HUMAN CAPITAL FORMATION IN ARGENTINA:
CONTRIBUTION TO GROSS DOMESTIC PRODUCT

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1 Introduction

The influence of human capital formation upon countries' gross domestic product and its long run growth path was always a matter of interest both for theorists on growth theory as well as for policy makers involved in the design of fiscal growth and development policies. The idea of the inclusion of human capital in production functions had already been considered by Uzawa (1965) and Lucas (1988) in their two sector endogenous growth models; in one sector, the final production stemmed from the combination of physical and human capital whereas in the other production and human capital accumulation were derived from human capital use alone.

Lucas theoretical contribution (1988, 1990) also dealt with externality features, by suggesting that investment in human capital not only enhanced individuals' earning abilities but might also generate an external effect that raised the aggregate level of productivity and served in turn to explaining countries' long run income diversity. Contemporaneously, Romer (1990) also highlighted the importance of human capital by putting forward his well-known $I + D$ and growth model in which the underlying research technology only depended on labour or human capital.

In assessing the hypothesis of human capital as "engine of growth", Frenkel and Razin (1996) carried out their analysis based on a classical textbook endogenous growth model including both physical and human capital and showed that the long-run growth rate was always positively related to the human capital saving rate but positively, negatively related or totally unrelated at all to the physical capital saving rate, this depending on the value taken by the reciprocal of the intertemporal elasticity of substitution in consumption; the above verification led Frenkel and Razin to defend public policies targeted at raising the human capital saving rate on grounds that they would directly impact on the economy's long-run growth rate.

In attempting to ascertain the role played by human capital, the influential paper by Mankiw, Romer and Weil (1992), focused on the empirics of economic exogenous growth and brought about a revaluation of the traditional Solow-Swan Model (SSM) by showing that the latter's predictions were somehow consistent with their own econometric evidences. Even though the SSM rightly predicted the directions of the effects of saving and population growth upon income, they found that estimates of parameters fell short of being satisfactory as they clearly overstated the size of the coefficient on physical capital compared to the actual capital share of one third usually assumed in the formulation of the Cobb Douglas production functions.

This empirical lack of consistency was dealt with by Mankiw *et al.* by building what they called an "Augmented Solow Model" which explicitly included human capital in the production function; the resulting log equation, holding now that real per capita income depended on population growth as well as on physical and human capital accumulation had, according to the econometric results, a much better performance as the human capital variable turned out to be significant, the size of the physical capital coefficient fell in line with it expected actual value and the fit of the equation improved compared to the regression in which human capital was omitted whereas the restriction that all three coefficients (on population growth and on propensities to accumulate physical and human capital) summed to zero was not rejected.

Following the line drawn by the above mentioned contributions, this research paper aims at assessing the impact of the Investment in Education in Argentina (as one of components of Human Capital Formation) upon the Gross Domestic Product, therefore the Augmented Solow Model is used as underlying the theoretical framework. It is worth point out here that the empirical developments due to Mankiw *et al.*, given difficulties found in computing the variable, resorted to a proxy for the propensity to invest in human capital accumulation consisting in taking the percentage of the working age population enrolled in secondary school; in connection to this, one main contribution of this paper resides in furthering the empirical treatment of the "augmented SSM" on the following three accounts: a) the possibility is investigated of finding better representations for the average propensity to invest in human capital other than the one above mentioned, b) missing components, such as the opportunity costs incurred by parents and students are added to all government and educational levels' budgetary expenditures and c) a methodology is developed for the measurement of the stock of human capital in order that the variable be available to be used, in a second stage to this project, in place of the rate of human capital accumulation.

Furthermore, and given the widespread admission that valuable empirical and policy implications may arise from including human capital, the Augmented SSM econometric performance is assessed by resorting to cointegration and error correction models and innovation accounting involving impulse response function and variance decomposition analysis.

A worth stressing point is that the advance on methodological aspects relating data treatment and measurement, as well as the results from the carried out econometric estimation of equations, are expected to serve as inputs for the second stage in which the inclusion of human capital will be assessed in the frame of endogenous growth models.

In line with objectives held above, the rest of the paper is organized as follows: Section 2 summarizes the theoretical treatment given by Uzawa (1965) and Lucas (1988) to the inclusion of human capital in endogenous growth models as well as a review of the Mankiw, Romer and Weil's Augmented Growth Model (1992); in Section 3 a methodological alternative is introduced and applied to the Argentine economic scenario, for computing both the average propensity to invest in human capital and its stock; Section 4 presents a synthetic review of stylized facts that highlights the joint performance –in the period considered- of gross domestic product and human capital; Section 5 presents the econometric estimation for Argentina of the Augmented Growth Model's parameters by using an Error Correction Model as well as the evaluation of results with tools of innovation accounting; section 6 concludes.

2 Human capital inclusion in economic growth models[1]

Theoretical contributions aimed at stressing the role of human capital in models of economic growth, and at empirically assessing its real impact upon long-run growth path, are ample and can be traced back close in time to the moment when the classical Solow-Swan Growth Model came into being.[2] Three of these contributions were selected to be reviewed: in the first two, Uzawa and Lucas, resorted to an endogenous growth model in which they included human capital whereas in the third one Mankiw, Romer and Weil (1992) extended the Solow-Swan Model by adding what they deemed to be the omitted variable; that is, human capital accumulation.

1 This section builds on papers by Uzawa (1965), Lucas (1988) and Mankiw *et al.* (1992) and on Heijdra and van der Ploeg (2002), ch. 14, and Sala-i-Martín (1994), ch. 8.

2 Suffice it in this connection to mention Schultz's communication (1961) on the impact of labour quality improvement upon the pattern of economic growth.

2.1 The Uzawa-Lucas Model

AK endogenous growth models including physical (*K*) and human capital (*H*) were founded on the assumption that both were similar goods, obtained with the same technology and able to be produced and accumulated out of not consumed units of production; as a consequence of this, the following two relationships between stocks of both capital variants were seen to hold implying that a temporal reduction in K (and in K/H ratio) would be made up by getting a part of H immediately converted in K:

$$\frac{K}{H} = \frac{\alpha}{1-\alpha} \tag{1}$$

$$H = K\,\frac{1-\alpha}{\alpha} \tag{2}$$

where $0<\alpha<1$ stood for the physical capital's share in the production function.

Simple and practical as it might appear, this unrealistic assumption was challenged by Uzawa by suggesting that technological knowledge could only be raised by devoting resources to this end, following a pattern of allocation conducive to optimum growth within the framework of a two sector aggregative growth model whose main features were intuitively simple. Uzawa started by drawing the productive sector represented by the production function (3) below, in which physical capital and labour used for final goods production combined and yielded a homogenous output which could be either instantaneously consumed or devoted to enhancing the stock of physical capital:

$$Y(t) = f\big(K(t), A(t)L_P(t)\big) \tag{3}$$

and where $A(t)$ stood for the state of technological knowledge at any time t[3] and L_P labour used in the production of final goods.

The second sector, broadly defined as "the educational sector", employed only labour and its impact diffused over the economy via the enhancement of labour efficiency $(\dot{A}L(t))$; Uzawa made the rate of change of labour efficiency to depend on non increasing marginal returns[4] and the ratio between labour employed by the educational sector and total labour force:

$$\frac{\dot{A}_L(t)}{A_L(t)} = \phi\left[\frac{L_E(t)}{L(t)}\right] \tag{4}$$

In interpreting expression in (4) it should be noticed that, for Uzawa, the larger the change in labour efficiency, the larger the amount of labour devoted to the educational sector (L_E) which, in the context of an inelastically supplied labour force growing at a rate n, amounted to meeting the restriction imposed by the identity (5):

$$L_E(t) + L_P(t) = L(t) \tag{5}$$

The rest of the model formulation was completed by traditionally stating the rate of physical capital accumulation as the difference between the positive annual rates of aggregate investment and of capital stock depreciation:[5]

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3 For Uzawa, changes in technological knowledge were exclusively embodied in labour and therefore labour efficiency's increases did not depend on the amount of employed physical capital.

4 Non increasing marginal returns to labour meant that $\phi'(s) \geq 0$ and $\phi''(s) \leq 0$ for all $0 \leq s \leq 1$.

5 It must be noted that while Uzawa used this equation to define the rate of capital accumulation, both Lucas and Mankiw *et al.* used a similar formulation to express the net investment in physical capital or, in other words, the capital accumulation (see equation 33 below).

$$\frac{\dot{K}(t)}{K(t)} = I(t) - \delta_K K(t) \tag{6}$$

and by introducing a linear utility function whereby the optimum time path was characterized in terms of the discounted sum of per capita consumption:

$$U(0) = \int \frac{C(t)}{L(t)} e^{-\rho t}\, dt \tag{7}$$

In relation to the treatment of human capital in endogenous growth models, the main thrust represented by Uzawa's contribution was however extended by Lucas, at least on the following three accounts: a) while Uzawa broadly regarded $A_L(t)$ as embodying educational activities, health and provision and building of public goods, Lucas modified the idea by interpreting $A_L(t)$ as human capital; b) based on empirical evidence[6] showing that individual earnings were consistent with a linear knowledge production function, Lucas rejected the assumption of diminishing returns to knowledge accumulation implied by expression (4) and put forward in change a modified expression (4') for the human capital accumulation function in which $\phi_E > 0$ was now a parameter:

$$\frac{\dot{H}(t)}{H(t)} = \varphi_E \left[\frac{L_E(t)}{L(t)}\right] \tag{4'}$$

Expression (4') rested on Rosen's theory, applied to each finite-lived individual and extended by Lucas to the same technology applied to an entire infinitely-lived representative household; that is, individuals' acquired human capital were somehow transferred to next generations.[7]

The third change consisted in Lucas' introduction of a curved intertemporal utility function for the representative infinitely lived household, in place of the linear function (7), as expressed now in (7'):

$$U(0) = \int \frac{C(t)^{1-\theta} - 1}{1 - \theta} e^{-(\rho - n)t}\, dt \tag{7}$$

in which θ stood for the reciprocal of consumption's intertemporal elasticity of substitution. As known, $\theta = 1/\sigma$ is a constant that measures the degree of concavity of the utility function (7') its value in turn implying that the larger θ the greater the interest in smoothing consumption over time.

With the modifications introduced by Lucas (shown by equations (4') and (7')) the model development, and its resolution, followed endogenous growth models' standard procedures by incorporating the ensuing per capita equations[8] for physical and human capital accumulation in which the simplifying assumption of similar depreciation rates was used:[9]

$$\dot{k} = A(t)k(t)^{\alpha} \left(u\, h(t)\right)^{1-\alpha} - c(t) - (\delta + n)\, k(t) \tag{8}$$

$$\dot{h} = \varphi_E (1 - u)\, h(t) - (\delta + n)\, h(t) \tag{9}$$

6 Rosen (1976).

7 The assumptions that individuals' capital formation followed the pattern depicted by 4' and that the initial level each family member began with was proportional to the level already accumulated by the family's older members led Lucas (1988, p. 19) to assert that human capital accumulation was a social activity with no counterpart in physical capital accumulation

8 Equations (8) and (9) were derived from accumulation equations $\dot{K}$ and $\dot{H}$ divided by L, making next $k = K/L$ and $h = H/L$, taking derivatives with respect to time in order to obtain $\dot{k} = \dot{K}/L - nk$ and $\dot{h} = \dot{H}/L - nh$ and replacing $\dot{K}/L$ and $\dot{H}/L$ for their equivalents in per capita accumulation equations.

9 Similar to the effect caused by δ, increases in the population's rate of growth (n) dwindle the available per capita physical and human capital stock.

Thus, while u stood for the proportion of total human capital used for the production of final goods, $(1–u)$ indicated in turn the effort devoted to human capital accumulation.[10] Let it be noticed that, if L were normalized to unity in (5), L_E and L_P would respectively equal to $(1–u)$ and u^2.[11]

In line with the usual procedure, Uzawa-Lucas made individuals to choose temporal trajectories for consumption and stocks of physical and human capital that maximized the utility function already introduced; that is, equation (7') was maximized subject to non leisure time individuals devoted to each of the two sectors (time constraint 10) and the accumulation restrictions 8 and 9, as represented by the Hamiltonian in (11), including now two state variables (k and h) and two control variables (c and u):

$$h(t) = u\,h(t) + (1 - u)\,h(t) \tag{10}$$

$$\begin{aligned}\mathcal{H}(t) = e^{-(\rho-n)t}\,\frac{C(t)^{1-\theta}-1}{1-\theta} + \eta_K[A(t)k(t)^{\alpha}\big(u\,h(t)\big)^{1-\alpha} - c(t) \\ -(\delta+n)\,k(t)] + \eta_H\,[\varphi_E(1-u)h(t) - (\delta+n)h(t)]\end{aligned} \tag{11}$$

where the co-state variables $\eta_K(t)$ and $\eta_H(t)$ respectively stood for shadow prices of per capita investment in physical and human capital $k(t)$ and $h(t)$. The corresponding first order conditions, resulting from the derivation of the Hamiltonian with respect to control and state variables, and the transversality conditions, were:[12]

$$e^{-(\rho-n)t}C(t)^{-\theta} = \eta_K(t) \tag{12}$$

$$\eta_K(t)\,A(t)\,k(t)^{\alpha}\,(1-\alpha)u^{-\alpha}\,h(t)^{1-\alpha} = \eta_H(t)\varphi_E\,h(t) \tag{13}$$

$$-\dot{\eta}_K(t) = \eta_K(t)\Big(A(t)\alpha\,k(t)^{\alpha-1}\big(u\,h(t)\big)^{1-\alpha} - (\delta+n)\Big) \tag{14}$$

$$-\dot{\eta}_H(t) = \eta_K(t)(A(t)k(t)^{\alpha}\,u^{1-\alpha}\,(1-\alpha)h(t)^{-\alpha}) + \eta_H(t)\big(\varphi_E(1-u) - (\delta+n)\big) \tag{15}$$

$$\lim_{t\to\infty}\eta_K(t)k(t) = \lim_{t\to\infty}\eta_H(t)h(t) = 0 \tag{16}$$

What first order conditions were stating was that produced output must on the margin be equally valuable in its uses, either as consumption or investment goods (12), while at the same time individuals' non leisure time must also be equally valuable in its uses, namely, physical and human capital accumulation (13). Finally, first order conditions (14) and (15) reflected the fundamental principle of valuation of the perfect competition institutional setting whereby the rate of return on different assets (in this case physical and human capital) must also be equalized. In Lucas' words, "…equations (4') and (12)-(16) implicitly describe the optimal evolution of $k(t)$ and $h(t)$ from an initial mix of these two kinds of capital".[13]

By taking logarithms and derivatives with respect to time in (12), and replacing $\eta_K(t)$ by its expression in (14), the resulting consumption dynamic equation was obtained that placed the

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[10] Although physical capital may not straightforwardly be ruled out as an input for the production of human capital, the accumulation equation (9) reflects Uzawa-Lucas assumption that only human capital is used to enhancing human capital stock.

