Cohen and Soto's (2001). Finally, using extrapolated estimates of the corrected values and an extension of the classical errors-in-variables model, they evaluate that the "true" elasticity of output with respect to average years of schooling is very likely to be above 0.50.

In a study of absolute convergence across Canadian provinces, Coulombe and Tremblay (2001) use a model where human capital has only partial mobility[12] in contrast to a perfectly mobile financial and physical capital. The accumulation of human capital cannot be financed abroad because domestic residents cannot use human capital or raw labor as collateral. Using an empirical model *à la* Barro, Mankiw and and Sala-I-Martin (1995) for an open economy, they find that the accumulation of physical capital across Canadian provinces between 1951 and 1996 is driven by the accumulation process of human capital and also that the share of human capital in output is around 0.5. Moreover, their results suggest that the dynamics of human capital accumulation dictates[13] the evolution of physical capital, per capita income and output, and that these key macroeconomic observables all converge at the speed of convergence of human capital.

Coulombe (2000, 2003) also studied the role of urbanization[14] in a conditional convergence context for the Canadian provinces. Extending the model developed in Coulombe and Tremblay (2001) for the open economy and imperfect human capital

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[12] Partial mobility of human capital occurs because national agents cannot borrow abroad with human capital as collateral.

[13] They specifically state that this is a causal and unidirectional process.

[14] Urbanization in this context is considered as a reasonable proxy for economic development.

mobility, Coulombe uses data on the relative rates of urbanization across provinces[15] to explain the relative long-run provincial steady state levels of the human capital indicator and of the nominal per capita income. The results from these studies suggest that provinces have converged at an average speed of 5 percent a year, and that the differences between the respective provincial steady states appear not to be nominal but real. Another important conclusion from these studies is that human capital alone cannot account for the observed regional disparities in the macroeconomic observables. A relatively higher degree of urbanization seems to be concurrently necessary to bring about a higher long-run growth.

Another interesting paper is that by Bassanini and Scarpeta (2001). Using de la Fuente and Doménech's (2000) data set and a new pooled mean group – consistent – estimator (PMG,) Bassanini and Scarpeta conduct panel data estimations for 21 OECD countries. The PMG is said to allow for the speed of convergence and the short-term dynamics and variances to vary across countries as opposed to other panel estimations reported above. In practice, instead of taking five or ten year intervals, they use annual data for the variables included in their regressions. They conclude that they observed a " positive and significant impact of human capital accumulation" on the countries' growth paths. More precisely, they estimate a *long-ru*[16]*n* elasticity of output per capita to human capital of 0.6, which they interpret in saying that one more year of education has the effect of raising output per capita by about 6 percent - which they claim to be in accord with evidence from micro data. This is also consistent with de la Fuente and Doménech's (2002) estimated value to be above 0.5. On the other hand, their estimation of the speed of convergence (around 15 percent per year) is higher than the 2-5 percent estimated by other studies based on neoclassical human capital augmented models. As already stated in previous studies and mentioned above (Coulombe and Day, 1996; de la Fuente, 1998), such high speeds of convergence are to be regarded as manifestations of business cycle short term fluctuations that arise when using annual data in panel estimations.

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[15] Urban population is defined as " the population living within census metropolitain areas and census agglomeration with over 10,000 inhabitants"

[16] This appears to be different from the long run elasticities reported in our paper. See definition in Table 4.

2.6 About gender specific human capital effects

The literature survey above concentrated on human capital effects on growth for a population as a whole. But a quick thought about developing countries reminds us that for many societies, education is still mainly a man's privilege. As reported by Dollar and Gatti (1999): "*In the poorest quartile of countries in 1990, only 5% of adult women had any secondary education, one-half of the level for men. In the richest quartile, on the other hand, 51% of adult women had at least some secondary education, 88% of the level for men.*" Why then is there so little investment in girls' education in many countries is a question that instantly pops up. Again Dollar and Gatti (1999) provide us with insights. From their panel estimations, they identify religious preferences, regional factors and civil freedom as strong factors that hinder investment in girls' education. Another aspect to take into account is the fact that while women in a society might be highly educated, this is unlikely to contribute to growth if women do not have the possibility to earn income from their expertise. As Barro (2001) reports: "*One possible explanation for the weak role of female upper-level schooling in the growth panel is that many countries follow discriminatory practices that prevent the efficient exploitation of well-educated females in the formal labour market.*"

Another interesting facet to tackle in the relationship between education and growth is the impact of education on growth as the levels of income and/or education increase. Dollar and Gatti (1999) report that the relationship between income and female attainment is a convex function when moving from an extremely poor to a poor society. In other words, female education has no or little effect in an extremely poor society. Only when the level of income attains a *lower-middle* income level does female education translates into a rapid relative improvement as the society moves towards a more developed stage. The possibility of such a non-linear behaviour should be kept in mind too when studying OECD countries, which remain our chosen sample for the study of education and growth.

Although gender specific effects have been studied from microeconomic data since the 1970's, the corresponding macroeconomic literature on the subject starts with Benavot (1989) who first notes the absence of empirical study on the gender specific effects of education on growth. As cited above, Barro (1997) reports that female education appears to have no significant effect on growth at any level, which led him to formulate his hypothesis for the weak role of female education in growth (see previous paragraph, Barro (2001)). But in Barro and Lee's (1994) previous and much cited study, one could read that while male education enhances growth, female education appears to have a negative effect on growth. Barro and Lee interpret these results in terms of a measure of backwardness and a potential for higher growth. To fix ideas, Barro and Lee's (1994) estimation of the effect of male and female education on growth uses seemingly unrelated regression equations (SURE) technique. They regress growth on initial levels of stocks of physical and human capital and a set of variables that reflect the current political context like black market premium, the number of revolutions per year and the ratio of government consumption to GDP. The data used is that of Barro and Lee's (1993) average schooling years cross-country data for two ten-year intervals (1965-1975 and 1975 and 1985).[17]

Barro and Lee's results ran against the microeconomic evidence according to which female education lowers fertility rates (Cain and Weininger, 1973; Blau, 1986) and increases life expectancy (Blau, 1986). Another such micro study (Psacharopoulos, 1994) even reported that female's rate of return to education was positive and slightly higher than men's. Needless to say that Barro and Lee's (1994) results raised interest, and that their methods were closely examined. Two of the studies to scrutinize that perplexing result and propose explanations are that of Stokey (1994) and Lorgelly and Owen (1999). Stokey reports that Barro and Lee's female education variable becomes insignificant when adding dummy variables for geographic location of the four Asian Tiger countries (Hong Kong, Korea, Singapore and Taiwan) and so suggests that the female education

[17] A constraint is imposed so that estimated coefficients be the same across the two time periods.

variable appears to act as a dummy for groups (countries, ethnic groups, etc) that provide different education schemes for men and women.

These results are confirmed by Lorgelly and Owen (1999) who also find that the four Asian Tigers exert an influence such that it induces the female education variable to become negative. The interpretation given to this is that Barro and Lee (1994) obtain these results because of the weight exerted by the low educational attainment of women in the high growth regions of Hong Kong, Korea, Singapore and Taiwan. Furthermore, Lorgelly and Owen (1999) note that the backwardness argument proposed by Barro and Lee (1994) is not convincing because the initial period income per capita is included in the estimation equation and should therefore account for the convergence process. In addition, in their in-depth analysis of the Barro-Lee model, Lorgelly and Owen (1999) find that the significance of the *male* education variable is affected by the four Tigers data. They also suggest that these volatile results are affected by a high degree of multicollinearity found between male and female education variables.[18] More generally, Lorgelly and Owen observe the lack of robustness check through standard diagnostic tests by Barro and Lee. These criticisms apply as well to Perotti (1996) who also obtains a negative sign on female education for regressions carried out using the Barro-Lee cross-country estimation technique. Perotti goes as far as providing the same backwardness explanation as Barro and Lee to justify his results.

In contrast, the literature also provides us with studies that have found a positive effect of female education on growth. Although not without shortcomings of their own, these studies happen to obtain results in accord with micro data and the more general understanding of the benefits of education on growth. See for example Benavot (1989), Schultz (1995), Hill and King (1995), Caselli *et al.* (1996), Birdsall *et al.* (1997), Forbes (1998), Dollar and Gatti (1999), Klasen (1999, 2002) and Knowles *et al.* (2002). These studies use panel estimation techniques, typically with five-year time intervals, and aim at

[18] Both male and female education variables are simultaneously included on the right hand side of the regression equation in Barro and Lee (1994)

measuring long-run effects on growth, productivity or output levels. They also estimate different equations for males or females to avoid the multicollinearity problem. As concluded by Lorgelly (2000), panel estimations that include period averages of their education measures - instead of measures in the base period – obtain a positive and significant coefficient on the female education variable. Lorgelly also deplores the lack of formal theoretical background between education and growth and suggests that it might lead to regression results that are difficult to interpret and might even be misinterpreted in some cases. Never better served than by oneself, Knowles, Lorgelly and Owen (2002) develop an extension of Solow's human capital augmented model where they treat separately male and female human capital. Their model suggests that the narrowing of the educational gender gap contributes to increasing the level of GDP per capita in the steady state.

