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Social Ingredients and Conditional Convergence in the Study of Sectoral Growth

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Social Ingredients and Conditional Convergence in the Study of Sectoral Growth

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Abstract

In this research article, we investigate the improved modelling ability and the outstanding policy advocacy of infusing health and education in sectoral growth equations of the South African economy. Our findings not only include improved and dependable modelling results but also provide distinct estimates of the returns on investment in health and education per sector using Iterative Seemingly Unrelated Regressions techniques. Additionally, this paper provides a theoretical description of the productivity effects of HIV/AIDS using sectoral equations. Also, this research investigates the diffusion process in the technological progress at the South African sectoral level and its impact on the study of social ingredients. Using a fixed effects model, some features of the diffusion process are explained.

Keywords: *Coefficient of effectiveness; Diffusion process; Fixed effects model; Seemingly Unrelated Regressions.*

JEL Code: **E23, I39**

1 Introduction

The importance of health as a component of human capital has captivated the attention of several researchers in macroeconomics as well as policy makers. Developments in the world economy are closely linked to health related predicaments. The labour force through its productivity sees its contribution to economic growth enhanced by human factors such as: the workers' endurance and capacities (mental or physical); the workers' aptitude to make use of their reasoning ability; the workers devotion to delivering efficiently on time; etc. (Canning & Bloom, 2005). The design of any valid macroeconomic policy cannot be performed without inclusion of a health component. Health and education too, might be considered as human capital determinants. Although health on its own constitutes an important ingredient in any growth or development study, both require a particular consideration, especially with regard to their effects on effective labour.

The disaggregating approach used in this study helps with comparison of the effects of increased investment in health or schooling at the sectoral and national levels. One cannot disregard the fact that a healthier worker with higher educational background and more experience is usually more productive. Therefore, the use of physical labour force features while ignoring the effectiveness aspect is no longer sufficient in explaining the production setting. This study acknowledges the fact that technological components also have a labour-related contribution. The coefficient of effectiveness used in this study implicitly includes the level of health and schooling investment per worker as well as the level of experience. It remains plausible that other labour augmentation factors have been omitted in this analysis. Nevertheless, useful outcomes can be extracted.

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The importance of health in macroeconomic models is much more perceptible in the developing world where the majority of economies are labour intensive. A stronger level of labour effectiveness will tend to give rise to higher economic growth and *vice versa*. Further evidence of these effects has been garnered using microeconomic approaches (Strauss & Thomas, 1998).

The objective of this paper is to show that the development of a full-fledged macroeconomic model employing effective labour is a valid exercise and that it is much more informative than traditional macroeconomic models. Secondly, the research aims to present evidence that the outcomes of investment in health and/or schooling differ according to the sector targeted. Parameter estimates for South African economic sectors are discussed and, under very specific assumptions, the model can be regarded as representative of other African economies. Accordingly, this paper incorporates an analysis of the technological diffusion process in South African growth sectors.

Health has often been measured in terms of life expectancy. From an expenditure perspective, per capita (or per worker) health expenditure can also be used as an indicator of health when data on life expectancy are unavailable. The same measure, *i.e.*using expenditures as a proxy, is applicable for schooling. The pathways investigated in this paper are plausible in explaining the macroeconomic effect of health and schooling in the South African economy, although, data restrictions impose limitations on the study. Consequently, analysis could only be performed on five sectors, namely: (1) Agriculture; (2) Mining; (3) Construction; (4) Transport and Communications; and (5) Manufacturing; spanning the period from 1995 to 2006.

2 Background

As mentioned earlier, social ingredients, which appear in various forms in the growth literature, have a relatively rich history. They underscore most of economic thinking on the issue. Health and education are among the most important social ingredients referred to in macroeconomic studies. As mentioned earlier, in most of the references studied, health is presented in the form of life expectancy while a weighted average of total years of schooling is used as a proxy for education.

The use of effective labour, defined in terms of social variables, has produced interesting outcomes in terms of policy analysis. A study conducted by Fogel (1994) provides evidence that a large part of British economic growth in the 1970s was the result of a larger volume of effective labour inputs. Effective labour input was associated with workers with improved health and sufficient nutrition. Very similar results were obtained for the Korean economy where improved nutrition caused available labour input to rise by one percent for the period 1962 to 1995 (Sohn, 2000).

The effects of health improvement on economic growth follow different channels that converge towards income growth (Bloom *et al.* 2000, 2003, 2004). Investment in human capital associated with labour market participation and worker productivity have influenced the path of economic growth.