[11] What Lucas called effective workforce in production (or skill-weighted man hours devoted to current production) was precisely $N(t) = uH(t)$, or $N(t) = L_P H(t)$, were L is being normalized to unity.

[12] As known, equal to 0 first order conditions are required for derivatives of the Hamiltonian with respect to control variables whereas for Hamiltonian's derivatives with respect to state variables first order conditions must equal the negative of shadow prices' derivatives with respect to time.

[13] Lucas (1988), p. 21.

consumption growth rate in terms of the model's variables:[14]

$$\frac{\dot{c}}{c} = \gamma_C = \frac{1}{\theta}\left(A(t)\alpha k(t)^{\alpha-1}\left(uh(t)\right)^{1-\alpha} - (\delta + \rho)\right) \tag{17}$$

In accompanying Lucas' solution for steady state values of variables c, k and h,[15] it is easily verifiable that by passing to the left hand side of equation (17) all constant terms, and taking logarithms and derivatives with respect to time, the resulting expression will fall in line with the steady state underlying principle asserting that all variables (in this case physical and human capital) must exhibit an equal and constant growth rate:

$$0 = (\alpha - 1)\gamma_k^* + (1-\alpha)\gamma_h^* \qquad or \qquad \gamma_k^* = \gamma_h^* \tag{18}$$

By dividing next for k the equation for physical capital accumulation (8), and passing to the right hand side all steady state constant terms, equation (19) was obtained:

$$\frac{c}{k} = A(t)(u^*)^{1-\alpha}\left[\left(\frac{h(t)}{k(t)}\right)^*\right]^{1-\alpha} - (\delta + n) - \gamma_k^* \tag{19}$$

from which (20) was straigthforwardly assumed to follow:[16]

$$\gamma_k^* = \gamma_h^* = \gamma_c^* \tag{20}$$

Finally, by taking logarithms of the production function for final goods (y), and derivatives with respect to time, the rate of growth of final output would be depicted by the ensuing expression (21):

$$\gamma_y = \alpha\gamma_k + (1-\alpha)\gamma_u + (1-\alpha)\gamma_h \tag{21}$$

which for steady state growth rate values, and given that $\gamma_u^* = 0$, permitted also to include γ_y^* in expression (22):

$$\gamma_y^* = \gamma_k^* = \gamma_h^* = \gamma_c^* \tag{22}$$

Thus far, growth rates in (22), apart from including γ_h^*, did not add any other relevant element to the already traditional conclusion of endogenous growth models; that is, in the steady state all variables grow at a similar constant rate. It is therefore important to show in what Lucas-Uzawa Model's rates differ from those yielded by other endogenous growth models (as, for instance, the AK Model) which did not explicitly include human capital stock and accumulation.

The matter raised in the above paragraph is easily dealt with by following a few simple mathematical steps whereby both sides of the first order condition (13) are multiplied by u and appropriately cancelling where required:

$$\eta_K(t)A(t)k(t)^{\alpha}(1-\alpha)u^{1-\alpha}\,h(t)^{-\alpha} = \eta_H(t)\varphi_E\,u \tag{23}$$

In taking next logarithms and derivatives with respect to time, the expression turned into (24) showing equality of shadow prices' growth rates:[17]

$$\gamma_{\eta h}^* = \gamma_{\eta k}^* \tag{24}$$

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[14] As can be seen, the rate of growth of consumption was, in the Uzawa-Model, also function of the physical capital marginal product; nevertheless, the latter not only depends now on the stock of physical capital but also on the share of human capital stock used for the production of final goods.

[15] As the amount of human capital devoted to final goods production was a positive constant of the total stock h, the steady state value of u^* is also fixed and its rate of growth equal to 0.

[16] A constant quotient $(k/h)^*$ means that –in the steady state- both capital stocks grow at the same rate; as the same should apply to $(c/k)^*$, growth rates for consumption and physical capital will necessarily be equal and similar to the rate of growth of human capital.

[17] In obtaining (24) it must be remembered that all steady state terms in (23) were constant, except the two shadow prices.

The left hand side of (23) is identical to the first term in the right hand side of (15). Consequently, substituting it in the first order condition and cancelling terms, the steady state rate of growth of shadow price η_H is brought out:

$$\left(-\frac{\dot{\eta}_H}{\eta_H}\right)^* = -\gamma_{\eta h}^* = \varphi_E - \delta - n \tag{25}$$

By taking next logarithms and derivatives with respect to time of the first order condition (12), the ensuing equation results:

$$\frac{\dot{c}}{c} = \gamma_C = \frac{1}{\theta}\left(-\frac{\dot{\eta}_K}{\eta_K} - (\rho - n)\right) = \frac{1}{\theta}\left(\varphi_E - \delta - \rho\right) \tag{26}$$

and given that all variables must have, in the steady state, an equal rate of growth:

$$\gamma_y^* = \gamma_k^* = \gamma_h^* = \gamma_c^* = \frac{1}{\theta}\left(\varphi_E - \delta - \rho\right) \tag{27}$$

As can be seen, conversely to AK Models in which the rate of growth was affected by the production function's exogenous productivity constant, the long-run economic growth here is affected by the educational sector's productivity parameter φ_E. Needless to say, this result rests on Lucas' assumption that only human capital was used by the educative sector to producing human capital (equation (9)) and that there existed a linear knowledge production function (expression in (4')).

On the other side, feasibility of (27) will depend on the relationship between the intertemporal substitution elasticity, represented by $1/\theta$ and the productivity constant φ_E ; in this connection, expression in 4' suggested that if the entire non leisure time were devoted to human capital production (that is, if u=0) φ_E would be the maximum attainable γ_h , therefore (27) would stand if and only if and this would require in turn would the following upper limit to be placed upon the intertemporal elasticity of substitution:

$$\frac{1}{\theta} < \frac{\varphi_E}{\varphi_E - \rho} \tag{28}$$

Although not considered in the carried out review, it is important however to point out that Lucas stressed also out the possibility of knowledge having a positive external effect upon productivity, apart from the effects of and individual's on his own productivity, what he modeled as follows:

$$N(t)c(t) + \dot{K}(t) = A(t)k(t)^{\alpha}\big(u(t)h(t)N(t)\big)^{1-\alpha}h_a(t)^{\zeta} \tag{29}$$

In the above formulation the net national product (left hand side member) is still seen to depend on the levels of capital and labour inputs and on the level of a constant $A(t)$ technology, but also on the term $h_a(t)^{\zeta}$ intended to capture what Lucas called possible external effects of human capital.[18]

2.2 *The Augmented Solow Model*

In the very influential paper by Mankiw, Romer and Weil (1992), one of the outstanding features was its empirical success in revaluing Solow's Model by econometrically proving that their predictions were in principle consistent with evidence;[19] thus, while estimated coefficients' signs rightly predicted the direction of effects of investing in physical capital, and of population

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[18] As stressed by Heijdra and van der Ploeg (2002, ch. 14, p. 463), in so doing Lucas aimed at reinforcing the notion that the formation of human capital was, in part, a social activity.

[19] In Mankiw *et al.*'s words, "…the Solow model gave the right answers to the questions it was designed to address".

growth, they failed in correctly predicting magnitudes. The matter of the assumedly failure of countries' income per capita convergence was also empirically analyzed and restated in the paper as the authors concluded that – instead of convergence – the Solow Model should rather be viewed as implying that countries would reach in general different steady states.[20]

The response to the deemed high influence of saving and population growth had to be sought, as explained below, at the exclusion of human capital from the traditional Solow Model which resulted in disproportionate larger but biased variables' estimated regression coefficients, as physical capital accumulation and population growth failed to reflect that part of their impact upon income was due to the omitted human capital variable.

The introduction of human capital within the traditional Solow Model permitted not only to solve the mentioned inconsistencies, arising when this variable, was omitted but also to use the model with greater confidence on its predictive potential. In this regard, and as is shown in the coming sections, the possibility of drawing empirically sound evidences from the model's testing enhances its policy implications with respect to the cost-benefit analysis of devoting tax revenue to human capital formation.

In presenting the augmented Solow Model, the equation (30) shows how the Cobb Douglas production function looks like after the omitted variable is included alongside physical capital:

$$Y(t) \;=\; K(t)^{\alpha}H(t)^{\beta}[A(t)L(t)]^{1-\alpha-\beta} \tag{30}$$

$K(t)$, $H(t)$ and $L(t)$ represent now the stocks of physical and human capital and labour availability respectively, $A(t)$ the technological level, $[A(t)\,L(t)]$ the effective units of labour[21] and α, β, and $(1–\alpha–\beta)$ the respective factor shares.[22] Similar to the original Solow-Swan Model, Mankiw *et al.* consider logarithmic labour and technology functions whose exogenous growth rates are respectively n and g:

$$L(t) = L(0)\, e^{nt} \tag{31}$$

$$A(t) = A(0)\, e^{gt} \tag{32}$$

The inclusion of human capital makes the model to consider now not only what determines the evolution of physical capital stock but also that of human capital, as the two ensuing capital accumulation equations show:

$$\dot{k}(t) \;=\; s_k y(t) \;-\; (n + g + \delta)\, k(t) \tag{33}$$

$$\dot{h}(t) \;=\; s_h y(t) \;-\; (n + g + \delta)\, h(t) \tag{34}$$

obtained by making $y=Y/AL$, $k=K/AL$, and $h=H/AL$ and s_k and s_h respectively standing for the fraction of income invested in physical and human capital.[23]

As in the traditional Solow-Swan Model, decreasing returns to scale entail that the economy will converge to a steady state in which $\dot{k}(t) = \dot{h}(t) = 0$ and $k(t) = k^*$ and $h(t) = h^*$; consequently, by using the production function in (30) and capital accumulation equations in (33) and (34), the following two expressions are obtained:

20 In connection to this argument, the point was emphasized that – when differences in saving and population growth rates were taking into consideration – convergence was seen to exist at a rate in line with the model's prediction.

21 The effective units of labour grow at the compound rate $(n+g)$.

22 In stating that $\alpha+\beta<1$, Mankiw, Romer and Weil keep Solow's assumption of decreasing returns to physical and human capital, although the assumption that $\alpha+\beta=1$ is also critically discussed in the paper.

23 Equations (33) and (34) do not only imply that both types of capital have the same depreciation rate but also that one unit of consumption can costlessly be changed into either a unit of physical or human capital, which notoriously differ from the assumptions upheld in the Lucas-Uzawa model.

$$k* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta}} \tag{35}$$

$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta}} \tag{36}$$

By substituting (35) and (36) into the Cobb Douglas production function (30), and taking logarithms, the estimable expression in (37) standing for per capita income along the balanced growth path is achieved:[24]

$$\ln\left(\frac{Y(t)}{L(t)}\right) = \ln A(0) + gt - \frac{\alpha+\beta}{1-\alpha-\beta} ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta} ln(s_h) \tag{37}$$

It is worth emphasizing that although coefficients are still predicted as function of factor shares, the above expression is better fitted to explaining cross-country income differences, owing to the fact that human capital accumulation now accompanies population growth and physical capital accumulation. In this regard, Mankiw *et al.* pointed out in the first place that, even if $ln(s_k)$ were independent of other variables in the right hand side of expression (37), its coefficient would still be greater than in the classical Solow Model without human capital; since higher saving would lead to higher income, this would, in turn, lead to a higher steady-state level of human capital even if s_h remained unchanged, the implication being that the inclusion of human capital accumulation enlarged the impact of physical capital accumulation. Moreover, the coefficient on $ln(n+g+\delta)$ is, in absolute value, greater than $ln(s_k)$'s coefficient reflecting the fact that high population growth lowers income per capita as physical and human capital stocks need now to be spread over more individuals.

Mankiw, Romer and Weil also suggest an alternative way, stemming from the combination of (37) and the steady-state level of variable h in (36), whereby the impact of human capital upon per capita income can be highlighted. As can be seen below, the resulting equation renders now income per capita as a function of the propensity to accumulate physical capital, the population growth rate and the level of human capital:[25]

$$\ln\left(\frac{Y(t)}{L(t)}\right) = \ln A(0) + gt + \frac{\alpha}{1-\alpha} ln(s_k) - \frac{\alpha}{1-\alpha} ln(n+g+\delta) + \frac{\beta}{1-\beta} ln(h^*) \tag{38}$$

As there exist now two variants for the Augmented Solow Model's econometric estimation; that is, one in which the rate of human capital accumulation is resorted to and another including the level of human capital, Mankiw *et al.* aimed at empirically sorting out the posed testing dilemma by suggesting to verify – in the first place – whether human capital's available data corresponded to (s_h) or to (h) a matter that, for Argentina, will be dealt with in the next section.