Despite Lorgelly's claim of the lack of theoretical models, Galor and Weil (1996) and Lagerlöf (2002) had already developed models that link fertility to growth respectively through the gender wage gap and the gender educational gap. They both make use of an overlapping generations model in which there are positive feedback loops involving relative female wages, fertility and growth of the capital/labour ratio in the case of Galor and Weil; or involving educational gender gap, fertility and the growth of investments in children's education in the case of Lagerlöf. These feedback effects have the potential to drive the system into different meta-stable states that depend on the actions taken (or not taken) to guide the dynamic – economic - system whether on an accelerated growth path, or in a poverty trap. Both Galor and Weil, and Lagerlöf's theoretical models lead to the conclusion that an increasing gender gap in education or wages is detrimental to growth. While these conclusions are in accord with the empirical results that find a positive effect of increased female education on growth, they conversely further isolate Barro (1997) who states that female higher education has no effect on growth.

While thinking about the empirical settings to use when testing these models, it is interesting to note that both theoretical models propose a double causality between fertility and educational/wage gender gaps. One should therefore remain vigilant when formulating regression specifications to avoid the potential multicollinearity problems these models involve. Moreover, the presence of a positive feedback loop linking education, fertility and growth can be understood in terms of a multiplier effect. This interesting feature is to be matched up with Psacharopoulos (1994) who reports that female's rate of return to education was positive and slightly higher than men's.

2.7 A few words about female labour force participation

The previous section briefly introduced the models of Galor and Weil (1996) and Lagerlöf (2002). We have also identified channels through which female educational attainment can improve the level of income per capita, among which we identified a reduced fertility rate, improvements in children's health capital, and female's participation in the labour market (Dollar and Gatti, 1999 and Barro 2001). For example, Galor and Weil identify three phases of development in their model:

1. Whenever there is an increase in capital per worker, it is accompanied by an increase in women's relative wages presumably because " *capital is more complementary to women's labour input than to men's* ";
2. an increase in women's relative wages has the effect of decreasing fertility because it raises the cost of having children relative to income;
3. a decrease in fertility raises the level of capital per worker.

As for Lagerlöf:

1. With a starting educational gender gap, parents who maximize their children's household well-being, will invest more in their son's education as their daughter will more likely marry an educated man. The reverse is less likely;
2. because the opportunity cost of having children is low for women, this association is likely to increase the fertility rate;
3. the increased fertility rate decreases investments in sons' education with the potential to drive the economy into a poverty trap.

While these models have a potential for describing the evolution of developing countries, one is justified to ask what happens if, like in many OECD countries with a high level of income per capita, the female participation rate has stabilised around that of males', while at the same time the fertility rate is at or below the replacement level and starts experiencing a slight increase? How should it affect the long run level of income per capita? or the level of productivity per worker ?

This is a situation quite different from what developing countries experience in the first phases of development. As the gender wage gap closes further in OECD countries, employers have fewer opportunities to hire women at a much lower salary in the expectation of increased profits. Also, more educated women on the labour market implies a higher proportion of educated individuals in a country. This might have the effect of decreasing the relative salaries of the highly educated compared to those who are not. Another point to take into account is that at a certain female labour participation threshold, societies endow themselves with social policies such as childcare services and parental leaves that depend on the economic context. What happens then when there is a recession with the associated cuts in social services? How do households who had a child during the last burst of economic growth decide to behave? So again, what does this imply in terms of changes of the steady state levels of output per capita and productivity per worker compared to a situation in which females yet are educated but do not participate enough in the labour market to induce social changes as OECD countries have experience during the past 15-20 years? Clearly, a more complete (overlapping generations) model would include other feedback loops stemming from the stationary state of high income per capita, low fertility and high female participation. The types of interactions would involve different preferences, available choices and constraints, as well as income and substitution effects (e.g. between male and female education) that appropriately describe the conditions that prevail in OECD countries. These would appropriately describe the transitions to the next steady states, following a perturbation in one of the degrees of freedom.

In terms of panel estimation, we have yet to define what is the correct specification to use and what interpretation should be given to the coefficients in the absence of a formal model that includes both the fertility and female market participation channels. Modelling the feedback loops described above and including (or not) fertility, education and female participation simultaneously on the right hand side of the regression is another point to be settled. The methods and specifications used for the purpose of this major paper constitute a step towards this objective.

Chapter 3: Methodology

3.1 Data

The present investigation is restricted to 14 OECD countries: Belgium (Flanders), Canada, Denmark, Finland, Germany, Ireland, Italy, Netherlands, Norway, New Zealand, Sweden, Switzerland, United Kingdom and the United States. The data used for this project come from different sources and cover at least the 1960 to 1995 period.

First, there are variables for which information was directly available. The fertility rates were drawn from the United Nations' database, while the women labour force participation rates were collected from the World Bank's World Development Indicators 2002. Information on GDP per capita and per worker, imports and exports, and the investments rates (investment as a share of GDP) were gathered from the Penn World Tables (version 6.1). These are in terms of purchasing power parity (PPP) in order to be able to compare real quantities between countries. The openness ratio stands for the relative amount of exports plus imports to GDP, normalized according to land area and population of a country as in Barro (2001). Fertility and investment rates as well as openness ratios are averaged over five year periods.

Second, the human capital variable is proxied by data on education. The indicators used are computed from the test results of the 1994 International Adult Literacy Survey (IALS). This survey provides data on individuals between 16 to 65 years of age whose literacy skills were tested on the subjects of prose, quantitative and document. Doug Willms from the University of New-Brunswick set up synthetic time series from the cross-section data - using the age distributions of the test results – and assuming that individuals keep a constant level of human capital all the way through their lives. The data can be separated between the two gender groups for each of the 14 OECD countries.

The indicators used are based on the literacy test results of 17 to 25 years old individuals in a specific period. They are then used as proxies for the previous period's investment in human capital. Since the same tests were conducted internationally, these literacy scores have the advantage of being comparable between different national education systems.

Consequently, they can be used as a direct measure of the relative quality of human capital between countries. This is not the case with schooling data. One weakness of these synthetic indicators is that they do not allow for migration flows during the period considered. Another shortcoming is that since individuals are assigned a level of literacy for a period earlier in their actual lives, these indicators do not capture the changes in the human capital quality as a result of learning and depreciation.

3.2 Empirical Methods

The present research examines the relationship between economics growth and a selection of its well known determinants. In an empirical setting framework, the dependent variable considered is the level of GDP per capita or GDP per worker (labour productivity), while the independent variables are the initial GDP per capita or worker, the investment rate, the openness ratio, the fertility rate, the female labour participation rate and the male or female literacy indicator.

The cross-sectional dimension of the empirical methodology used to study the relationship between economic growth and its determinants is based on that of Mankiw, Romer and Weil (1992), and Barro and Sala-i-Martin (1992). Furthermore, these methods were extended to panel estimation techniques to include a temporal dimension according to Coulombe and Lee (1995) and Islam (1995) among others. The principal steps of the panel estimation technique used in this project are presented below. The complete details can be found in Coulombe, Tremblay and Marchand (2003). The following econometric specifications imply that we assume equal growth rates of technological progress and equal depreciation rates across countries. But since the regressions performed include fixed effects, different levels of technology across countries are also allowed in this context.

The empirical analysis is based on the following regression equation:

$$\Delta y_{i,t} = \varphi_1 y_{i,t-1} + \varphi_2 s(k)_{i,t} + \varphi_3 s(h)_{i,t} + \varphi_4 n_{i,t} + \varphi_5 open_{i,t} + \varphi_6 wlfp_{i,t} + \varphi_{7,i} FE_i + \varepsilon_{i,t}, \qquad (1)$$

with $t = 1, \ldots, 8$ where period 1 corresponds to 1960 and period 8 to 1995 for each country i of the sample of 14 OECD countries. Here, the dependent variable is the measured mean annual growth rate of country i in period t. The dependent variables are respectively - in their order of appearance in equation 1 - the initial period (lagged) level of GDP per capita or per worker; the investment ratio variable $s(k)_{i,t}$ is the mean ratio of investment in physical capital to GDP in period t; $s(h)_{i,t}$ is the mean ratio of investment in human capital to GDP in period t; $n_{i,t}$ is either the mean rate of population growth or the fertility rate in period t; $open_{i,t}$ is the (adjusted) openness ratio variable; $wlfp_{i,t}$ represents women's labour force participation rate relative to men; FE_i are country specific fixed effects, and the $\varepsilon_{i,t}$ are the additive error terms. In this theoretical framework, the point estimate of the φ_1 parameter is the estimated speed of convergence averaged over the sample of 14 countries.

The grouping of time series and cross-sectional data in growth regressions requires that special care. To obtain unbiased estimates, common trends and shocks have to be removed from the time series data. A suitable approach used here is that presented in Coulombe and Lee (1995), Coulombe (2000, and 2003), de la Fuente (1998, and 2002) among others. The procedure consists in defining the Y and Z variables as logarithm deviations from the cross-sectional sample mean:

$$x_{i,t} = \log\left(X_{i,t} \Big/ \sum_{i=1}^{N} \tfrac{1}{N} X_{i,t} \right),$$

where X is a variable included in our panel regression. This has the advantage of tackling the multicollinearity problem that arises when there is a possibility of correlation between the independent variables. This has probably been true since 1960 for our 14 OECD countries given that the evolution of women education, fertility rate, and relative labour participation have influenced one another because of the socio-economic evolution of the relationships between men and women.