An interesting debate raised around the macroeconomic effects of health is that many regressions run in past studies were unable to indicate whether the coefficients obtained were the true reflection of the direct benefits of health on growth or whether they were just a proxy for other mismeasured variables (Bloom *et al.* 2003). In order to assuage this criticism, Bloom *et al.* included health in a full-fledged production function and conducted several tests to determine the direct effect of health on labour productivity. Their model encompasses multiple dimensions of human capital in an aggregate growth function. The combination of life expectancy and years of schooling used by Bloom *et al.* (2005) in their modelling of a coefficient of effectiveness using a panel of countries (Penn World Tables version 6.0) for the time period 1960 to 1995 remains a major contribution to the macroeconomics of health. A few questions could be raised with regard to the assumption that the coefficient of effectiveness equals one whenever life expectancy and years of schooling simultaneously equal zero. In this regard it is important to highlight the fact that the two parameters are specified as summing to unity. When health (life expectancy) equals zero the coefficient of effectiveness will automatically equal one no matter what value the parameter of schooling takes. In fact, it is hardly conceivable that a workforce unit can increase its effectiveness just by using schooling. In this study, a third factor has been introduced, namely a constant that capture any omitted variable. When a worker has no life expectancy, none of the other factors can improve his effectiveness. However, when a worker has some life expectancy with a certain level of education, his effectiveness will be increased by a higher level of experience. The present research does not involve enough tests which indicate whether or not the impact of experience in the coefficient of effectiveness is mixed up with other mismeasured factors.

It is a difficult exercise to establish whether quantitative evidence of the relationships between education (schooling) and economic growth exists. The majority of studies previously conducted on schooling as a social ingredient to economic growth have made use of variables such as: school enrolment; literacy rates; years of schooling; etc. Schooling implies better skills and higher productivity and a higher level of education in the workforce increases the absorption rate of technology (Barro *et al.*, 2000). The interesting question raised in Barro's study relates to the adequacy of these variables in the measurement of the stock of available human capital. The matter is addressed by measuring education levels for a panel of countries conducted on intervals of five years. The research provides relevant findings in terms of advice on how to measure the macroeconomic impact of schooling. The authors make adjustments to cover missing observations using gross school enrolment features capturing the movement from students repeating years. Additionally, the average years of schooling used in the research account for amendments in the total number of years of schooling in the panel. This paper addresses the issue slightly differently, by taking the public expenditure side into consideration. Both health and schooling are defined in terms of per capita expenditure[1]. It might be unwise to argue that more money spent by the government on schooling or health will directly translate into a larger contribution of these two factors to economic growth. However, once it is assumed that government expenditure is efficient, higher per capita expenditures on health or schooling translates into a greater investment in human capital which can then be expected to generate higher worker productivity. By expenditures on schooling we mean real expenditures per member of the school age population. We could not use a direct measure of average years of schooling of the labor force since this type of data is currently unavailable or hard to access at sectoral level. Addressing the issue from an expenditure point of view eliminates some of the criticisms made towards earlier studies concerning potential bias that could occur in estimating the macroeconomic effects of health (through life expectancy) in countries or sectors with high life expectancy. These countries or sectors tend to have older workforces (the ageing phenomenon) meaning that expenditure on health and schooling do not always translate into greater labour productivity. Nevertheless, older workforces with higher experience are meant to be more productive as long as they remain within the working age. Data constraints have forced us to use expenditures measures in lieu of superior direct measures for schooling and education.

3 The Theoretical Model

Production functions

In this paper an economy with n sectors operating at time t, each with a Cobb-Douglas production specification (Zellner, 2003) is assumed:

$$Q_{it} = A_{Ni}(z_{it}L_{it})^{\alpha}K_{it}^{\beta} \tag{1}$$

with: - A_{Ni} :Neutral technological change factor in sector i;

[1] The use of public expenditures figures on health and education may present some drawbacks. During major health outbreaks, public expenditures on health may be subject to unusual increases. In this study, the use of seasonally adjusted data helps assuage this weakness.

- z_{it} :Labour augmentation factor reflecting changes in labour quality (level of human capital in per capita terms).