[24] The point is worth mentioning that, for Mankiw *et al.*, $lnA(0)$ also reflects, apart from technology, other features such as resource endowments or institutions, therefore the term is better depicted as being equal to $\alpha+\varepsilon$ where α is a constant and ε stands for a country's specific shock.

[25] It is easily noticed that the structure of 38 is practically similar to the traditional Solow-Swan equation without human capital in which the latter is part of the error term. Since saving and population growth rates influence h^*, human capital should be expected to be positively correlated with the saving rate and negatively in turn with population growth. In reason of this Mankiw *et al.* suggested that omission of the term on h^*, in Solow's Model, biased coefficients on saving and population growth.

3 Methodologies for computing the human capital stock and the average propensity to invest in human capital

3.1 *Preliminary ideas*

Even acknowledging the difference between this paper's aims and those in articles which explicitly refer to economic growth, such as Mankiw *et al.*, the construction of a variable that clearly serves the purpose of capturing the effect of human capital upon gross domestic product contributes to enriching future empirical results. Simple as it was, Mankiw's proxy did what it was intended to do, but it fell short from unveiling the policy effectiveness of budgetary efforts directed to human capital creation, therefore more accurate measures are in order.

Even by restricting to a single narrow variant of human capital, i.e. investment in education, Mankiw *et al.* acknowledged from the outset the "practical difficulties" involved in the variable's measurement, particularly if the model's second alternative (involving human capital level) were aimed at for econometric estimation. On grounds therefore of statistical feasibility, the first alternative was resorted to by using a proxy for the rate of human-capital accumulation (s_h) which simply approximated the percentage of the working-age population actually enrolled in secondary school; however, the authors pointed out that the measure was not free from flaws, at least on the following four accounts: primary and university education were not included, the input of teachers was also ignored, students' forgone earnings and their variation with the level of human capital investment were not considered, and the proxy resulted from two data series respectively embodying the eligible population (12 to 17 years) and the working age population of school age (15 to 19 years) that clearly covered different age ranges. Needless to say, these flaws did not impede that a one sector model were used; the mentioned omissions and inconsistencies would be however a bounding restriction should a proper production function for human capital were included.

In the light of the above comments, efforts in the rest of the section are oriented to describing components of investment in human capital and to computing both the variables better representing in Argentina the level of per capita human capital (h) and the rate of human capital accumulation (s_h); while the former is required for the estimation of equation (38), the latter, whose new computed value seeks to avert the criticisms Mankiw *et al.* placed upon their proxy variable, is in turn used for testing equation (37).

3.2 *An alternative estimation of* s_h *and* h

From the outset, the specification of what "investment in human capital" will mean or include is crucial as, despite that much has been said and written in this matter, the need of counting with an econometrically practical variable and the scarceness of available data imposed always severe constraints. In this connection, the following principles governed the methodology followed to achieving variables standing for human capital in Argentina:

i) Notwithstanding the relevance of activities in the form of health and construction and maintenance of public goods, whose importance as components of human capital was particularly stressed by Uzawa as they resulted in an improvement of labour efficiency, difficulties involved in gathering data[26] and jointly dealing with all of them advise to focus only in investment in education.[27]

[26] This was particularly true for health expenditures as major modifications underwent by the system during the period considered made very difficult to obtain statistical series while at the same time benefits rendered by their inclusion were scant.

[27] Technical knowledge (derived from investment in education), must be built upon an inherited social capital, should it be expected to *(continues)*

ii) In correctly ascertaining the real value of the variable, the opportunity costs of investment in education; that is, the forgone income of working age students, should be determined and added to the actual budgetary resources component. The importance of opportunity costs in empirical work has repeatedly been noticed, as was the case in Kendrick's calculations (1976). Maintenance costs of university students, borne by parents, must also be taken into account as a component of opportunity costs.

iii) Investment in education is an all inclusive term, therefore primary, secondary and higher education, as well as science and technology, are also encompassed.[28]

iv) Budgetary expenditures in the field of Culture are excluded on grounds that they generally yield consumption rather than productive goods.

v) In a country like Argentina, characterized by a federal institutional setting in which investment in education spreads over the three government levels, the variable's right assessment calls for national, provincial and municipal spending in education to be altogether considered.[29]

In order to meet the preceding general guidelines, the variable standing for investment in human capital is built considering the following methodological principles:

a) Educational expenditure is an overall item including actual budgetary outlays in basic education (primary and secondary levels) and higher education (tertiary and university studies) of all the three government levels: central government, provinces and municipalities.

b) National and subnational spending in science and technology is also included, inasmuch as they aim at raising productivity by helping to develop the current state of the applied scientific knowledge and productive techniques.

c) Minima legal wages are used to approximately computing opportunity costs on the following two grounds: they by definition represent households' cost of basic needs whereas they also serve as a proxy for incomes earned for working age students still no having completed their higher studies.
Nevertheless, secondary students' maintenance costs borne by parents are not added in opportunity costs, the idea being that households customarily support children up to the age of eighteen. By the same token, not forgone incomes are suppose to exist in the case of secondary students under fifteen as labour regulations and practical limitations are more strictly applied upon this particular age range. This explains the decision not to compute forgone earnings for secondary students under fifteen while only a minimum legal wage was taken for students above this age.

d) Contrariwise to what is asserted in the preceding paragraph, higher education and university students are expected to somehow support themselves, therefore the following three cases may be considered: a) they work full time and bear their maintenance costs; b) they work part time but their parents still bear their maintenance cost and c) they do not work at all and therefore, apart from forgone incomes, their maintenance cost is also borne by their parents. These three categories serves to explain the opportunity cost structure that follows: a double legal minimum wage is assigned to the percentage of higher education students who, according to statistical information drawn from household and university surveys, do not work; in this case, one

improving the country's productivity matrix. In this context the expression embodies elements such as institutions, values and social and collective behaviour.

28 Expenditures devoted to different university's careers are not made explicit at this stage. Given that disciplines can have different marginal impacts on gross domestic product this could be a further step in future investigations.

29 As of the nineties, primary and secondary education became in Argentina a provincial budgetary responsibility, the national government performing thereafter a subsidiary role through annual transfers sent to the subnational level (based on the so-called Ley del Financiamiento Educativo 26075). The national government keeps in change the responsibility of wholly financing national public universities whereas spending in science and technology is a shared commitment, though mostly funded by the central government.

minimum wage accounts for forgone earnings and the other for students' maintenance costs borne by parents. For the percentage of students having a job but still receiving economic support from their families, no forgone incomes are assumed and only one minimum wage is computed in order to reflect maintenance's costs. For students that work and defray their own expenses no opportunity costs are assigned.

e) Outlays in a)-b) above stand for the investment in human capital restricted to budgetary expenditures in Education, Science and Technology. By including c)-d) an augmented version of human capital investment is obtained which also includes opportunity costs. By dividing both variants of investment in Education by gross domestic product, average propensities to invest in human capital result.

f) In building up series for human capital stock the conventional assumption is upheld that actual educational investments, similarly to physical capital, are subject to an annual depreciation rate of 10 per cent.[30] The reason for using a single depreciation rate for both capital assets not only responds to computational simplification, but also seeks to reduce the loss of degrees of freedom: should more than one depreciation rate be used, more parameters will have to be estimated and the data constraint binds tighter.

g) All variables are in real terms, deflated by CPI series (see sources in Annex 1).

3.3 Variables' specification

Once components of investment in human capital are completely assessed and included, both variants of the average propensity to invest in human capital are computed; nevertheless, only the variant "average propensity to invest in human capital (inclusive of opportunity costs)" is used in the econometric estimation. The variable's computed values (with and without opportunity costs) are shown in Annex 1, whereas that its performance over time is depicted by figures in next section, in which stylized facts related to human capital performance in Argentina are considered.

As for human capital stock (H), the annual value of the variable includes the preceding years' still not depreciated investment together with the year's actual not amortized investment (e.g., if 1998's human capital stock is to be computed, 90 per cent of the year's investment is included plus the remaining not amortized investments from previous periods). The value of variable human capital stock (H) needs not be confused with the variable (h) in equation (38), representing per capita human capital stock.[31] The variants included here are in line with different forms of regarding human capital (with and without opportunity costs) and their graphical evolution is considered in the next Section. Although computing both H and h appears like a major step in fathoming with some of postulated questions, the econometric use of these variables has not proven fruitful in the present step of the investigation. Nevertheless, a better performance is expected from theirs being used in an endogenous model, where a human capital production function is included.

4 Stylized facts concerning the evolution of gross domestic product and human capital formation

In analyzing Figure 1 below, tracing the evolution, as of 1978, of the Argentine gross domestic product and human capital stock, this having been computed as explained in Section 3

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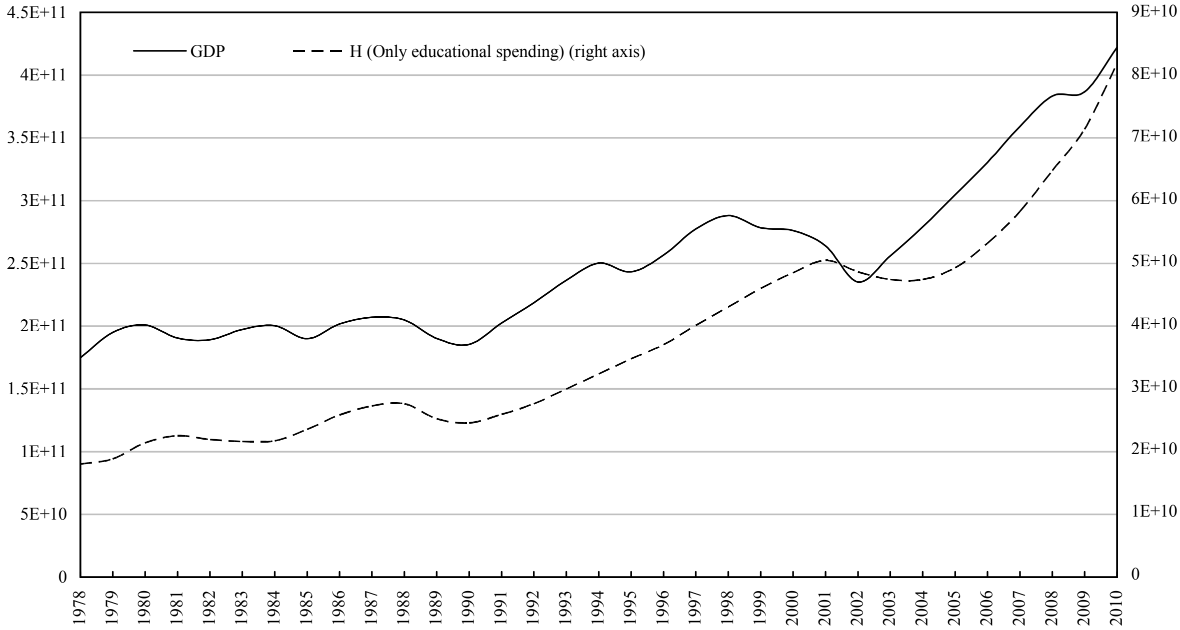
[30] It is obvious that this simplifying assumption does not rule out alternatives; thus, while Mankiw *et al.* prefer a longer amortization period (a smaller depreciation rate), the argument may also be defended that amortization need not be linear but decreasing.

[31] See the value for h (inclusive of opportunity cost) in Annex 1, quoted as HOCPC.

Figure 1

Series Stand for Gross Domestic Product and Human Capital Stock at Current Prices



and including only budgetary outlays in Education,[32] an immediate feature deserving being stressed is the direct correlation found between both series. A more careful inspection of the figures, however, sheds light on the matter of causation closely, which, in turn, is related to objectives motivating this research. As can be seen, the gap between GDP and H shrinks in time in coincidence with the working of the so-called “Ley de Financiamiento Educativo”, whereby educational spending should be gradually increased until it reaches a determined percentage of GDP. One important preliminary conclusion, verified below by the econometric results and running counter to what it would have been expected, is that GDP clearly hauled human capital formation (represented here by investment in education), with little evidence of the reverse causation order significantly taking place.