The long run output level effect of a permanent shock to any z_i independent variable can also be calculated from the steady state solution to equation 1, where $\Delta y_{i,t} = 0$ at $y = y*$. Hence, the long run elasticities for the various z are:

$$\frac{\partial y_i *}{\partial z_i *} = -\frac{\hat{\varphi}_{z,i}}{\hat{\varphi}_1} \qquad (2)$$

The panel estimations are performed with both the iterated feasible generalized least-squares (IFGLS) and the iterative weighted two-stage least squares with instrumental variables (IWTSLS-IV) techniques. Iterative techniques for updating coefficients and the weighting matrix were used for both methods when possible.

The IFGLS results were obtained from generalized least-squares (GLS) estimations with cross-sectional weights attributed to each country in the regressions. This is done in order to make up for the presence of cross-sectional heteroskedasticity. In addition, the White heteroskedasticity consistent standard errors (HCCME) are calculated to obtain asymptotically valid inferences when there is time series heteroskedasticity.

Another way of accounting for cross-sectional heteroskedasticity is to perform estimation using instrumental variables (IV) concurrently with the IWTSLS technique. The IV method is the standard procedure to palliate the simultaneity/endogeneity problem that might occur when there is a bi-directional contemporaneous relationship between one or many of the independent variables and the dependent variable.

Chapter 4: Results and discussion

4.1 Results from Coulombe, Tremblay and Marchand (2003)

Most of the results and analysis presented in this chapter appear separately in Coulombe, Tremblay and Marchand (2003). Some of the results and analysis produced by the other authors are summarized in the following paragraph, but the remainder of this chapter is the present author's original work.

The results from Coulombe *et al.* (2003) indicate that the average literacy scores used to construct the proxies for human capital have a positive and significant effect on the long run levels of GDP per capita and per worker when considering the whole population. The method and results obtained from it appear to outperform the de la Fuente and Doménech's (2002) schooling indicators. Also, the results suggest that the average test scores of the whole population perform better than the indicators based on the proportion of high achievers in the population (those who attained at least level 4 of 5). The more specific results that need to be introduced are those from the regressions that simultaneously include men and women's respective average literacy scores as the human capital indicators. These regressions had the difference of GDP per capita or GDP per worker as the dependent variables, with the initial GDP per capita or worker, the investment rate, the openness ratio, the fertility rate and the men and women literacy indicator as the independent variables. All the resulting point estimates of women's literacy score were positive and highly significant while those for men were insignificant and sometimes with a negative sign, which is opposite to what is expected.

Based on these results and on the corresponding literature survey, it was decided to perform separate regressions for men and women and to introduce women's relative labour force participation as a supplementary regressor to the equation. Regressions of GDP per capita and per worker have been performed as the GDP per worker results initially appeared more robust.

4.2 Results specific to this major paper

Tables 1 and 2 respectively contain the regression results for the conditional convergence of GDP per capita and GDP per worker obtained from equation 1, using average literacy test scores of men and women as measures of human capital investment. In all cases the point estimate on women's literacy indicator is close to or the double of that observed for men for both GDP per capita and GDP per worker. However, only the literacy point estimates observed in the case of GDP per worker are significant for both men (5% level of significance) and women (1% level of significance). In the case of GDP per capita, only the literacy point estimates of women come out significant (1% level). Surprisingly enough, the point estimates on women's relative labour force participation indicator are consistently negative and significant at the 1% level except in men's GDP per capita IFGLS regression where it is significant at the 5% level.

What happens to the point estimates of the other indicators depends on whether we deal with the GDP per capita or per worker regression. In the case of GDP per capita, the point estimates on the initial GDP per capita and the investment rate have the correct positive sign and all are significant at the 1% level. The point estimates on the fertility rate also have the correct sign and are all significant at the 5% level. The point estimates on the openness ratio still have the correct sign, but loose their significance (except for men's IFGLS regression) contrary to those obtained in regressions excluding women's labour participation rate (Coulombe et al., 2003).

Except for the positive but insignificant point estimate of the fertility rate, the other indicators' point estimates obtained from the GDP per worker regressions all have the correct sign and are all significant at the 1% level. The R^2 for the GDP per capita IFGLS regressions are 0.58 and 0.59 respectively for men and women; and those for the GDP per worker are 0.73 and 0.75 respectively for men and women. In all cases, the Durbin-Watson test results suggest that there is no significant problem of serial correlation.

TABLE 1: Conditional Convergence of GDP Per Capita Using Average Literacy Scores of Men and Women Aged 17-25 as Human Capital Investment Measures.
Estimations over the 1960-1995 period, with country fixed effects

Dependent variable: Log difference of GDP per capita				
	IFGLS		**IWTSLS-IV**	
Independent variables	**Men**	**Women**	**Men**	**Women**
Initial GDP	-0.065*** (0.014)	-0.082*** (0.013)	-0.065*** (0.012)	-0.082*** (0.012)
Women labour participation	-0.087** (0.034)	-0.093*** (0.032)	-0.089*** (0.032)	-0.093*** (0.031)
Human capital	0.047 (0.029)	0.094*** (0.030)	0.047 (0.030)	0.094*** (0.029)
Openness ratio	0.013* (0.008)	0.012* (0.007)	0.013 (0.008)	0.012 (0.008)
Investment rate	0.031*** (0.009)	0.038*** (0.007)	0.030*** (0.008)	0.038*** (0.008)
Fertility rate	-0.020** (0.009)	-0.017** (0.008)	-0.019** (0.008)	-0.017** (0.008)
R^2	0.58	0.59		
Durbin-Watson	2.30	2.40		

Notes: There are respectively 94 and 95 observations in each IWTSLS-IV and IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; IWTSLS-IV: iterative weighted two-stage least squares with instrumental variables. Instruments used for the IWTSLS-IV estimations are initial GDP per worker and the lagged values of the investment rate, of the openness ratio, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women.

TABLE 2: Conditional Convergence of GDP Per Worker Using Average Literacy Scores of Men and Women Aged 17-25 as Human Capital Investment Measures.
Estimations over the 1960-1995 period, with country fixed effects

Dependent variable: Log difference of GDP per worker				
	IFGLS		**IWTSLS-IV**	
Independent variables	**Men**	**Women**	**Men**	**Women**
Initial GDP	-0.054*** (0.011)	-0.070*** (0.010)	-0.054*** (0.010)	-0.070*** (0.009)
Women labour participation	-0.155*** (0.037)	-0.158*** (0.028)	-0.156*** (0.034)	-0.158*** (0.029)
Human capital	0.056** (0.026)	0.105*** (0.023)	0.058** (0.026)	0.105*** (0.022)
Openness ratio	0.016*** (0.005)	0.017*** (0.004)	0.016*** (0.006)	0.017*** (0.006)
Investment rate	0.028*** (0.006)	0.034*** (0.005)	0.028*** (0.007)	0.034*** (0.006)
Fertility rate	0.001 (0.007)	0.010 (0.007)	0.001 (0.007)	0.010 (0.006)
R^2	0.73	0.75		
Durbin-Watson	2.50	2.57		

Notes: There are respectively 89 and 90 observations in each IWTSLS-IV and IFGLS regression. The pool of countries excludes Germany because of missing data. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; IWTSLS-IV: iterative weighted two-stage least squares with instrumental variables. Instruments used for the IWTSLS-IV estimations are initial GDP per worker and the lagged values of the investment rate, of the openness ratio, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women.

Regression results obtained when using the human capital indicator for the total population (men and women pooled together) are presented in Table 3. The point estimates on the human capital variable are significant at the 5% level for the conditional convergence of GDP per capita (IFGLS, IV-WTSLS), and significant at the 1% level in the case of GDP per worker (IFGLS, IV-WTSLS). Except for the IFGLS / GDP per capita result – which is significant at the 5% level – all other point estimates on the women labour force participation variable are significant at the 1% level. Again, the point estimates on the initial GDP per capita and the investment rate have the correct

TABLE 3: Conditional Convergence of GDP Per Capita and per Worker Using Average Literacy Scores of the Population Aged 17-25 as Human Capital Investment Measures.

Estimations over the 1960-1995 period, with country fixed effects

Dependent variable: Log difference of				
	GDP per capita		**GDP per worker**	
Independent variables	**IFGLS**	**IWTSLS-IV**	**IFGLS**	**IWTSLS-IV**
Initial GDP	-0.071*** (0.013)	-0.070*** (0.011)	-0.059*** (0.010)	-0.059*** (0.009)
Women labour participation	-0.088** (0.034)	-0.089*** (0.032)	-0.162*** (0.033)	-0.163*** (0.032)
Human capital	0.081** (0.034)	0.081** (0.033)	0.092*** (0.027)	0.093*** (0.028)
Openness ratio	0.014* (0.007)	0.013 (0.008)	0.016*** (0.004)	0.016*** (0.006)
Investment rate	0.035*** (0.008)	0.035*** (0.008)	0.032*** (0.006)	0.032*** (0.007)
Fertility rate	-0.018* (0.009)	-0.017** (0.008)	0.005 (0.007)	0.006 (0.007)
R^2	0.59		0.75	
Durbin-Watson	2.34		2.53	

Notes: There are respectively 94 and 95 observations in each GDP per capita IWTSLS-IV and IFGLS regression. There are respectively 89 and 90 observations in each GDP per worker IWTSLS-IV and IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. The pool of countries excludes Germany in the case of GDP per worker. GDP per capita and per worker are adjusted for PPP. IFGLS: iterated feasible generalized least squares; IWTSLS-IV: iterative weighted two-stage least squares with instrumental variables. Instruments used for the IWTSLS-IV estimations are initial GDP per capita or worker and the lagged values of the investment rate, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women.

positive sign and all are significant at the 1% level. The point estimates on the fertility rate for the GDP per capita regressions are significant at the 10% and 5% respectively for the IFGLS and IV-WTSLS methods; it loses any significance in the GDP per worker regression.[19] The openness ratio is significant at the 1% level in the GDP per worker

[19] Problems of double causality are discussed below.

regressions but significant at the 10% level in the GDP per capita IFGLS regression and otherwise insignificant.