From the existing literature (see Bloom *et al.*), the coefficient of effectiveness is developed through the following equations:

Effective wage:

$$w_e = zw \tag{2}$$

Labour effectiveness[2]

$$z = e^{\gamma s+\delta h} \tag{3}$$

Aggregate level of human capital:

$$Z = \sum_i e^{\gamma s_i+\delta h_i} \tag{4}$$

Log of aggregate level of human capital:

$$\ln Z = \sum_i (\gamma s_i + \delta h_i)/L + \sigma^2/2 \tag{5}$$

New logged aggregate production:

$$\ln Q = a + \alpha(\ln gL + \gamma s + \delta h) + \beta \ln K \tag{6}$$

By logging the production function while including the z function, two equations are obtained:

$$\ln Q_{it} = \ln A_{N\,i} + \alpha \ln z_{it} + \alpha \ln L_{it} + \beta \ln K_{it} \tag{7}$$

$$\ln Q_{it} = \ln A_{N\,i} + \alpha\gamma s_t + \alpha\delta h_t + \alpha c_i + \alpha \ln L_{it} + \beta \ln K_{it} \tag{8}$$

In (5), σ represents the standard deviation of the log wages (lnw). The growth accounting equation is obtained by differentiating both sides of equation (8) with respect to time. In this regard, this section provides a theoretical discussion of two variants of the problem (see sub-sections 3.1 and 3.2). Another plausible option (see sub-section 3.3), relies on the fact that workforces go through a process of recruitment before they form part of a specific industrial sector. Should the given sector decide to recruit a worker, a minimum level of investment on health and education should be observed in the individual. In other words, at recruitment, the worker is expected to have a certain level of education while being in good health. Therefore the model specification can be written as follows:

$$z_{it} = e^{\gamma(s_t-s_o)+\delta(h_t-h_o)+c_t}, \tag{9}$$

where $s_o$and h_o are the minimum levels of money invested in schooling (education) and health per unit of workforce, respectively. The more money is invested in the worker in terms of health and education, the more productive the worker will be. It is a delicate exercise to find the threshold in terms of basic requirements per industrial sectors (s_o and h_o).

[2] This normalisation of the effective labour unit to one with zero s (per capita expenditure on schooling) and zero h (per capita expenditure on health) has been borrowed from Bloom et al. (2005) However, the use of a constant or a time trend improves the definition of estimation or calibration of z.

3.1 A general approach without specific disentangling of A_{iN}(assumed to be constant over time)

$$Q^{\bullet}_{it}/Q_{it} = \alpha\gamma s^{\bullet}_{t} + \alpha\delta h^{\bullet}_{t} + \alpha L^{\bullet}_{it}/L_{it} + \beta K^{\bullet}_{it}/K_{it}; \tag{10}$$
$$G_Q = Q^{\bullet}/Q;$$
$$G_L = L^{\bullet}/L; and$$
$$G_K = K^{\bullet}/K.$$

The growth accounting equation can be written as follows:

$$G_Q = \alpha\gamma s^{\bullet}_{t} + \alpha\delta h^{\bullet}_{t} + \alpha G_L + \beta G_K, and \tag{11}$$

$$G_Q = \alpha(\gamma s^{\bullet}_{t} + \delta h^{\bullet}_{t} + G_L) + \beta G_K. \tag{12}$$

Assuming an annual increase ($dt = 1$), increasing investment in human capital, for example health per capita by one monetary unit, will lead to a '$\alpha\delta$' increase in the growth rate of output. Additionally, an increase by one monetary unit of schooling expenditure per capita will cause the growth rate of output to increase by '$\alpha\gamma$'. Using these outcomes, a comparison between the effects of more investment in human capital on the growth rate can be validly made and some policy recommendations in terms of a sectoral scheme of expenditures in both health and schooling can be suggested.

3.2 A more specific approach that includes HIV factors which affect z_{it}, assuming that technological factors vary across time

The two HIV-related factors included in this scenario are the death rate and the absenteeism rate due to an advanced stage of the infection. These factors are considered among variables affecting the labour augmentation factor.

$$Q_{it} = A_{Nit}[z_{it}(a_{it}; d_{it}; o_{it})L_{it}]^{\alpha} K^{\beta}_{it} \tag{13}$$

with:

- a_{it} : Work absenteeism observable in HIV patients;
- d_{it} : Death rate associated to HIV pandemic;
- o_{it} : Other omitted factors linked to labour productivity.

Once again, by logging both sides of equation 13 and deriving it with respect to time, the following growth accounting equation is obtained:

$$\ln Q_{it} = \ln A_{Nit} + \alpha \ln z_{it}(a_{it}; d_{it}; o_{it}) + \alpha \ln L_{it} + \beta \ln K_{it}. \tag{14}$$