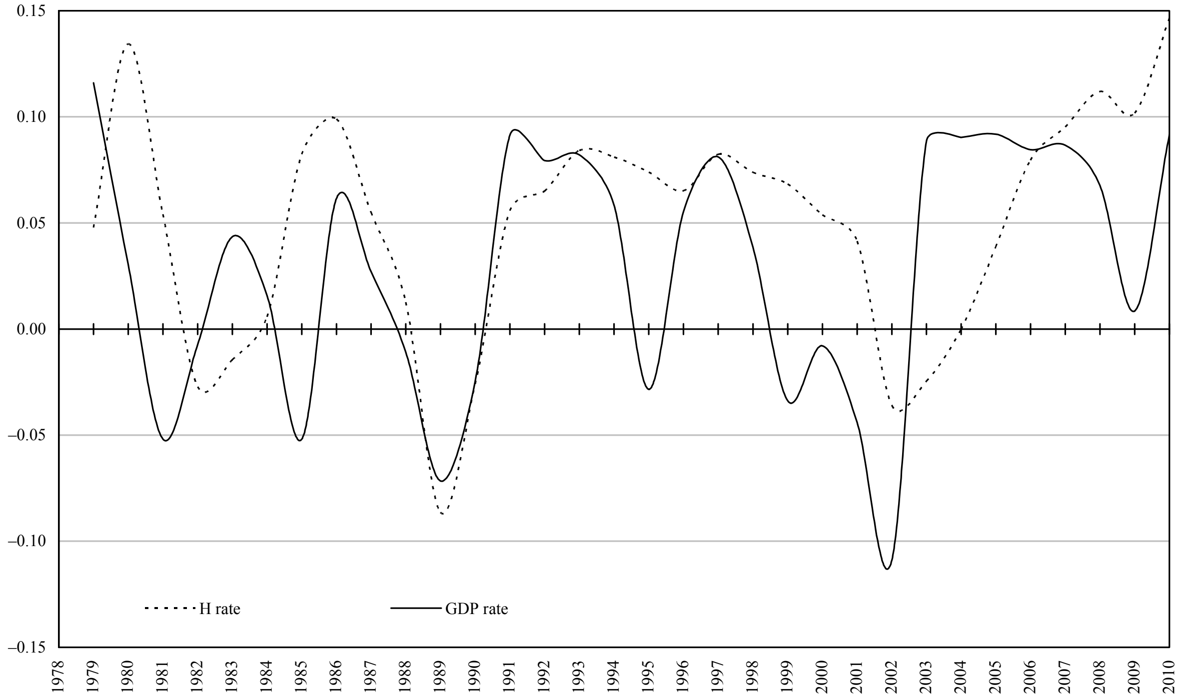
A conclusion somehow similar to the one just arrived upon in the previous diagram can be drawn when GDP and H’s growth rates are jointly assessed, as in the following Figure 2: strikingly, except for a few periods in which both growth rates exhibited the same pattern, there seems not to be a particular positive correlation between the series’ respective maxima and minima values; thus, growth rates, rather than coinciding, behave differently in a large part of the period considered and it is also noted that when both have a decline – as in the period 1983-2002) the fall is more deeper in the case of the gross domestic product growth rate. In line with what the cointegration analysis will show in Section 5, bad or good performances of the overall Argentine growth rate seem to be based in factors no considered here and it can hardly be argued that investment in education significantly counted as one of them.

It is therefore important to point out that, however expected the evolution of human capital stock following the path traced by GDP (mainly due to the form in which the variable was computed), hopes that H would somehow behave as a GDP’s growing factor or stabilizer can be hardly fed from evidences in the figures shown.

[32] That is, investment in education is here computed exclusive of opportunity costs.

Figure 2

Gross Domestic Product and Human Capital Stock Growth Rates Derived from the Respective Series in Current Prices



The next diagram, in which the ratios of investment in education over gross domestic product and over the previous period's gross domestic product (the lag of the same variable) are respectively plotted, not only enriches the analysis of the real impact of human capital upon product but also help in reasserting conclusions derived in the preceding paragraphs by introducing an element that has so far not been considered. The steady increase of H throughout the whole period (see Figures 1 and 3) is seen to be practically accompanied by a similar performance of ratios H/GDP shown in Figure 3, except for some isolated cyclical decreases the latter underwent; since ratios stand for human capital stock per unit of product, it is possible to argue that the nature, quality and efficacy of human investment (measured as outlays for education) fell short of what was expected in terms of their product enhancing capacity and that may in turn explain why an incremental product-investment in education relationship failed to prevail.

Suffice it to mention that the second ratio was aimed at ascertaining whether human capital formation had a lagged impact upon product; needless to say, this hypothesis could not either being proven as the similar pattern exhibited by dashed line ruled out chances of a clearer relationship and higher impact between variables stemming from taking policy variables' lagged values.

The conclusion obtained from the graphs in Figure 3 is still more evident when the plots of product and average propensity to invest in human capital growth rates, shown in Figure 4, are carefully observed. Even though the former (already shown in Figure 2) shares its cyclical behaviour with S_h, ups and downs of the average propensity to invest in education and technology's growth rate were by far much more marked, and yet this did not seem to have had a definite weight upon the evolution of the product's growth rate, let alone the fact that their performance run counter in several time spans during the period analyzed.

Figure 3

Ratios of Human Capital Stock/Gross Domestic Product in 1993 Prices
(figures in left and right vertical axis respectively stand for the value of the ratio and the human capital stock)

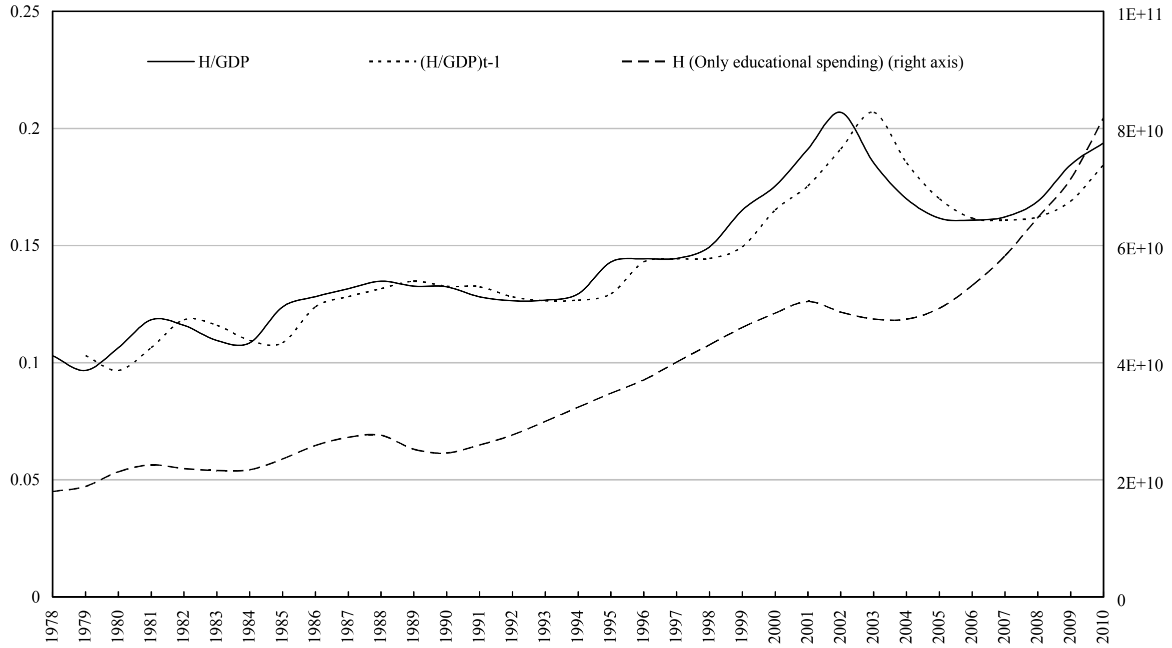


Figure 4

Rates of Growth of the Average Propensity to Invest in Human Capital (When Opportunity Costs are Not Considered) and of Gross Domestic Product

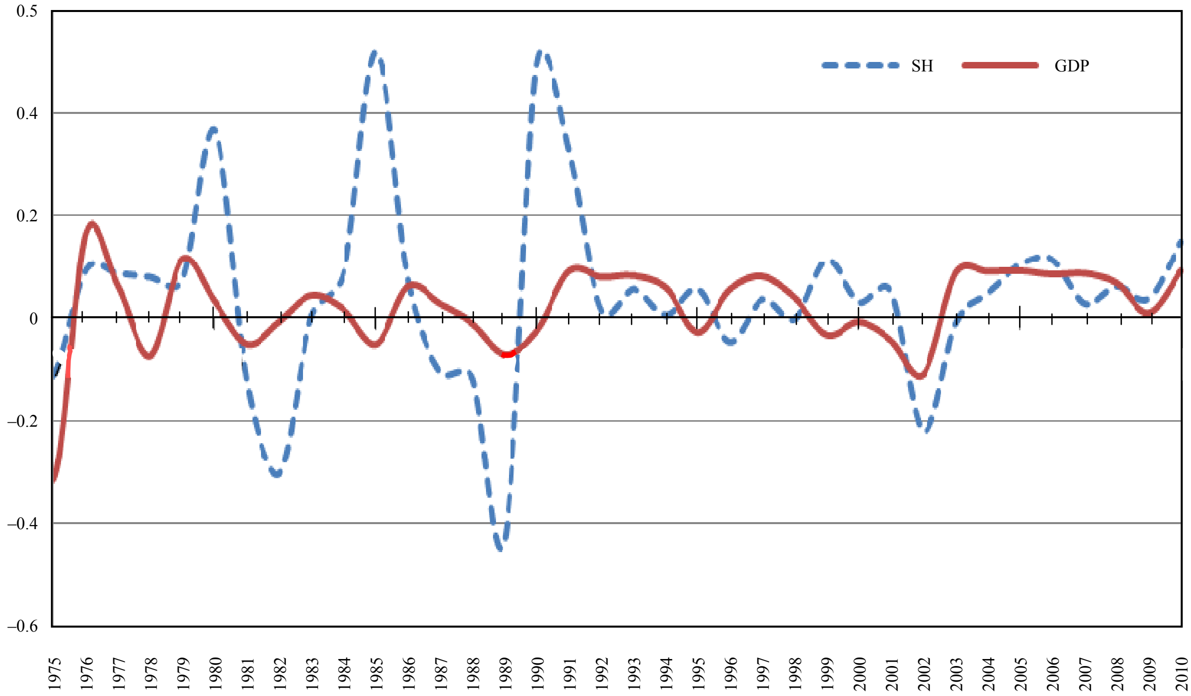
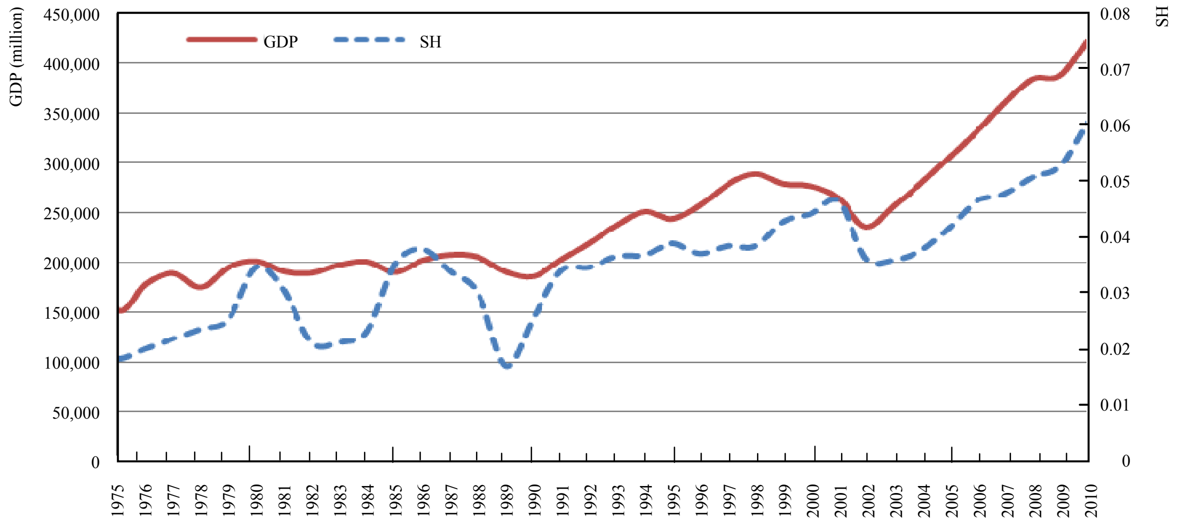


Figure 5

Series for Gross Domestic Product and Average Propensity to Invest in Human Capital



When the gross domestic product and average propensity to invest in human capital series are plotted together, as in Figure 5, their evolution did not seem to offer explanations different to what has so far been presented: for the first part of the period, S_h exhibited a marked cyclical behavior not accompanied by the steady low growth path of product while the stable increase of S_h as of 2003, for reasons given above, did not seem to have produced any particular incremental effect upon product but rather the other way round.

The performance in the period 1991-98 is however worth mentioning as it seems to have been the only case in which human capital formation exerted any incremental effect upon product; this situation was also reflected in Figure 4, as can be easily noticed when the behaviour of product and average propensity rates of growth is observed.