The R^2 for the IFGLS GDP per capita and GDP per worker regressions are respectively 0.59 and 0.75. These numbers are consistent with those obtained for the gender separate regressions (see Tables 1 and 2). Again, the Durbin-Watson test results indicate no problem of serial correlation.

Table 4 presents the long run elasticities of GDP per capita and GDP per worker with respect to investment in the human capital of men and women. The long-run elasticity is defined as minus the ratio of the coefficient of the human capital variable to the coefficient of initial GDP per capita. The long-run elasticities and levels of significance for the literacy measure were calculated from the results contained in Tables 1 and 2 (IFGLS and IV-WTSLS). The detailed IFGLS results for the document, prose and quantitative human capital investment measures are not shown. Like for the conditional convergence results, the long run elasticities in Table 4 suggest that investment in women's education has a stronger effect on the long-run level of output. More precisely, women's long run elasticities are always larger than men's, with a level of significance of 1% for the four human capital investment indicators. Only in the case of GDP per worker do men's long-run elasticities attain a level of significance of 5% (except for the document skills). The R^2, calculated from the conditional convergence regression results, are around 0.59 for GDP per capita and around 0.75 for GDP per worker.

The results also indicate a stronger impact on growth from investment in women's prose skills in the case of GDP per capita, and quantitative skills in the case of GDP per worker. Men's results could suggest that document skills are less important in the case of GDP per capita, but the document skills' long-run elasticity is not significant. For the case of GDP per worker, the document skills' long run elasticity is slightly lower than for the other skills but again no firm conclusion can be drawn from this result, because the difference is small and it does not exhibit a high level of significance (10%).

TABLE 4: Long Run Elasticity of GDP per Capita and per Worker with Respect to Human Capital Investment Measures.

Estimations over the 1960-1995 period, with country fixed effects.

		Literacy IFGLS	**Literacy** IV-WTSLS	**Document** IFGLS	**Prose** IFGLS	**Quantitative** IFGLS
GDP per Capita	**Men**	0.82*	0.81	0.63	0.88*	0.88*
	R^2	[0.58]		[0.57]	[0.57]	[0.59]
	Women	1.23***	1.23***	1.20***	1.30***	1.10***
	R^2	[0.60]		[0.58]	[0.60]	[0.60]
GDP per Worker	**Men**	1.04**	1.08**	0.91*	1.07**	1.02**
	R^2	[0.73]		[0.72]	[0.73]	[0.74]
	Women	1.49***	1.51***	1.25***	1.36***	1.77***
	R^2	[0.75]		[0.73]	[0.78]	[0.76]

Notes: There are respectively 89 and 90 observations in each IWTSLS-IV and IFGLS regression; the pool of countries excludes Germany. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation. IWTSLS-IV: iterative weighted two-stage least squares with instrumental variables. Instruments used for the IWTSLS-IV estimations are initial GDP per worker and the lagged values of the investment rate, of the openness ratio, of the fertility rate, of the de la Fuente and Doménech average schooling years variable and of the labour force participation of women. The long run elasticity is defined as the ratio of the coefficient of initial GDP per capita - or per worker - to that of human capital obtained from an IFGLS or IWTSLS-IV regression.

At this stage, the overall results suggest that:

- Investment in the total population's literacy skills has a positive and significant impact on the growth of GDP per capita (5% level) and GDP per worker (1% level).
- Investment in women's literacy has a highly significant (1%) and stronger impact than investment in men's literacy on growth of GDP per capita and per worker.

- Women's labour force participation has a highly significant (1%) and negative impact on growth of GDP per capita and per worker for both men and women's estimations, and for the total population.
- The initial GDP per capita and per worker, and the investment rate have a highly significant (1%) and positive impact on the long-run levels of GDP per capita and per worker for both men and women's estimations, and for the total population.
- The openness ratio has a highly significant (1%) and positive impact on the long-run levels of GDP per worker for both men and women's estimations, and for the total population.
- The fertility rate has a moderately significant (5%) and negative impact on the long-run levels of GDP per capita for both men and women's estimations, and for the total population.

The first surprise that comes out of these results is the fact that investment in women's overall literacy skills has a stronger effect on subsequent growth than investment in men's literacy skills. It is important to stress again that the regressions already control for fertility and women's labour force participation and so the impact of women's literacy on growth should be independent from the influence exerted by fertility and women's labour participation. Another surprise is the fact that women's labour force participation has a negative and highly significant (1%) impact in all cases. Before concluding that educated women who stay at home are the key to a strong economy, it was decided to perform robustness checks on the conditional convergence regressions.

Regressions carried out for the 1960-1980 and 1980-1995 subperiods are presented in Table 5. This first test is to assess the robustness of our results with respect to the sequence of data points in the countries' time series. What Table 5 suggests is that our results are unstable throughout the whole period: the point estimates of the initial GDP per capita variable were all positive and significant at the 1% level, similar to the investment rate and the male and female literacy variables results; otherwise, some of the point estimates have the wrong sign, e.g. the fertility rate in the 1960-1980 subperiod, and the openness ratio in the 1980-1995 subperiod, although none is significant. The sign of

TABLE 5: Conditional Convergence of GDP Per Capita Using Average Literacy Scores of Men and Women Aged 17-25 as Human Capital Investment Measures.
IFGLS estimations over the 1960-1980 and 1980-1995 periods, with country fixed effects

Period		Investment rate	Openness ratio	Fertility rate	Human capital	Women labour participation rate
1960-1980	**Men**	0.023***	0.025	0.012	0.11***	0.18***
	R^2 D.-W.	0.71 2.66				
	Women	0.030***	0.025	0.015	0.129***	0.203***
	R^2 D.-W.	0.75 2.68				
1980-1995	**Men**	0.116***	-0.036**	-0.043***	0.076***	-0.069***
	R^2 D.-W.	0.999 2.64				
	Women	0.116***	-0.039***	-0.047***	0.083***	-0.123***
	R^2 D.-W.	0.999 2.61				

Notes: There are respectively 53 and 42 observations in the 1960-1980 and 1980-1995 IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares.

the point estimate on the women labour participation rate variable has the right positive sign and is significant at the 1% level between 1960-1980, but changes to a negative sign and is significant (1%) in the 1980-1995 subperiod, similar to the results obtained for the whole period. Moreover, the R^2 of the 1980-1995 subperiod regression is 0.999 which is an indication of a problem.

Tables 6 and 7 present the results of the robustness tests carried on the regression results that appear in Tables 1 and 2. Specifically, each of the 14 test regressions performed excludes a different one of the initial set of 14 OECD countries. The point estimates on the human capital (literacy) indicator and on women's labour force participation are

TABLE 6: Robustness Check of the Conditional Convergence of GDP Per Capita Using Average Literacy Scores of Men and Women Aged 17-25 as Human Capital Investment Measures.

Estimations over the 1960-1995 period, with country fixed effects

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		**Women**	
Country removed from regression	Human capital	Women labour participation	Human capital	Women labour participation
Belgium	0.044 (0.030)	-0.093*** (0.033)	0.095*** (0.034)	-0.096*** (0.032)
Canada	0.077** (0.033)	-0.040 (0.045)	0.083** (0.034)	-0.059 (0.043)
Switzerland	0.032 (0.031)	-0.107*** (0.031)	0.099*** (0.031)	-0.107*** (0.031)
Denmark	0.056* (0.030)	-0.083** (0.035)	0.090*** (0.030)	-0.092*** (0.033)
Finland	0.047 (0.030)	-0.099*** (0.032)	0.092*** (0.028)	-0.101*** (0.031)
Germany	0.051* (0.030)	-0.066 (-0.046)	0.099*** (0.030)	-0.066 (0.040)
Ireland	0.038 (0.030)	-0.076** (0.035)	0.097*** (0.030)	-0.082** (0.034)
Italy	0.050* (0.030)	-0.086** (0.034)	0.095*** (0.031)	-0.092*** (0.032)
Netherlands	0.051* (0.029)	-0.103*** (0.033)	0.098*** (0.029)	-0.106*** (0.032)
Norway	0.040 (0.029)	-0.110*** (0.032)	0.099*** (0.030)	-0.112*** (0.031)
New Zealand	0.044 (0.030)	-0.087** (0.034)	0.093*** (0.031)	-0.092*** (0.033)
Sweden	0.047 (0.030)	-0.076* (0.040)	0.088*** (0.030)	-0.087** (0.040)
United Kingdom	0.022 (0.033)	-0.061* (0.034)	0.072** (0.035)	-0.070** (0.033)
United States	0.053 (0.040)	-0.086** (0.035)	0.095** (0.037)	-0.095*** (0.034)

Notes: There are 88 observations in each of the 14 GDP per capita IFGLS regressions, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes a specified country from the initial sample of 14.

given as a function of the country removed from the sample. A significant variability across the 14 regression results (each excluding a different country) should be interpreted as a lack of robustness of the initial conditional convergence results including the complete set of 14 countries.

Table 6 displays the test results for the conditional convergence of GDP per capita. The point estimate on women's literacy indicator appears to be robust, at least with respect to sample variability. The point estimate remains significant in all cases (1%) except that the level of significance drops to 5% when Canada, the United States or the United Kingdom is removed from the sample. On the other hand, men's literacy point estimate exhibits a significant variability: when Canada is removed from the sample, the literacy point estimate becomes significant at the 5% level, and significant at the 10% level when Denmark, Germany, Italy or Netherlands is removed. It otherwise remains insignificant. For both men and women, the point estimate on women's labour force participation also reveals itself vulnerable to sample variability, and loses any significance when Canada or Germany is removed from the sample.

Homologous results for GDP per worker are shown in Table 7. Again, the point estimate on women's literacy indicator is robust with respect to sample variability and remains highly significant (1%) in all cases. On the other hand, men's literacy point estimate is once more vulnerable to sample variability and loses any significance when the United Kingdom is removed from the sample of countries. And once more, for both men and women, the point estimate on women's labour force participation becomes insignificant when Canada is removed from the sample. Interestingly, Canada is the only country that generates a significant negative sign to this point estimate.

At this stage, the test results suggest that the conditional convergence regressions are not overall robust for all point estimates. In order to further evaluate the robustness of the results, the sample cross-sectional variability of the long-run elasticities with respect to the remaining independent variables were calculated for both men and women in the cases of GDP per capita and GDP per worker (IFGLS estimations only). They are

TABLE 7: Robustness Check of the Conditional Convergence of GDP Per Worker Using Average Literacy Scores of Men and Women Aged 17-25 as Human Capital Investment Measures.

Estimations over the 1960-1995 period, with country fixed effects

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		**Women**	
Country removed from regression	Human capital	Women labour participation	Human capital	Women labour participation
Belgium	0.061** (0.027)	-0.157*** (0.038)	0.116*** (0.024)	-0.151*** (0.028)
Canada	0.125*** (0.034)	0.003 (0.054)	0.134*** (0.034)	-0.042 (0.055)
Switzerland	0.055** (0.026)	-0.170*** (0.037)	0.106*** (0.023)	-0.167*** (0.028)
Denmark	0.062** (0.026)	-0.152*** (0.038)	0.104*** (0.024)	-0.157*** (0.028)
Finland	0.063** (0.026)	-0.162*** (0.036)	0.108*** (0.023)	-0.158*** (0.027)
Germany				
Ireland	0.048* (0.027)	-0.147*** (0.038)	0.108*** (0.023)	-0.152*** (0.028)
Italy	0.054** (0.027)	-0.159*** (0.038)	0.102*** (0.024)	-0.161*** (0.029)
Netherlands	0.060** (0.026)	-0.161*** (0.038)	0.110*** (0.023)	-0.162*** (0.028)
Norway	0.054** (0.026)	-0.184*** (0.038)	0.104*** (0.023)	-0.176*** (0.028)
New Zealand	0.055** (0.027)	-0.155*** (0.038)	0.102*** (0.024)	-0.160*** (0.028)
Sweden	0.056** (0.027)	-0.167*** (0.059)	0.106*** (0.023)	-0.142*** (0.040)
United Kingdom	-0.037 (0.043)	-0.097** (0.040)	0.090*** (0.032)	-0.138*** (0.031)
United States	0.052* (0.028)	-0.154*** (0.039)	0.084*** (0.027)	-0.168*** (0.032)

Notes: There are 83 observations in each of the 14 GDP per worker IFGLS regressions. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes Germany and another specified country from the initial sample of 14.

reported in Tables 8 to 17 and are also defined as minus the ratio of the coefficient of the relevant variable to the coefficient of initial GDP per capita.

Without going into the details of each Table, the test results reveal that, among the point estimates obtained from the conditional convergence estimations of GDP per capita and per worker, only the initial GDP[20], the investment rate and the women literacy point estimates are stable. These are the only point estimates that remain at least at a 5% level of significance after the removal of a country from the sample, and are thus robust with respect to sample cross-sectional variability. The other variables lose their significance when only one of the 14 countries is removed from the sample and are therefore unstable.

Although their specification and estimation methods are different, de la Fuente and Doménech (2002) conducted a similar procedure to test for the robustness of their estimations. Their sample initially included 21 OECD countries with countries such as Greece, Portugal and Spain that drew themselves nearer to the average OECD level during the period. Unfortunately, data for these three countries were not available for the purpose of our work. Their robustness analysis[21] indicates that, when dropping one country at the time for each of the 21 countries from the regression, the estimated coefficients on human capital with their respective confidence interval, vary the most when one Greece, Portugal or Spain is removed from the sample. Indeed, their coefficient on human capital is only marginally significant when the sample excludes Portugal.In particular, their human capital point estimate becomes marginally significant when deleting Portugal from their pool of 21 OECD countries.

Granger causality tests have also been carried out for each country (results not shown) to assess the possible double causality between independent variables. In particular, we looked for indications of double causality between fertility and female or female education, fertility and women labour participation, male of female education and women labour participation or male and female education. Results confirmed that there is

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[20] Initial GDP per capita and per worker

[21] As illustrated in Figure 9 on page 30 of the August 2002 version of their paper.

evidence of significant Granger causality (at least at the 5% level) for Switzerland, Ireland, the Netherlands, Sweden, the United Kingdom and the United States. All of the possible combinations cited above were detected. Also important to note is the possibility of reverse causality between the dependent variable and any of its independent variables. As noted in Coulombe, Tremblay and Marchand (2003), "*The possibility of reverse causality is particularly relevant in our analysis, given that our human capital investment measures are based on literacy tests performed at the end of the period of analysis, and are therefore distorted, among other things, by the migration flows that occurred over the period.*"

On the whole, all the robustness and Granger causality analysis results point to multicollinearity problems: point estimates proved very sensitive to variations in the sample size and some of the point estimates have an unexpected sign in particular regressions. Nevertheless, of the preliminary evaluation we made of the results, the following deductions remain:

1. Investment in women's literacy has a highly significant (1%) and strong impact on growth of GDP per capita and per worker. Moreover, women's long run elasticities with respect to literacy are always larger and more significant than men's. More precisely, while women's literacy has a significant effect at the 1% level on both GDP per capita and per worker, investment in men's literacy only has a significant effect at the 5% level on GDP per worker. Hence, results seem to indicate that investment in women's literacy probably has a stronger impact on growth than investment in men's literacy. This aspect is discussed below.

2. The initial GDP per capita and per worker, and the investment rate have a highly significant (1%) and positive impact on the growth of GDP per capita and per worker for both men and women's estimations.

We unfortunately have to admit that robustness tests on the regressions involving data for the population as a whole are missing. Results to this effect should be computed and are essential to assess the validity of the results for the whole population.

Our regression results suggest that investment in women's literacy has a stronger impact than for men. It is possible that the female literacy variable proxies concurrently for other aspects of women's contribution to economic growth, like social capital. In addition, it is possible that, given the fact that there were initially social barriers to the education of women, investment in females' education may have been provided to the more ambitious and intellectually capable individuals (Coulombe, Tremblay and Marchand, 2003). On the other hand, to have an impact on growth, women had to actually use their acquired competencies in participating in the labour market. Because there were also cultural barriers that prevented educated women to work and earn money outside the household, the democratisation of the workplace might also have been incorporated in the female literacy variable.

Another way to look at the greater impact of women education on growth is that the fall of cultural barriers to women education and labour force participation probably involved a greater impact on GDP because of *marginal return effect* (Coulombe, Tremblay and Marchand, 2003). The marginal increase in labour productivity that results from an increase in human capital and democratisation of the labour market is higher for those with low initial levels of human capital. Psacharopoulos (1994) reports similar findings on the rates of return to education between sexes.

Finally, referring again to Coulombe et *al.* (2003), since men labour and women labour are not perfect substitutes, there is the possibility of an imbalance effect between physical and human capital because of the initial low level of education of women. The idea is that the imbalance between physical and human capital stocks generates a higher marginal return for the scarcer capital stock and its accumulation therefore induces rapid growth.