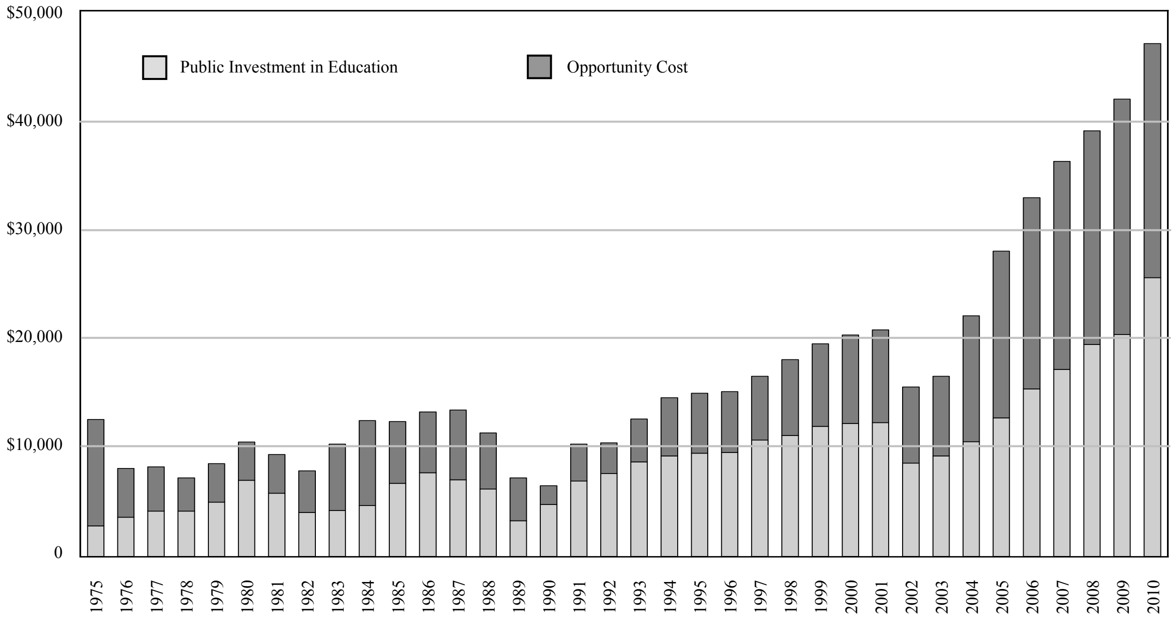
The presentation of stylized facts is completed with the analysis of the following figures in which the overall concept of investment in education, embodying budgetary outlays as well as the opportunity costs (as defined in the preceding section) is considered. In the first place, the graph in bars of Figure 6 showing the evolution of the actual investment in education aims at highlighting how their two components evolved throughout the period.

The first worth pointing out evidence shown by Figure 6 is that students' forgone earnings and maintenance costs supported by parents have been an important component of the overall investment in education all throughout the period; in this regard, the very magnitude of opportunity costs as a representation of the burden implied for the society as whole poses a question whose answer falls well beyond this paper's reach but that seems anyhow worth ascertaining in terms of cost benefit analysis.

The second evidence yielded by Figure 6 is that opportunity costs' percentage share within investment in education was not stable but underwent significant variations throughout the years. The explanation for that must be sought at the form opportunity costs were computed; that is, in terms of minima legal wages. It is therefore clear that opportunity costs' share of investment in education was straightaway conditioned by updating opportunities of minima legal wages by the government.

Figure 6

Public Investment in Education (Budgetary Outlays) and Opportunity Costs (Forgone Incomes and Maintenance Costs Borne by Households)
(million pesos of 1993)



Finally, the evolution of the overall average propensity to invest in education (Figure 7) is in turn split in order to show its two components' actual weight. Although bars in Figure 7 are expected to follow the pattern set by the investment in education in Figure 6, figures for S_h permit in turn to add some additional comments that shed light on human capital performance in Argentina during the period considered. In the first place, the evolution of both the overall average propensity to invest in education as well as components' share did not appear to follow a definite pace, conversely to what by and large happened as of the nineties.

However, one interesting feature revealed in the bar Figure 7 is that, apart from the positive effect of parliamentary mandated increases in education outlays, which subsequently raised the percentage participation of investment in education to gross domestic product, the opportunity cost component grew steadily as of the nineties to the extent that its participation ranged between 40 per cent and 45 per cent of the overall average propensity to invest.

5 Econometric estimation for Argentina of an Error Correction Model

5.1 *Theoretical aspects of the Error Correction Model*

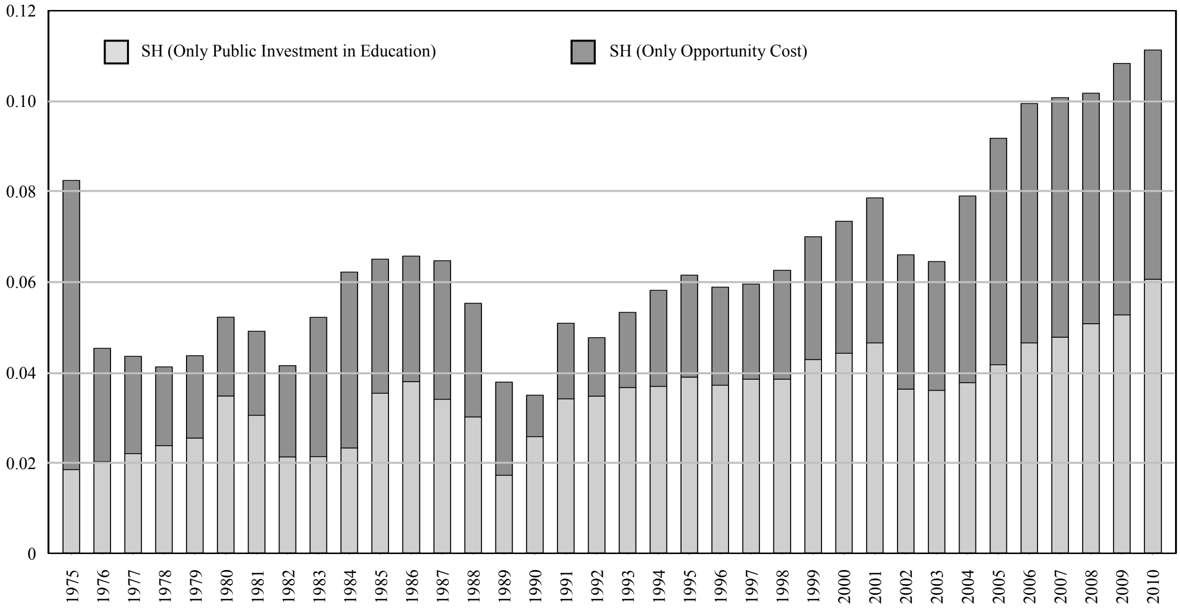
As known, an error correction model responds to the following structure:

$$\Delta X_t = \pi_0 + \pi X_{t-1} + \sum_{i=1}^{p} \pi_i \Delta X_{t-i} + \phi D_t + \varepsilon_t \tag{39}$$

where ΔX_t stands for a $(n \times 1)$ vector representing the set of endogenous variables, π_0 is a constant terms vector included in the VAR, ΔX_{t-1} stands in turn for the "i periods" lagged vector

Figure 7

Average Propensity to Invest in Education



of variables while the dummies vector D aims at capturing the model's structural break points. The term πX_{t-1} is important in so far as it differences the ECM from a VAR in differences by incorporating information contained in variables in levels; matrix π results from the product of matrices α' and β', the first embodying speed of adjustment parameters to short term changes respect of long run (or equilibrium) relations whereas the second one holds cointegration coefficients by means of which a linear combination of order one integrated variables comes up to be stationary. Thus, equation (39) can be similarly represented by the following expression:

$$\Delta X_t = \pi_0 + \alpha\beta' X_{t-1} + \sum_{i=1}^{p} \pi_i \Delta X_{t-i} + \phi D_t + \varepsilon_t \tag{40}$$

The rank of matrix $\pi = \alpha\beta'$ suffices to determine the number of cointegration equations: if it were zero, the matrix would be null (π=0) and the model would be stated in terms of a VAR(p) in differences; if there is, on the contrary, a complete Rank matrix, all variables will be stationary, as a stationary variable cannot be equaled to a non-stationary one (in this case integrated of order one).

When the rank of π is r, (for $0<r<n$), there will be r cointegration equations, β will be now a $(n\times r)$ matrix, and product $\beta' X_{t-1}$ generates stationary variables that will stand for the short-run disequilibria with respect to each of the long-run relations. Matrix α also $(n\times r)$ holds the parameters determining the adjustment speed *vis-à-vis* these disequilibria.

The Johansen Methodology permits to calculate the rank of π by means of a Dickey-Fuller multivariate proof,[33] from which characteristic roots are obtained; the amount of distinct-from-0 roots will indicate the rank of π and the amount of linearly independent cointegration equations.

[33] When having the expression $X_t = A_1 X_{t-1} + \varepsilon_t$, in which X is a vector, the Dickey-Fuller Proof permits to check whether the matrix π in $\Delta X_t = (A_1 - \mathrm{I}) X_{t-1} + \varepsilon_t$, or in $\Delta X_t = \pi X_{t-1} + \varepsilon_t$, is null or not.

Trace and Maximum Eigen Value Statistics are used to identify the number of statistically different from zero roots: while the former one test the null hypothesis that the number of linearly independent cointegration equations is equal to or smaller than r, as against the alternative of greater than r, the second test is used to check the null hypothesis that the number of cointegration equations is r as against the alternative $r+1$.

It is expected to find, for the Augmented Solow Model, only one long run relation representing equation (37) above, from which all produced disequilibria will force variables to move till they newly reach equilibrium, both by means of long run effects included in the error correction term and through the VAR's short run effects.

5.2 Econometric estimation of the ECM for the Argentine case

The assessment of the impact of human capital upon the Argentine per capita gross domestic product is carried out for the period 1975-2010. Diverse data sources were resorted to in order to construct the series necessary for the econometric estimation of variables' coefficient, whose detail is referred to in Annex 1.

As will be shown below, variables in levels are not stationary (that is, not $\sim I(0)$), which can bring about the problem of spurious correlation and its undesired effects. Despite the fact that some controversy still exists in the literature as to whether to discard non stationary variables in time series regression, other solutions are at hand to deal with the problem,[34] as is the case of cointegration and the error correction model developed in the preceding section and used in this paper for estimating the previously introduced equation (37):

$$ln\left(\frac{Y(t)}{L(t)}\right) = \ln A(0) - \frac{\alpha + \beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}ln(s_h) \qquad (37)$$

Variables used in order to estimate the model are described below:

$ln[Y(t)/L(t)]$**,** indicating the log of per capita (or per effective labour unit) income (hereafter quoted as GDPPC);

$ln(n+g+\delta)$**,** standing for the log of the sum of population and knowledge rates of growth plus the depreciation rate (hereafter quoted as NDG). As it is obvious, the coefficient must be negative since the effect of a raise in the first two rates – by increasing both the population and the number of effective units of labour – will be a smaller per capita o per worker income.

$ln(s_k)$, $ln(s_h)$, respectively showing the log of the propensity to invest in physical (SK) or human capital. As in the previous case, their positive coefficients will indicate the expansive effect exerted by higher propensities. As said, s_h admits the two variants: actual expenditures in education over gross domestic product (SH) and actual expenditures in education plus opportunity costs over gross domestic product (SHOC); the statistical software EViews was used to obtain the econometric results of regression equation (37) shown above.

As the estimation process requires, in the first place, the order of integration of series used to be determined, Table 1 shows results of unit root tests;[35] as can be noticed, variables are not stationary.

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[34] In particular, the risk of spurious regressions disappears if a lineal combination of non stationary series happens to be stationary or $I(0)$. As Rezk and Irace (2008) pointed out, the economic significance is in this case no minor as the existence of cointegrated series indicate in turn a long run equilibrium relation among the variables.

[35] All variables are in logs and the amount of lags used for the Dickey-Fuller Test was automatically determined by Schwarz Information Criterium. The human capital stock (h^*) was not used in this case as its first difference turned out to be not stationary (see tests in Annex 3, Table 7).

Table 1

Augmented Dickey-Fuller and Phillips-Perron Test

Levels	ADF	PP
GDPPC	–1.301158	–1.277143
NDG	0.450308	0.180568
SK	–2.979997	–2.501809
SHOC	–1.334194	–1.320521
SH	–1.471598	–1.120892

First Diff.	ADF*	PP*
Δ*GDPPC*	–6.328994	–6.328994
Δ*NDG*	–5.232868	–3.616207
Δ*SK*	–5.060128	–4.931142
Δ*SHOC*	–5.350248	–6.77113
Δ*SH*	–6.315386	–10.48566

* In all cases, the null hypothesis is rejected for/at 1 per cent significance level.

Table 2

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Max-Eigen Statistic	0.05 Critical Value
None*	0.819268	98.19719	54.07904	61.58658	28.58808
At most 1**	0.390939	36.61061	35.19275	17.8501	22.29962
At most 2	0.26849	18.76051	20.26184	11.25518	15.8921
At most 3	0.188184	7.505336	9.164546	7.505336	9.164546

* The hypothesis of no integration equations is rejected for/at a 5 per cent significance level, as against the alternative of one equation (Max-Eigen Vaule) or more than one (Trace).
** The Trace Test rejects the null hypothesis of one cointegration equation as against the "more than one" alternative whereas the Max-Eigen Test does not reject the null hypothesis of one cointegration equation as against the "two cointegration equations" alternative.

Johansen Cointegration Method was resorted to for the ECM estimation, including respectively a constant term (both in the cointegration equation and the VAR) and a dummy for year 2002, when the country incurred in default of its external debt.[36] Given the constraint imposed by the scarce data availability, variables were in turn allowed only one lag.

Results for the Johansen Test are shown in Table 2 above, in which the computed Trace and Maximum Eigen statistics were compared with their respective critical levels for a significance level of 0.05.

Even though the Trace Statistic seems to suggest that two long run equilibrium relations exist, only one is pointed out by the Max-Eigen Statistic, therefore the ECM is finally estimated with one long run relation.[37]

[36] The dummy variable previously included for 1989, the year of hyperinflation, but it was discarded as it turned to be not significantly different from 0 in all cases.

[37] On the basis of results yielded by the Trace Statistic, the error correction model was also estimated for two cointegration equations but, in one case, results were scarcely significant.

Table 3

The Cointegration Equation

	GDPPC		**C**	**NDG**	**SK**	**SHOC**
Coefficient	1	=	8.47	–0.33	0.34	0.17
t-statistic			*(31.14)*	*(–6.88)*	*(11.17)*	*(5.08)*

Cointegration coefficients (β matrix in equation (40)) turned out to be significant and held also the expected signs; after coefficients are normalized, and taking GDPPC as the dependent variable, the expression representing equation (37) of the Augmented Solow Model is obtained, as shown in Table 3.