TABLE 8: Long Run Elasticity of GDP per Capita with Respect to Human Capital.
Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to human capital	Initial GDP per capita	Long run elasticity of GDP per capita to human capital
Belgium	-0.067*** (0.015)	0.657	-0.079*** (0.013)	1.203***
Canada	-0.052*** (0.014)	1.481**	-0.072*** (0.013)	1.153**
Switzerland	-0.076*** (0.014)	0.421	-0.090*** (0.013)	1.100***
Denmark	-0.058*** (0.014)	0.966*	-0.076*** (0.013)	1.184***
Finland	-0.061*** (0.015)	0.770	-0.078*** (0.013)	1.179***
Germany	-0.062*** (0.014)	0.823*	-0.081*** (0.013)	1.222***
Ireland	-0.075*** (0.014)	0.507	-0.089*** (0.013)	1.090***
Italy	-0.066*** (0.015)	0.758*	-0.080*** (0.014)	1.188***
Netherlands	-0.062*** (0.014)	0.823*	-0.080*** (0.013)	1.225***
Norway	-0.070*** (0.014)	0.571	-0.087*** (0.013)	1.138***
New Zealand	-0.069*** (0.015)	0.638	-0.087*** (0.014)	1.069***
Sweden	-0.065*** (0.014)	0.724	-0.081*** (0.013)	1.087***
United Kingdom	-0.043*** (0.016)	0.512	-0.060*** (0.017)	1.200**
United States	-0.068*** (0.014)	0.779	-0.087*** (0.014)	1.092**
Average of the 14 long run elasticities		0.745 [0.721, 0.769]		1.152 [1.138, 1.166]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes a specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of human capital to that of initial GDP per capita. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 9: Long Run Elasticity of GDP per Worker with Respect to Human Capital.
Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to human capital	Initial GDP per worker	Long run elasticity of GDP per worker to human capital
Belgium	-0.052*** (0.013)	1.173**	-0.065*** (0.010)	1.785***
Canada	-0.040*** (0.011)	3.125***	-0.069*** (0.011)	1.942***
Switzerland	-0.058*** (0.012)	0.948**	-0.074*** (0.010)	1.432***
Denmark	-0.051*** (0.011)	1.216**	-0.067*** (0.010)	1.552***
Finland	-0.051*** (0.011)	1.235**	-0.069*** (0.010)	1.565***
Germany				
Ireland	-0.061*** (0.012)	0.787*	-0.076*** (0.010)	1.421***
Italy	-0.058*** (0.013)	0.932**	-0.072*** (0.011)	1.417***
Netherlands	-0.053*** (0.011)	1.132**	-0.071*** (0.010)	1.549***
Norway	-0.058*** (0.012)	0.932**	-0.073*** (0.010)	1.425***
New Zealand	-0.055*** (0.012)	1.00**	-0.071*** (0.010)	1.437***
Sweden	-0.053*** (0.011)	1.057**	-0.070*** (0.010)	1.514***
United Kingdom	-0.027* (0.015)	-1.370	-0.057*** (0.016)	1.579***
United States	-0.055*** (0.012)	0.945*	-0.069*** (0.011)	1.217***
Average of the 14 long run elasticities		1.008 [0.943, 1.073]		1.526 [1.503, 1.549]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 13 regressions excludes Germany and another specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of human capital to that of initial GDP per worker. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 10: Long Run Elasticity of GDP per Capita with Respect to Women Labour Participation.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to women labour participation	Initial GDP per capita	Long run elasticity of GDP per capita to women labour participation
Belgium	-0.067*** (0.015)	-1.382**	-0.079*** (0.013)	-1.212**
Canada	-0.052*** (0.014)	-0.768	-0.072*** (0.013)	-0.822
Switzerland	-0.076*** (0.014)	-1.404***	-0.090*** (0.013)	-1.190***
Denmark	-0.058*** (0.014)	-1.433**	-0.076*** (0.013)	-1.204***
Finland	-0.061*** (0.015)	-1.623***	-0.078*** (0.013)	-1.293***
Germany	-0.062*** (0.014)	-1.060	-0.081*** (0.013)	-0.815
Ireland	-0.075*** (0.014)	-1.013**	-0.089*** (0.013)	-0.917**
Italy	-0.066*** (0.015)	-1.304**	-0.080*** (0.014)	-1.155***
Netherlands	-0.062*** (0.014)	-1.668***	-0.080*** (0.013)	-1.330***
Norway	-0.070*** (0.014)	-1.571***	-0.087*** (0.013)	-1.288***
New Zealand	-0.069*** (0.015)	-1.268**	-0.087*** (0.014)	-1.059***
Sweden	-0.065*** (0.014)	-1.163*	-0.081*** (0.013)	-1.081**
United Kingdom	-0.043*** (0.016)	-1.430*	-0.060*** (0.017)	-1.169**
United States	-0.068*** (0.014)	-1.258**	-0.087*** (0.014)	-1.090***
Average of the 14 long run elasticities		-1.310 [-1.273, -1.347]		-1.116 [-1.086, -1.146]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes a specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the women labour participation rate to that of initial GDP per capita. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 11: Long Run Elasticity of GDP per Worker with Respect to Women Labour Participation.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to women labour participation	Initial GDP per worker	Long run elasticity of GDP per worker to women labour participation
Belgium	-0.052*** (0.013)	-3.018***	-0.065*** (0.010)	-2.320***
Canada	-0.040*** (0.011)	0.086	-0.069*** (0.011)	-0.609
Switzerland	-0.058*** (0.012)	-2.923***	-0.074*** (0.010)	-2.258***
Denmark	-0.051*** (0.011)	-2.984***	-0.067*** (0.010)	-2.339***
Finland	-0.051*** (0.011)	-3.174***	-0.069*** (0.010)	-2.287***
Germany				
Ireland	-0.061*** (0.012)	-2.408***	-0.076*** (0.010)	-1.997***
Italy	-0.058*** (0.013)	-2.742***	-0.072*** (0.011)	-2.240***
Netherlands	-0.053*** (0.011)	-3.040***	-0.071*** (0.010)	-2.282***
Norway	-0.058*** (0.012)	-3.167***	-0.073*** (0.010)	-2.407***
New Zealand	-0.055*** (0.012)	-2.816***	-0.071*** (0.010)	-2.254***
Sweden	-0.053*** (0.011)	-3.141***	-0.070*** (0.010)	-2.030***
United Kingdom	-0.027* (0.015)	-3.610**	-0.057*** (0.016)	-2.417***
United States	-0.055*** (0.012)	-2.806***	-0.069*** (0.011)	-2.440***
Average of the 14 long run elasticities		-2.750 [-2.657, -2.842]		-2.145 [-2.080, -2.209]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 13 regressions excludes Germany and another specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the women labour participation rate to that of initial GDP per worker. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 12: Long Run Elasticity of GDP per Capita With Respect to the Fertility Rate.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to the fertility rate	Initial GDP per capita	Long run elasticity of GDP per capita to the fertility rate
Belgium	-0.067*** (0.015)	-0.296**	-0.079*** (0.013)	-0.204*
Canada	-0.052*** (0.014)	-0.422**	-0.072*** (0.013)	-0.287**
Switzerland	-0.076*** (0.014)	-0.288**	-0.090*** (0.013)	-0.196**
Denmark	-0.058*** (0.014)	-0.350**	-0.076*** (0.013)	-0.230**
Finland	-0.061*** (0.015)	-0.254	-0.078*** (0.013)	-0.177
Germany	-0.062*** (0.014)	-0.309**	-0.081*** (0.013)	-0.199*
Ireland	-0.075*** (0.014)	-0.177	-0.089*** (0.013)	-0.122
Italy	-0.066*** (0.015)	-0.299**	-0.080*** (0.014)	-0.201*
Netherlands	-0.062*** (0.014)	-0.34**	-0.080*** (0.013)	-0.223**
Norway	-0.070*** (0.014)	-0.297**	-0.087*** (0.013)	-0.198**
New Zealand	-0.069*** (0.015)	-0.316**	-0.087*** (0.014)	-0.215**
Sweden	-0.065*** (0.014)	-0.271	-0.081*** (0.013)	-0.209
United Kingdom	-0.043*** (0.016)	-0.279	-0.060*** (0.017)	-0.186
United States	-0.068*** (0.014)	-0.418**	-0.087*** (0.014)	-0.286**
Average of the 14 long run elasticities		-0.309 [-0.301, -0.317]		-0.210 [-0.203, -0.216]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes a specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the fertility rate to that of initial GDP per capita. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 13: Long Run Elasticity of GDP per Worker With Respect to the Fertility Rate.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		Women	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to the fertility rate	Initial GDP per worker	Long run elasticity of GDP per worker to the fertility rate
Belgium	-0.052*** (0.013)	0.024	-0.065*** (0.010)	0.174
Canada	-0.040*** (0.011)	-0.264	-0.069*** (0.011)	-0.054
Switzerland	-0.058*** (0.012)	0.013	-0.074*** (0.010)	0.135
Denmark	-0.051*** (0.011)	0.006	-0.067*** (0.010)	0.134
Finland	-0.051*** (0.011)	0.067	-0.069*** (0.010)	0.166*
Germany				
Ireland	-0.061*** (0.012)	0.065	-0.076*** (0.010)	0.181*
Italy	-0.058*** (0.013)	0.003	-0.072*** (0.011)	0.139
Netherlands	-0.053*** (0.011)	0.030	-0.071*** (0.010)	0.156
Norway	-0.058*** (0.012)	-0.005	-0.073*** (0.010)	0.121
New Zealand	-0.055*** (0.012)	-0.003	-0.071*** (0.010)	0.123
Sweden	-0.053*** (0.011)	-0.027	-0.070*** (0.010)	0.192
United Kingdom	-0.027* (0.015)	-0.143	-0.057*** (0.016)	0.165
United States	-0.055*** (0.012)	-0.050	-0.069*** (0.011)	0.064
Average of the 14 long run elasticities		-0.022 [-0.015, -0.029]		0.131 [0.122, 0.139]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 13 regressions excludes Germany and another specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the fertility rate to that of initial GDP per worker. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 14: Long Run Elasticity of GDP per Capita With Respect to the Openness Ratio.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to the openness ratio	Initial GDP per capita	Long run elasticity of GDP per capita to the openness ratio
Belgium	-0.067*** (0.015)	0.175	-0.079*** (0.013)	0.143
Canada	-0.052*** (0.014)	0.394**	-0.072*** (0.013)	0.255**
Switzerland	-0.076*** (0.014)	0.166*	-0.090*** (0.013)	0.134*
Denmark	-0.058*** (0.014)	0.254*	-0.076*** (0.013)	0.170*
Finland	-0.061*** (0.015)	0.179	-0.078*** (0.013)	0.137
Germany	-0.062*** (0.014)	0.257*	-0.081*** (0.013)	0.200**
Ireland	-0.075*** (0.014)	0.132	-0.089*** (0.013)	0.111
Italy	-0.066*** (0.015)	0.185	-0.080*** (0.014)	0.147
Netherlands	-0.062*** (0.014)	0.284**	-0.080*** (0.013)	0.201**
Norway	-0.070*** (0.014)	0.165	-0.087*** (0.013)	0.125
New Zealand	-0.069*** (0.015)	0.182*	-0.087*** (0.014)	0.136
Sweden	-0.065*** (0.014)	0.206*	-0.081*** (0.013)	0.157*
United Kingdom	-0.043*** (0.016)	-0.365	-0.060*** (0.017)	-0.154
United States	-0.068*** (0.014)	0.228*	-0.087*** (0.014)	0.148
Average of the 14 long run elasticities		0.174 [0.158, 0.191]		0.137 [0.124, 0.149]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes a specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the openness ratio to that of the initial GDP per capita. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 15: Long Run Elasticity of GDP per Worker With Respect to the Openness Ratio.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to the openness ratio	Initial GDP per worker	Long run elasticity of GDP per worker to the openness ratio
Belgium	-0.052*** (0.013)	0.305***	-0.065*** (0.010)	0.273***
Canada	-0.040*** (0.011)	0.925***	-0.069*** (0.011)	0.497***
Switzerland	-0.058*** (0.012)	0.250***	-0.074*** (0.010)	0.213***
Denmark	-0.051*** (0.011)	0.329***	-0.067*** (0.010)	0.254***
Finland	-0.051*** (0.011)	0.293***	-0.069*** (0.010)	0.238***
Germany				
Ireland	-0.061*** (0.012)	0.261***	-0.076*** (0.010)	0.214***
Italy	-0.058*** (0.013)	0.266***	-0.072*** (0.011)	0.219***
Netherlands	-0.053*** (0.011)	0.299***	-0.071*** (0.010)	0.234***
Norway	-0.058*** (0.012)	0.225***	-0.073*** (0.010)	0.204***
New Zealand	-0.055*** (0.012)	0.294***	-0.071*** (0.010)	0.230***
Sweden	-0.053*** (0.011)	0.295***	-0.070*** (0.010)	0.253***
United Kingdom	-0.027* (0.015)	-0.769	-0.057*** (0.016)	0.091
United States	-0.055*** (0.012)	0.311***	-0.069*** (0.011)	0.232***
Average of the 14 long run elasticities		0.253 [0.229, 0.276]		0.242 [0.231, 0.254]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 13 regressions excludes Germany and another specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the openness ratio to that of the initial GDP per worker. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 16: Long Run Elasticity of GDP per Capita With Respect to the Investment Rate.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per capita using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per capita	Long run elasticity of GDP per capita to the investment rate	Initial GDP per capita	Long run elasticity of GDP per capita to the investment rate
Belgium	-0.067*** (0.015)	0.453***	-0.079*** (0.013)	0.479***
Canada	-0.052*** (0.014)	0.758***	-0.072*** (0.013)	0.538***
Switzerland	-0.076*** (0.014)	0.350***	-0.090*** (0.013)	0.421***
Denmark	-0.058*** (0.014)	0.547***	-0.076*** (0.013)	0.491***
Finland	-0.061*** (0.015)	0.465***	-0.078*** (0.013)	0.465***
Germany	-0.062*** (0.014)	0.485***	-0.081*** (0.013)	0.459***
Ireland	-0.075*** (0.014)	0.362***	-0.089*** (0.013)	0.418***
Italy	-0.066*** (0.015)	0.481***	-0.080*** (0.014)	0.476***
Netherlands	-0.062*** (0.014)	0.486***	-0.080*** (0.013)	0.474***
Norway	-0.070*** (0.014)	0.413***	-0.087*** (0.013)	0.444***
New Zealand	-0.069*** (0.015)	0.458***	-0.087*** (0.014)	0.446***
Sweden	-0.065*** (0.014)	0.460***	-0.081*** (0.013)	0.454***
United Kingdom	-0.043*** (0.016)	0.978***	-0.060*** (0.017)	0.753***
United States	-0.068*** (0.014)	0.494***	-0.087*** (0.014)	0.446***
Average of the 14 long run elasticities		0.514 [0.505, 0.522]		0.483 [0.479, 0.487]

Notes: There are 88 observations in each IFGLS regression, except for Germany for which there are 90 observations. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per capita is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per capita, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 14 regressions excludes a specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the investment rate to that of the initial GDP per capita. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

TABLE 17: Long Run Elasticity of GDP per Worker With Respect to the Investment Rate.

Estimations over the 1960-1995 period, with country fixed effects.

Dependent variable: Log difference of GDP per worker using IFGLS				
	Men		**Women**	
Country removed from regression	Initial GDP per worker	Long run elasticity of GDP per worker to the investment rate	Initial GDP per worker	Long run elasticity of GDP per worker to the investment rate
Belgium	-0.052*** (0.013)	0.544***	-0.065*** (0.010)	0.538***
Canada	-0.040*** (0.011)	1.137***	-0.069*** (0.011)	0.601***
Switzerland	-0.058*** (0.012)	0.492***	-0.074*** (0.010)	0.469***
Denmark	-0.051*** (0.011)	0.566***	-0.067*** (0.010)	0.514***
Finland	-0.051*** (0.011)	0.547***	-0.069*** (0.010)	0.497***
Germany				
Ireland	-0.061*** (0.012)	0.405***	-0.076*** (0.010)	0.425***
Italy	-0.058*** (0.013)	0.492***	-0.072*** (0.011)	0.477***
Netherlands	-0.053*** (0.011)	0.558***	-0.071*** (0.010)	0.503***
Norway	-0.058*** (0.012)	0.515***	-0.073*** (0.010)	0.492***
New Zealand	-0.055*** (0.012)	0.527***	-0.071*** (0.010)	0.485***
Sweden	-0.053*** (0.011)	0.535***	-0.070*** (0.010)	0.451***
United Kingdom	-0.027* (0.015)	1.713***	-0.057*** (0.016)	0.688***
United States	-0.055*** (0.012)	0.541***	-0.069*** (0.011)	0.514***
Average of the 14 long run elasticities		0.659 [0.647, 0.672]		0.512 [0.507, 0.517]

Notes: There are 83 observations in each IFGLS regression. White heteroskedasticity standard errors are shown in parentheses. *: Significant at 10 % level; ** at 5 % level; *** at 1 % level. GDP per worker is adjusted for PPP. IFGLS: iterated feasible generalized least squares; the set of independent variables includes the initial GDP per worker, the investment rate, the openness ratio, the fertility rate, human capital (literacy measure) and women labour force participation; each of the 13 regressions excludes Germany and another specified country from the initial sample of 14. The long run elasticity is defined as the ratio of the coefficient of the investment rate to that of the initial GDP per worker. The numbers in square brackets are the 95 per cent confidence interval of the corresponding long run elasticity.

Chapter 7: Conclusions

This major paper explored the relationship between gender separate human capital effects and economic growth using a neoclassical human capital augmented version of Solow's (1956) model. A particularity of this work is that we made use of direct indicators of human capital accumulation compiled for the 1960-1995 period from literacy scores available for a set of 14 OECD countries. The principal contributions of this major paper are the following:

1. Investment in women's literacy has a highly significant (1%) and stronger impact on growth of GDP per capita and per worker than investment in men's literacy.
2. The initial GDP per capita and per worker, and the investment rate have a highly significant (1%) and positive impact on the growth of GDP per capita and per worker for both men and women's estimations.

These results are consistent with other studies that also use panel estimation techniques with five-year subperiods to measure positive – stronger for women – effects of education on long-run levels of GDP per capita and per worker (see page 22 for references). Our results also show that the literacy indicators for women outperform the homologue set for men.

The fact that the effect is stronger for women should not be so surprising in view of the fact that not so long ago women were significantly less educated than men. Higher returns from female education should hence be expected, and this is what our results suggest. Part of the additional returns from female education might also be related to the fact that the human capital variable probably proxies for something more than education. What exactly it proxies for remains to be investigated. But we can speculate that since women are still more involved in housekeeping/child caring activities than men, even in OECD countries, perhaps their education has more opportunities to be passed on to children and improve the general well-being of the family.