Deviations with respect to this long run equilibrium relationship are stationary as shown by Table 4 in which the hypothesis of unit root is rejected at a 1 per cent significance level both by the Augmented Dickey-Fuller and Phillip-Perron Tests:[38]

Table 4

Augmented Dickey-Fuller and Phillip-Perron Tests

Level	**ADF Stat.***	**PP Stat.***
Coint. Eq.	–2.710985	–7.881003

* Unit root rejected at 1 per cent.

As short-run disequilibria are incorporated by the Error Correction Model via an "error correction vector", their actual impact upon endogenous variables is in turn determined by coefficients included in matrix α (equation (40)) standing for the adjustment speed. Table 5 shows the estimation's outcome.

The first column standing for matrix α, vector in this case, reveals that the speed of adjustment coefficients for both the gross domestic product and variable NDG are significantly different from zero, thus confirming the existence of an error correction vector. The following four columns (*endogenous variables*) represent matrix π_1 corresponding to the endogenous variables' first lag; finally, the last two columns stand for the vector of constant terms and dummies for year 2002 respectively.

Once the econometric estimation of coefficients is performed, tools provided by "innovation accounting" allow to assess the used model's adequacy, therefore the consideration of some impulse response functions (complete graphical detail in Annex 2) is accompanied by a variance decomposition analysis.[39] In the first place, Figure 8 highlights variables' response to a positive innovation in the average propensity to invest in human capital (inclusive of opportunity costs).

38 The amount of lags used resulted from the Schwarz Information Criterium (see Table 8 in Annex 3).

39 For IRF and Variance Decomposition the Cholesky Decomposition was resorted to with the following imposed variable ordering: SHOC-SK-NDG-GDPPC.

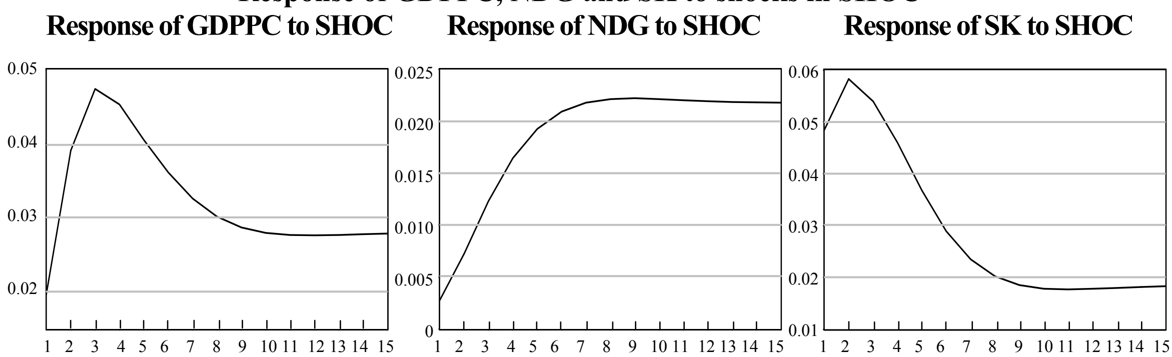
Table 5

	(α_i)	Endogenous Variables				Exogenous	
	$C.Eq_{t-1}$	$\Delta GDPPC_{t-1}$	ΔNDG_{t-1}	ΔSK_{t-1}	ΔSH_{t-1}	C	$D02$
$\Delta GDPPC_t$	**–1.002**	**0.3**	–1.3	–0.18	0.027	0.009	–0.19
	(–6.13)	***(2.13)***	*(–0.19)*	*(–1.79)*	*(0.34)*	*(0.54)*	*(–2.84)*
ΔNDG_t	**–0.011**	**0.008**	**0.76**	–0.003	0.0003	–0.0004	–0.001
	(–5.70)	***(4.96)***	***(9.56)***	*(–2.74)*	*(0.37)*	*(–2.06)*	*(–1.22)*
ΔSK_t	0.49	0.23	–24.43	0.19	0.088	–0.033	–0.34
	(1.51)	*(0.83)*	*(–1.84)*	*(0.92)*	*(0.57)*	*(–1.08)*	*(–2.49)*
ΔSH_t	0.46	**0.97**	–7.29	**–0.4**	0.24	0.003	–0.2
	(1.38)	***(3.41)***	*(–0.53)*	***(–1.95)***	*(1.52)*	*(0.08)*	*(–1.37)*

* t-statistics in parentheses.

Figure 8

Response to Cholesky One S.D. Innovations
Response of GDPPC, NDG and SK to shocks in SHOC[40]



As expected, gross domestic product's response to increases in the rate of expenditure in Education is positive and particularly greater in the first periods following the shock. The positive reaction of *NDG* *vis-à-vis* a *SHOC* innovation may be indicating that rises in the rate of investment in education somehow leads to more units of effective labour, as Mankiw *et al.* (1992) stated it in the Augmented Solow Model. Finally, *SK* also reacts in a positive way to a sudden rise in SHOC, which seems to suggest a sort of complementarity feature between both productive factors; nevertheless, the feature reverts when the impact on SH of a shock in SK (Figure 9) is considered, as in this sequence the negative response seems to indicate substitutability between both factors which deserves at least a further analysis.

[40] The used software EViews does not graphically show confidence intervals for the impulse response functions.

Figure 9

Response to Cholesky One S.D. Innovations
Response of SHOC to shocks in NDG, GDPPC and SK

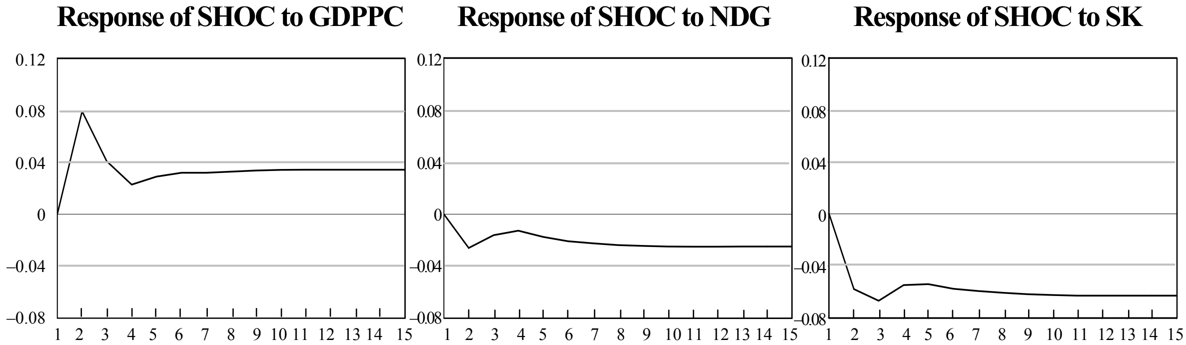
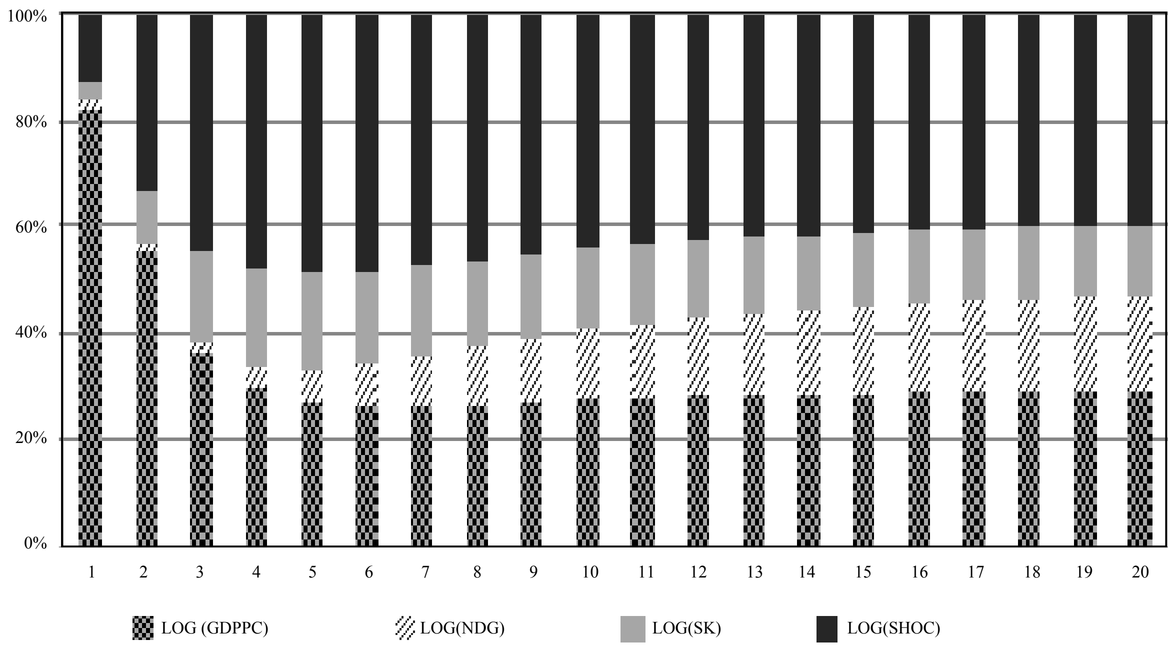


Figure 10

Variance Decomposition of Log of Gross Domestic Product Per Capita (GDPPC)



In completing the analysis of graphs in Figure 9, the expected positive response of SH to innovations in GDPPC reflects not only the common sense perception that societies will raise their demand for human capital formation as income per capita increases but, and for the Argentine case, the parliamentary decision that budgetary spending in Education should gradually reach 6 per cent points of GDP.

The recourse to variance decomposition permits in turn to ascertain the extent to which more relevant variables' total variance is explained by their own variance as compared to explanation given by other variables' variance. In order to illustrate the preceding statement, Figure 10 is used to show variance decomposition in the case of GDPPC.[41]

In spite that both impulse response functions and variance decomposition reveal that human capital investment (measured here as investment in Education) somehow impact upon gross domestic product, values for the Granger Causality Test for the GDPPC equation (shown in Table 6) run counter the preceding evidence since, only for the case of average propensity to invest in physical capital, the hypothesis that the s_k does not cause gross domestic product is rejected at/for a 10 per cent significance level (that is, SK Granger Causes GDPPC), whereas the non-causality hypothesis cannot be rejected for the rest of variables. Therefore, for the case expected to entail policy implications, preliminary results show that SHOC does not Granger-Cause GDPPC.[42]

Table 6

VEC Granger Causality/Block Exogeneity Wald Test

Dependent variable: D(GDPPC)

Excluded	Chi-sq	df	Prob.
D(NDG)	0.039624	1	0.8422
D(SK)	3.230270	1	0.0723
D(SHOC)	0.168026	1	0.6819
All	3.601399	3	0.3078

On the other side, it can be noticed that both GDPPC and SK Granger Caused SHOC (see Annex 3, Table 10), which is not an unexpected outcome regarding GDPPC, due to the already quoted parliamentary acts mandating that educational spending should gradually reach a percentage of product.

In conclusion, cointegration analysis and the error correction model enabled the empirical study to be carried out even though the involved variables were not stationary, and permitted also to verify the existence of a long run equilibrium relationship between gross domestic product and average propensities to invest in physical and human capital and population growth rate.

Furthermore, the error correction model with one lag permitted to find short run relations the most notable being the one between product and s_h which, conversely to what was expected and suggested by the Augmented Solow Model, indicated inverse causality; that is, from product towards SHOC but not from the latter to the former variable.

Nevertheless, impulse response functions as well as variance decomposition analysis do show a human capital participation or impact upon the trajectory of product due to the incorporation of a cointegration equation in the model.

41 Fort the rest of variables, variance decomposition is shown in graphs of Annex 4.

42 Although model included only one lag, Granger-causality was not reverted when it was allowed to include a larger amount of lags (see Granger-Causality Test in Annex 3, Table 10).

It is also worth pointing out, as a final comment, that residuals are normally distributed and that no heteroskedasticity was found when the joint test was performed; some point problems of autocorrelation were however detected. Test results are shown by Tables 11, 12 and 13 in Annex 3.

6 Preliminary conclusions

The proposed methodology allowed a new way of computing the series of marginal propensity to invest in human capital and of human capital stock in Argentina, which were later used in estimating the key equations of the Augmented Solow Model. One key aspect of the new methodology was that the variable standing for human capital formation (represented by Investment in Education) also included opportunity costs.

Given the econometric problems caused by variables' non stationarity feature, usual estimation procedures were discarded and alternative approaches, such as cointegration and the Error Correction Model, including lags and dummies, were resorted to. Results identified cointegration equations denoting in turn the existence of long run equilibrium relations among variables; in this connection, variables' coefficients showed the expected signs and were, in all cases, significantly different from zero.

Econometric estimates also exceeded the usual tests for specific problems. Traces of autocorrelation found in some of estimations remains as a point to be dealt with, although at this stage they did not affect results' soundness.

The Granger causality test did not indicate the expected sequence of causality between the average propensity to invest in human capital and the gross domestic product, but it did it in the opposite direction; that is, a change in human capital investment measured as public expenditure on education plus the opportunity cost, did not necessarily cause Argentine GDP to experience – in contemporaneous or subsequent periods – variations of the same sign.

Econometric results showing that per capita gross domestic product caused average propensity to invest in human capital, but not the other way round as suggested by empirical findings of the Augmented Solow Model, had also been sufficiently backed by the evidence yielded by stylized facts, which showed that in Argentina (and particularly as of 2003 when the Financiamiento Educativo law was enacted) investment in education was practically a function of income.