However, in view of the double Granger causality (multicollinearity) problems detected between the education, fertility and women labour participation variables in various situations, we cannot conclude that a key to economic growth consists in keeping educated women at home. But, if women labour participation were to come out as a negative effect on growth after correction for these problems, we would have to turn to our sample of 14 OECD countries which are very different from developing countries. As mentioned on page 25, perhaps that at a certain female labour participation threshold, far from that of developing countries, it is the fact that societies endow themselves with parental leaves and childcare services that starts to exert a negative effect on growth by favouring a renewed rise in the fertility rate (this is the case for some Nordic countries). This hypothesis would be one to test.

Furthermore, another source of error on the point estimates was retrospectively identified in the regressions we performed. It consists in the fact that there are problems with fixed effects when the number of cross-sectional observations is greater than the number of temporal observations, which is our case.

Comments on Coulombe, Tremblay and Marchand (2003) have been formulated since submission of the paper. Some of those comments are relevant to this major paper. One of the critics is that there is a specification problem with our regression equation. We agree with this view. There is very probably feedback between the growth of physical capital variable on the left hand side of the equation and the accumulation of human capital variable on the right hand side. Our robustness test results also point to the presence of multicollinearity and Granger causality. This is however not a big surprise in view of the probable feedback loops involved between the fertility, male and female education, and labour force participation. These were clearly exposed in the overlapping generations models of Galor and Weil (1996) and Lagerlöf (2002). Critics suggested using Hall and Jones model based on stocks of physical and human capital.

Finally one could argue that there is no clear reason that allows us to distinguish between men and women's literacy and therefore no reason for gender separate regression equations. We argue to this that, given differences in brain structure and functioning, learning patterns, as well as cultural constraints that treat men and women differently, there is no sound reason to think that men and women should be pooled together in the same regression system.

References

Barro, R.J. 2001. Education and Economic Growth," in J.F. Helliwell, ed., *The Contribution of Human and Social Capital to Sustained Economic Growth and Well-Being*, OECD, 2001.

Barro, R.J. 1997. *Determinants of Economic Growth: A Cross-Country Empirical Study*, MIT Press.

Barro, R.J. 1991. Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics* 106(2): 407-443.

Barro, R.J. and J.W. Lee. 1996. International Measures of Schooling Years and Schooling Quality. *American Economic Association Papers and Proceedings* 86(2).

Barro, R.J. and J.W. Lee. 1994. Sources of economic growth. *Carnegie-Rochester Conference Series on Public Policy* 40, 1-46.

Barro, R.J. and J.W. Lee. 1993. International Comparisons of Educational Attainment. *Journal of Monetary Economics* 32(3): 363-394.

Barro, R., G. Mankiw, and X. Sala-i-Martin. 1995. Capital Mobility in Neoclassical Models of Growth. *American Economic Review* 85(1): 103–115.

Barro, R. et X. Sala-I-Martin. 1995. *Economic Growth*, McGraw-Hill, New York.

Barro, R.J. and J.W. Lee. 1993. International Comparisons of Educational Attainment. *Journal of Monetary Economics* 32(3): 363-394.

Bassanini, A. and S. Scarpetta. 2001. Does Human Capital Matter for Growth in OECD Countries? Evidence from Pooled Mean-Group Estimates, Economics Department Working Papers No. 282, OECD, January 2001.

Baumol, W.J. 1986. Productivity Growth Convergence and Welfare: What Do the Long-Run Data Show? *American Economic Review* 76: 1072-85.

Benavot, A. 1989. Education, Gender, and Economic Development: A Cross-National Study. *Sociology of Education* 62, 14-32.

Bils, M. and P. Klenow. 2000. Does Schooling Cause Growth ? *The American Economic Review* 90(5): 1160-1183.

Blau, D.M. 1986. Fertility, Child Nutrition, and Child Mortality in Nicaragua: An Economic Analysis of Interrelationships. *The Journal of Developing Areas* 20, 185-202.

Cain, G.G. and A. Weininger. 1973. Economic determinants of fertility: results from cross-sectional aggregate data. *Demography* 10, 205-223.

Cohen, D. and M. Soto. 2001. Growth and Human Capital: Good Data, Good Results, CEPR Discussion Paper No. 3025.

Coulombe, S. and F.C. Lee.1995. "Convergence across Canadian Provinces, 1961 to 1991." *Canadian Journal of Economics* 28(4a): 886–898.

Coulombe, S. and K. Day. 1996. β-convergence, σ-convergence and the stationary-state level of regional disparities: the case of Canada, University of Ottawa Research Paper No. 9608E.

Coulombe, S. 2000. New Evidence of Convergence Across Canadian Provinces: the Role of Urbanization. *Regional Studies* 34(8): 713-725.

Coulombe, S. and J.-F. Tremblay. 2001. Human Capital and Regional Convergence in Canada. *Journal of Economic Studies* 28(3): 154-180.

Coulombe, S. 2003. Human Capital, Urbanization and Canadian Provincial Growth. *Regional Studies* 37(3): 239-250.

Coulombe, S., J.-F. Tremblay, and S. Marchand. 2003. Literacy Scores, Human Capital and Growth Across Fourteen OECD Countries. *mimeo*. Department of Economics, University of Ottawa.

De la Fuente, Angel, 1998. What Kind of Regional Convergence? CEPR Discussion Papers 1924, C.E.P.R. Discussion Papers.

De la Fuente, A. and R. Doménech. 2002. Human Capital in Growth Regressions : How Much Difference Does Data Quality Make? An Update and Further Results. Manuscript. Instituto de Análisis Económico (CSIC) and Universidad de Valencia.

Dollar, D., and R. Gatti. 1999. Gender Inequality, Income, and Growth: Are Good Times Good for Women ? Policy Research Report on Gender and Development. Working Paper Series No. 1. The World Bank, Washington D.C.

Galor, O. and D.N. Weil. 1996. The Gender Gap, Fertility and Growth. *The American Economic Review*. 86(3): 374-387.

Hanushek, E.A. and D.D. Kimko. 2000. Schooling, Labor-Force Quality, and the Growth of Nations. *The American Economic Review* 90(5): 1184-1208.

Islam, N. 1995. Growth Empirics: A Panel Data Approach. *The Quarterly Journal of Economics* 110(4): 1127-1171.

Islam, N. 1998. Growth Empirics: A Panel Data Approach – A Reply. *The Quarterly Journal of Economics* 113: 324-329.

Knowles, S., P.K. Lorgelly and P.D. Owen. 2002. Are Educational Gender Gaps a Brake on Economic Development ? Some Cross-Country Empirical Evidence. *Oxford Economic Papers* 54: 118-149.

Klasen, S. 2002. Low Schooling for Girls, Slower Growth for All ? Cross-Country Evidence on the Effect of Gender Inequality in Education on Economic Development. *The World Bank Economic Review* 16: 345-376.

Nils-Petter Lagerlof, 2002. Sex, Equality and Growth (in that order). GE, Growth, Math methods, 0212001, Economics Working Paper Archive at WUSTL.

Lee, K., M.H. Pesaran and R. Smith. 1998. Growth Empirics: A Panel Data Approach – A Comment. *The Quarterly Journal of Economics* 113: 319-323.

Lorgelly, P.K. and P.D. Owen. 1999. The Effect of Female and Male Schooling on Economic Growth: the Barro-Lee Model. *Empirical Economics* 24, 537-557.

Lucas, R.E., Jr. 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* 22(1): 3-42.

Maddison, A. 1982. *Phases of Capitalist Development*, Oxford University Press

Mankiw, N.G., D. Romer and D.N. Weil. 1992. A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107(2): 407-437.

Mauro, L. 2000. Human Capital and the Regional Italian Development: Does Unemployment Matter? Department of Economics and Statistics, University of Trieste, Working Paper No. 61.

Perotti, Roberto, (1996) "Growth, Income Distribution, and Democracy: What the Data Say," *Journal of Economic Growth* 1, 149-187.

Psacharopoulos, G. 1994. Returns to investment in education: a global update. *World Development* 22, 1325-1343.

Romer, P. M. 1986. Increasing Returns and Long-Run Growth. *Journal of Political Economy* 94(5): 1002-1037.

Romer, P.M. 1989. *Capital Accumulation in the Theory of Long-Run Growth*, in Modern Business Cycle Theory, Robert J. Barro, ed., Harvard University Press.

Solow, R.M. 1956. A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics* 70(1): 65-94.

Stokey, N. 1994. Comments on Barro and Lee. *Carnegie-Rochester Conference Series on Public Policy* 40, 47-57.

Summers, R. and A. Heston. 1988. A New Set of International Comparisons of Real Product and Price Levels Estimates for 130 Countries, 1950-85. *Review of Income and Wealth* 34: 1-26.

Swan, T.W. 1956. Economic Growth and Capital Accumulation. *Economic Record* 32: 334-361.

Temple, J. 1999. The New Growth Evidence. *Journal of Economic Literature* 37: 112-156.

Temple, J. 2000. Growth Effects of Education and Social Capital in the OECD Countries, Economics Department Working Papers No. 263, OECD, October 2001.