It follows from the above that although the formation of human capital (in part represented here by Expenditures in Education) grew substantially during the study period, there seemed not to exist a clear relationship between the characteristics and effectiveness of spending programmes and the needs of the country's productive technological matrix.

Innovation accounting tools, which include impulse response functions and variance decomposition analysis, were used in order to assess the adequacy of the model. VAR impulse response functions highlighting the response of GDP to shocks in average propensities to invest in physical and human capital appeared to be significantly different from zero, particularly in the early years following the innovations, in spite that what resulted from Granger Causality Tests.

Variance decomposition that shows the proportion of the movements in the sequence of a variable that is caused by its own shocks, versus shocks to the other variables, also yielded consistent results. Suffice it to point out here that despite different orderings imposed to the respective variables in Choleski decomposition, impulse response functions and variance decomposition yielded relatively similar results.

Bearing in mind the original objective of studying the link between human capital formation (represented here as investment in education) and economic growth, and of empirically assessing whether human capital helped enhancing the Argentine gross domestic product, it can be preliminary stated, in the light of commented results, that either it did not or it did it in a minor magnitude.

Although reasons for that were not sufficiently considered in the present study, it might be suggested that the nature, structure and design of current fiscal policies were in this field nor efficient neither efficacious to achieving human capital's greater contribution to product.

ANNEX 1

Argentine Macroeconomic Series

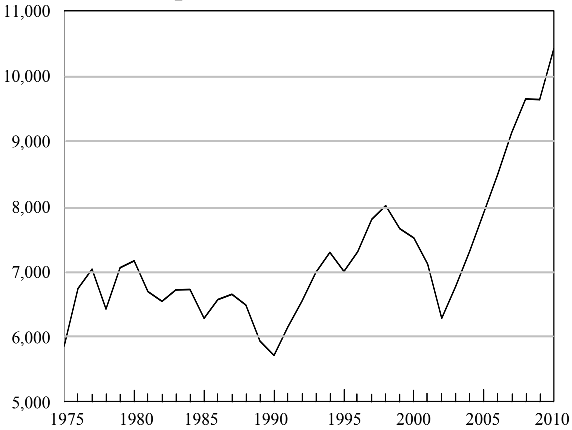
YEAR	GDPPC	NDG	SK	SH	SHOC	HOCPC
1970	7715.9264	0.1253	0.1997	0.0190	0.0470	
1971	7785.5126	0.1264	0.2105	0.0203	0.0526	
1972	7761.8169	0.1271	0.2100	0.0217	0.0526	
1973	9059.4481	0.1273	0.1641	0.0230	0.0558	
1974	8677.9784	0.1271	0.1752	0.0207	0.0693	
1975	5843.8484	0.1264	0.2564	0.0184	0.0825	
1976	6724.6234	0.1257	0.2422	0.0202	0.0453	
1977	7024.7289	0.1253	0.2761	0.0219	0.0435	
1978	6408.1012	0.1250	0.2600	0.0237	0.0412	1647.4577
1979	7045.6543	0.1250	0.2488	0.0254	0.0436	1563.9050
1980	7151.8987	0.1251	0.2544	0.0347	0.0522	1546.5807
1981	6678.3653	0.1253	0.2281	0.0304	0.0491	1491.0020
1982	6528.7571	0.1254	0.1840	0.0212	0.0414	1392.5059
1983	6709.6411	0.1254	0.1770	0.0213	0.0521	1388.3534
1984	6712.7158	0.1252	0.1671	0.0232	0.0622	1466.9411
1985	6270.0715	0.1250	0.1514	0.0353	0.0651	1540.4293
1986	6558.0232	0.1249	0.1583	0.0379	0.0657	1623.7858
1987	6636.7852	0.1249	0.1741	0.0340	0.0647	1692.6675
1988	6469.4241	0.1247	0.1698	0.0301	0.0553	1680.7746
1989	5921.0672	0.1244	0.1434	0.0171	0.0378	1544.7039
1990	5695.0102	0.1240	0.1222	0.0257	0.0349	1402.9336
1991	6130.8974	0.1237	0.1456	0.0341	0.0508	1377.9094
1992	6529.2661	0.1235	0.1789	0.0347	0.0476	1349.4917
1993	6972.9608	0.1232	0.1906	0.0366	0.0532	1379.4880
1994	7286.3332	0.1228	0.2047	0.0368	0.0581	1460.0144
1995	6992.3066	0.1224	0.1831	0.0389	0.0615	1543.1614
1996	7291.4349	0.1220	0.1889	0.0371	0.0589	1623.7531
1997	7792.3407	0.1216	0.2056	0.0385	0.0595	1733.5769
1998	8002.2277	0.1213	0.2110	0.0384	0.0626	1864.8330
1999	7647.7994	0.1209	0.1908	0.0428	0.0700	1999.7494
2000	7507.9856	0.1206	0.1792	0.0442	0.0735	2116.5662
2001	7105.0514	0.1201	0.1581	0.0465	0.0786	2216.1276
2002	6270.3354	0.1197	0.1128	0.0363	0.0660	2161.5160
2003	6760.6361	0.1194	0.1432	0.0360	0.0645	2124.0208
2004	7302.3836	0.1194	0.1765	0.0377	0.0790	2212.4454
2005	7897.0342	0.1196	0.1984	0.0417	0.0919	2418.6531
2006	8481.6154	0.1198	0.2161	0.0465	0.0995	2700.1878
2007	9126.0902	0.1199	0.2260	0.0478	0.1009	3010.3028
2008	9647.4593	0.1199	0.2309	0.0507	0.1018	3332.1291
2009	9635.2292	0.1198	0.2057	0.0527	0.1085	3663.9004
2010	10418.0894	0.1196	0.1822	0.0606	0.1114	4049.2467

Sources:
Gross Domestic Product: National Institute of Statistics and Censuses.
Gross Investment in Physical Capital: ECLAC STATS, Argentine Direction of National Accounts.
Consolidated budgetary educational expenditure and spending in science and technology: Direction for the Analysis of Public Spending and Social Programmes, Ministry of Economy of Argentina.
Consumer Price Index: National Institute of Statistics and Censuses and Statistics Direction, Province of San Luis, Argentina.
Population: National Institute of Statistics and Censuses.
Working Age Population: ECLAC, ILO.
Legal Minimum Wage: Ministry of Labour and Social Security.
Population enrolled in primary and secondary school and in universities: UNESCO.
Percentage of working age population over population in school age (secondary level): Argentine National Censuses.
University students having (not having) jobs and defraying (not defraying) their career and maintenance costs: Permanent Household Survey and information provided by the National Universities of Córdoba and La Plata.

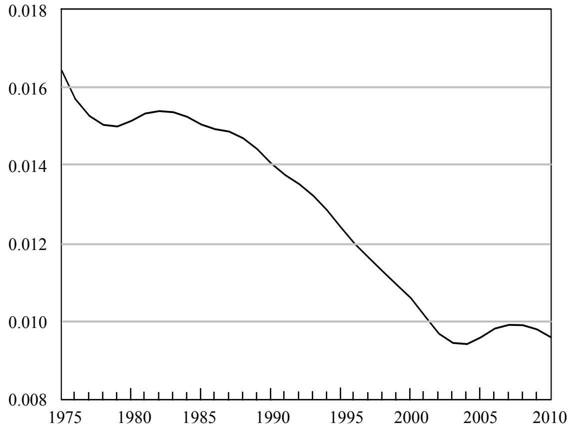
ANNEX 2

Argentina – Graphs in Levels of Macroeconomics Series

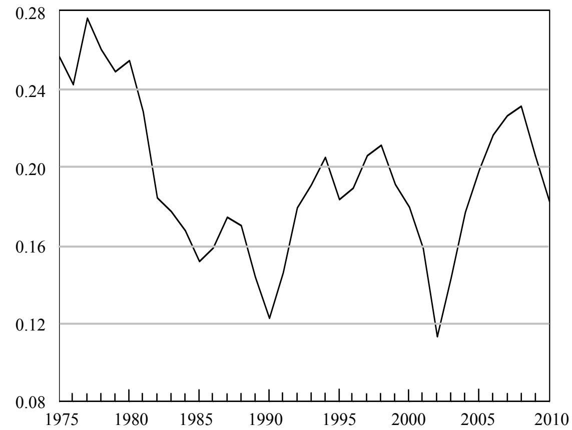
Per Capita Gross Domestic Product



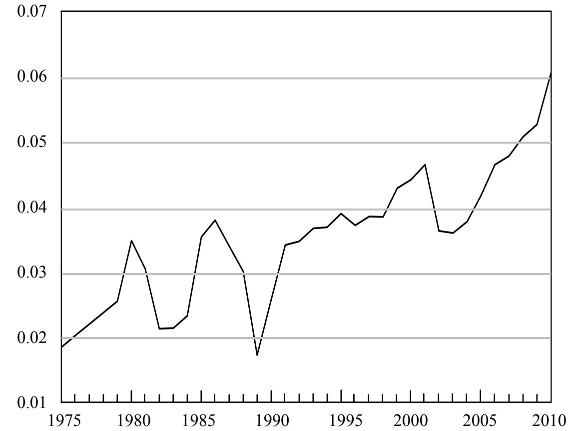
NDG



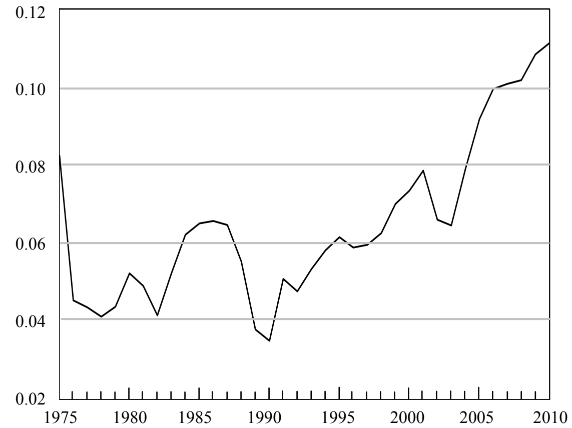
Average Propensity to Invest in Physical Capital



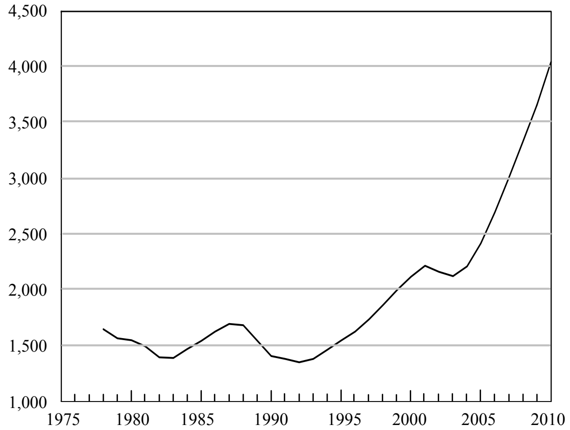
Average Propensity to Invest in Human Capital
(only public investment)



Average Propensity to Invest in Human Capital
(inclusive of opportunity costs)



Per Capita Human Capital Stock
(inclusive of opportunity costs)



ANNEX 3
ECONOMETRIC TESTS

Table 7

Unit root test for Per Capita Human Capital Stock
Augmented Dickey-Fuller test for Per Capital Human Capital Stock
(inclusive of opportunity cost)

Null Hypothesis: HOCPC has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic – based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		2.489400	1.0000
Test critical values:	1% level	–3.670170	
	5% level	–2.963972	
	10% level	–2.621007	

* MacKinnon (1996) one-sided *p*-values.

Augmented Dickey-Fuller test for First Difference of Per Capital Human Capital Stock
(inclusive of opportunity cost)

Null Hypothesis: D(HOCPC) has a unit root
Exogenous: None
Lag Length: 1 (Automatic – based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–0.688838	0.4100
Test critical values:	1% level	–2.644302	
	5% level	–1.952473	
	10% level	–1.610211	

* MacKinnon (1996) one-sided *p*-values.

Augmented Dickey-Fuller test for First Second of Per Capital Human Capital Stock
(inclusive of opportunity cost)

Null Hypothesis: D(HOCPC,2) has a unit root
Exogenous: None
Lag Length: 0 (Automatic – based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–3.724724	0.0005
Test critical values:	1% level	–2.644302	
	5% level	–1.952473	
	10% level	–1.610211	

* MacKinnon (1996) one-sided *p*-values.

Table 8

Unit Root Test for Cointegration Equation Residuals
Augmented Dickey-Fuller Test for CEq residuals

Null Hypothesis: CE has a unit root
Exogenous: None
Lag Length: 1 (Automatic – based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–2.710985	0.0082
Test critical values:	1% level	–2.634731	
	5% level	–1.951000	
	10% level	–1.610907	

* MacKinnon (1996) one-sided *p*-values.

Phillips-Perron Test for CEq residuals

Null Hypothesis: CE has a unit root
Exogenous: None
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. *t*-Stat.	Prob.*
Phillips-Perron test statistic		–7.881003	0.0000
Test critical values:	1% level	–2.632688	
	5% level	–1.950687	
	10% level	–1.611059	

* MacKinnon (1996) one-sided *p*-values.

Residual variance (no correction)	0.003609
HAC corrected variance (Bartlett kernel)	0.007622

Table 9

ECM Tests

Error Correction	D(LOG(GDPPC))	D(LOG(NDG))	D(LOG(SK))	D(LOG(SHOC))
R^2	0.620383	0.840351	0.324847	0.510517
Adj. R^2	0.541842	0.807320	0.185161	0.409244
Sum sq. resids	0.113939	0.001847	0.478804	0.497416
S.E. equation	0.062681	0.007981	0.128493	0.130967
F-statistic	7.898804	25.44145	2.325541	5.041027
Log likelihood	52.51918	126.7142	26.67790	25.99146
Akaike AIC	–2.528843	–6.650789	–1.093217	–1.055081
Schwarz SC	–2.220937	–6.342882	–0.785310	–0.747175
Mean dependent	0.005077	–0.016042	0.001096	0.013190
S.D. dependent	0.092604	0.018182	0.142346	0.170395
Determinant resid covariance (dof adj.)		3.50E-11		
Determinant resid covariance		1.47E-11		
Log likelihood		244.6247		
Akaike information criterion		–11.81249		
Schwarz criterion		–10.40491		

Table 10

Granger Causality Test

VEC Granger Causality/Block Exogeneity WaldTests
Date: 08/07/12 Time: 10:08
Sample: 1975 2010
Included observations: 36

Dependent variable: D(GDPPC)

Excluded	Chi-sq.	Df	Prob.
D(NDG)	0.039624	1	0.8422
D(SK)	3.230270	1	0.0723
D(SHOC)	0.168026	1	0.6819
All	3.601399	3	0.3078

Dependent variable: D(NDG)

Excluded	Chi-sq.	Df	Prob.
D(GDPPC)	15.96479	1	0.0001
D(SK)	3.704779	1	0.0543
D(SHOC)	0.118192	1	0.7310
All	17.88140	3	0.0005

Dependent variable: D(SK)

Excluded	Chi-sq.	Df	Prob.
D(GDPPC)	0.713625	1	0.3982
D(NDG)	3.141984	1	0.0763
D(SHOC)	0.222395	1	0.6372
All	3.313999	3	0.3457

Dependent variable: D(SHOC)

Excluded	Chi-sq.	Df	Prob.
D(GDPPC)	12.48611	1	0.0004
D(NDG)	0.476580	1	0.4900
D(SK)	4.269784	1	0.0388
All	13.63916	3	0.0034

Table 11

Normality Test

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 08/15/12 Time: 14:47
Sample: 1975 2010
Included observations: 36

Component	Skewness	Chi-sq.	df	Prob.
1	0.046288	0.012856	1	0.9097
2	–0.209914	0.264384	1	0.6071
3	0.397369	0.947411	1	0.3304
4	–0.202659	0.246425	1	0.6196
Joint		1.471075	4	0.8318

Component	Kurtosis	Chi-sq.	df	Prob.
1	2.942689	0.004927	1	0.9440
2	3.165719	0.041194	1	0.8392
3	2.975202	0.000922	1	0.9758
4	3.010935	0.000179	1	0.9893
Joint		0.047223	4	0.9997

Component	Jarque-Bera	Df	Prob.
1	0.017783	2	0.9911
2	0.305579	2	0.8583
3	0.948333	2	0.6224
4	0.246604	2	0.8840
Joint	1.518298	8	0.9924

Table 12

Heteroskedasticity Test

VEC Residual Heteroskedasticity Tests: Includes Cross Terms
Date: 08/15/12 Time: 14:48
Sample: 1975 2010
Included observations: 36

Joint test:					
Chi-sq	Df	Prob.			
221.1420	210	0.2854			
Individual components:					
Dependent	R^2	$F(21,14)$	**Prob.**	**Chi-sq.(21)**	**Prob.**
res1*res1	0.386844	0.420604	0.9645	13.92637	0.8727
res2*res2	0.506948	0.685455	0.7890	18.25012	0.6331
res3*res3	0.798639	2.644144	0.0330	28.75102	0.1201
res4*res4	0.460111	0.568154	0.8828	16.56399	0.7372
res2*res1	0.392246	0.430269	0.9608	14.12086	0.8644
res3*res1	0.689491	1.480342	0.2275	24.82166	0.2550
res3*res2	0.594404	0.977004	0.5318	21.39853	0.4348
res4*res1	0.472714	0.597669	0.8610	17.01770	0.7100
res4*res2	0.673155	1.373037	0.2744	24.23358	0.2819
res4*res3	0.568793	0.879383	0.6154	20.47656	0.4913

Table 13

Autocorrelation Test

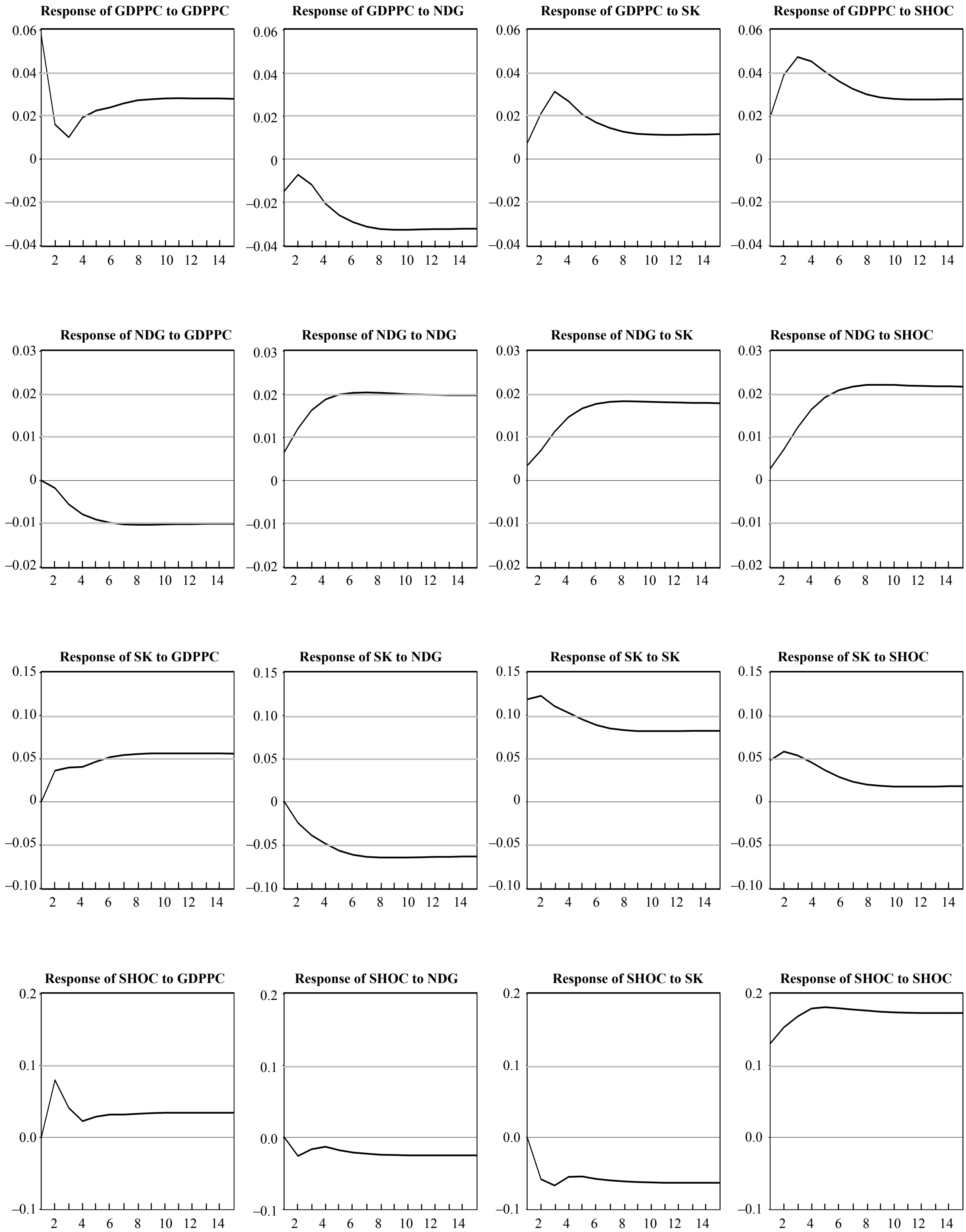
VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 08/15/12 Time: 14:50
Sample: 1975 2010
Included observations: 36

Lags	**LM-Stat.**	**Prob.**
1	51.97732	0.0000
2	25.25147	0.0655
3	22.28609	0.1342
4	12.98071	0.6742
5	14.12149	0.5897
6	28.47514	0.0277
7	24.30961	0.0830
8	17.28722	0.3673

Probs from chi-square with 16 df.

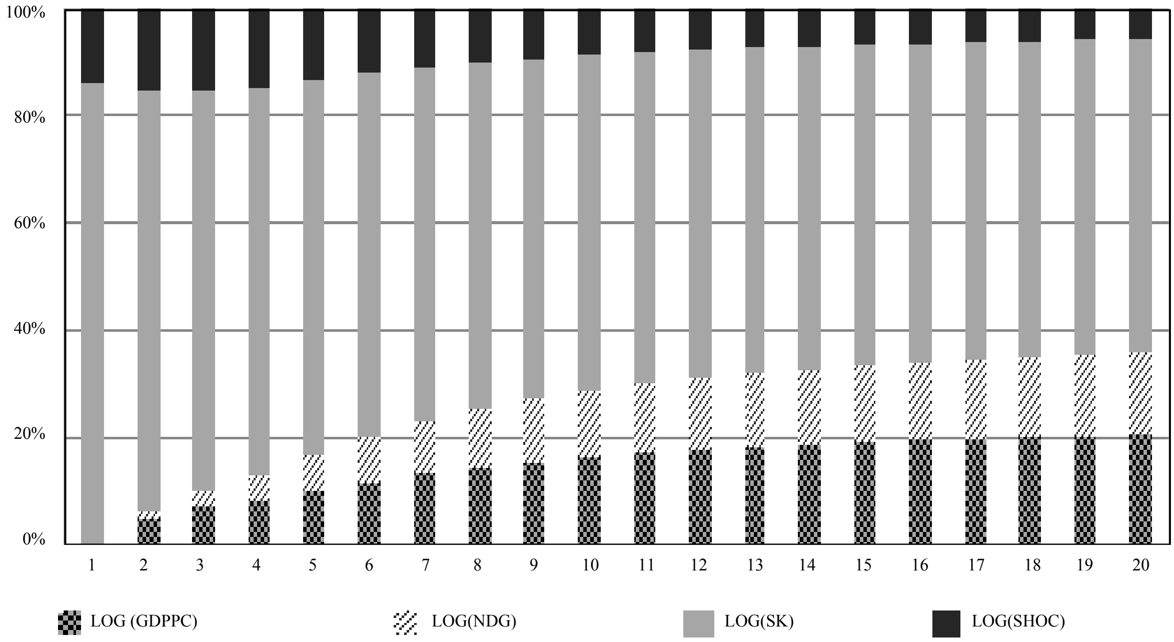
ANNEX 4
IMPULSE RESPONSE FUNCTION AND VARIANCE DECOMPOSITION

Impulse Response Functions
Response to Cholesky One S.D. Innovations



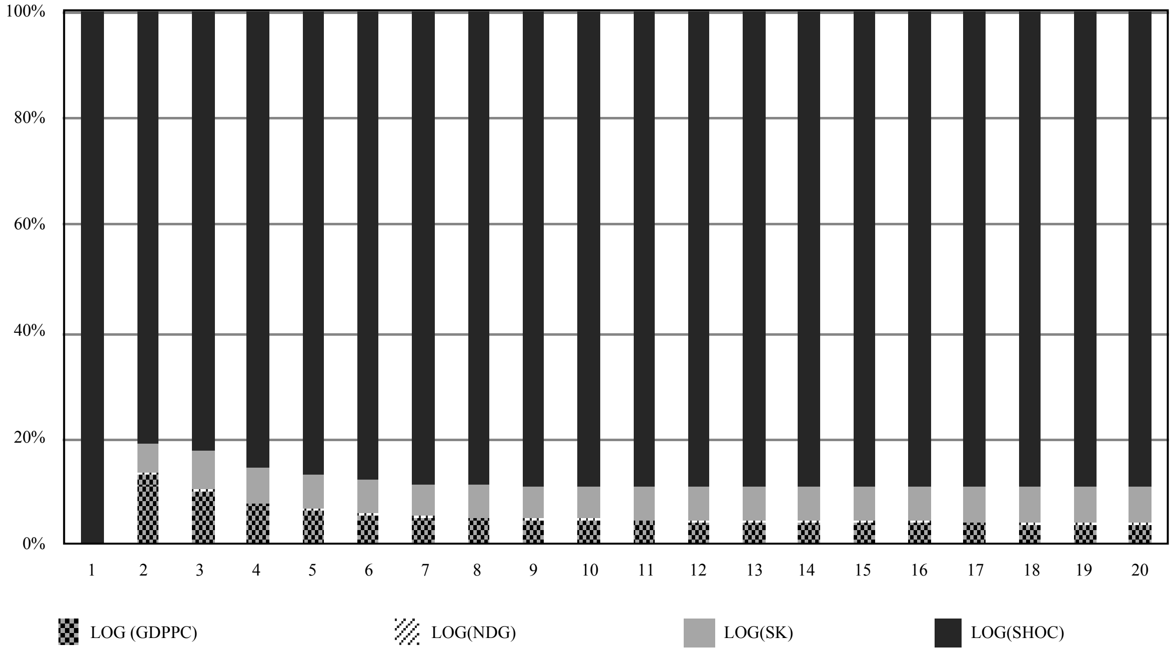
Variance Decomposition of Average Propensity to Invest in Physical Capital

SK



Variance Decomposition of Average Propensity to Invest in Human Capital
(inclusive of opportunity costs)

SHOC



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