Thereafter, by deriving the total equation with respect to time, the following is obtained:

$$\frac{\dot{Q}_{it}}{Q_{it}} = \frac{\dot{A}_{Nit}}{A_{Nit}} + \alpha \left[\frac{\partial \ln z_{it}}{\partial a_{it}}.\frac{da_{it}}{dt} + \frac{\partial \ln z_{it}}{\partial d_{it}}.\frac{dd_{it}}{dt} + \frac{\partial \ln z_{it}}{\partial o_{it}}.\frac{do_{it}}{dt}\right] + \alpha\frac{\dot{L}_{it}}{L_{it}} + \beta\frac{\dot{K}_{it}}{K_{it}} \tag{15}$$

and

$$G_Q = G_{AN} + \alpha \left[\frac{\partial \ln z_{itL}}{\partial a_{it}}.\frac{da_{it}}{dt} + \frac{\partial \ln z_{itL}}{\partial d_{it}}.\frac{dd_{it}}{dt} + \frac{\partial \ln z_{itL}}{\partial o_{it}}.\frac{do_{it}}{dt}\right] + \alpha G_L + \beta G_K. \tag{16}$$

Assuming that ARV (Antiretroviral) policies are well implemented and that both absenteeism and death rates decrease over time, the result will be that the output growth rate in the economy will be strengthened. Alternatively, assuming an increase in a and d over time, the overall output growth rate will be reduced accordingly. Good health policies in terms of HIV should cause a reduction in both absenteeism and death rates in all economic sectors in turn supporting more sustainable economic growth. Both a (absenteeism rate) and d (death rate) are assumed to be diminishing over time assuming that ARV policies reduce the magnitude of both a and d. We assume that the HIV prevalence rate itself follows a sigmoid pattern (see Figure 1).

Considering the sigmoid approach, this issue can be addressed in a slightly different manner. In the African context, policy measures have very little effect on controlling the dynamics of HIV/AIDS. For this reason, referring to related literature, one can depict the production implications of HIV/AIDS through a non-linear function assumed to be logistic. The first stage of HIV prevalence is expected to be exponential. However, as antiretroviral treatment is supplied together with other preventive and counter-cyclical actions, the prevalence decreases and is expected to become completely preventable.

Herewith the parameters introduced in the labour augmentation factor concerning HIV:

- $h(t)$: HIV prevalence rate;
- $a(t)$:work absenteeism observable in HIV/AIDS patients;
- $d(t)$: death rate associated with HIV/AIDS pandemic.

The following is assumed:

$$h(t) = \varphi_i \frac{1}{1+e^{-t}} = \varphi_i \frac{e^t}{1+e^t}; \tag{17}$$

$$a(t) = \varphi_i \frac{e^{t-\overset{\approx}{\alpha}}}{1+e^{t-\overset{\approx}{\alpha}}} \quad ; and \tag{18}$$

$$d(t) = \varphi_i \frac{e^{t-\overset{\approx}{d}}}{1+e^{t-\overset{\approx}{d}}}; \tag{19}$$

with:

- φ_i : parameter, assumed to be constant[3] over time in the model that captures the link of HIV prevalence with sectoral production;
- $\overset{\approx}{\alpha}$:average period[4] observed for a tested HIV positive individual to develop AIDS symptoms;
- $\overset{\approx}{d}$:average period observed for a tested HIV positive individual to die of AIDS: $\overset{\approx}{d} > \overset{\approx}{\alpha}$.

Absenteeism occurs with a time lag of $\overset{\approx}{\alpha}$ periods relative to the infection stage. In other words, the longer $\overset{\approx}{\alpha}$ is, the larger the gap becomes, and the smaller the negative effects of the pandemic on economic growth. The same applies to the death rate. Death occurs with a time lag of $\overset{\approx}{d}$ periods relative to the infection stage.

Applying the concept of derivatives to this second variant, the relevant information can be derived in a similar way to the first variant discussed earlier.

$$\begin{aligned} a(t) &= \varphi_i \tfrac{e^{t-\overset{\approx}{\alpha}}}{1+e^{t-\overset{\approx}{\alpha}}} \\ a(t) &= \varphi_i \tfrac{1}{1+e^{-(t-\overset{\approx}{\alpha})}} \\ \lim_{a^{\approx}\to\infty} a(t) &= \varphi_i. \end{aligned} \tag{20}$$

[3] This assumption can validly be removed since this parameter is supposed to change over time.

[4] This period could also be assumed as the average across SSA (Sub-Saharan African) countries (3 years) with t(time of reference based on the HIV prevalence).

The larger $\widetilde{\widetilde{\alpha}}$ is, the smaller a becomes (work absenteeism as a function of time observable in an infected patient). An adequate ARV treatment supply or a complete eradication of the infection leads $\widetilde{\widetilde{\alpha}}$ to tend toward infinity. In fact, infinity in this case only means that the worker will actually never be absent from work because of an HIV infection. Infinity therefore refers to the time of the worker's normal resignation. In other words, an infected patient who receives adequate ARV supply will probably never be absent from work due to HIV infection[5]. Linking this to the growth accounting equation, the negative effect of $a(t)$ in A_{iN} will disappear or rather, the derivative of a(t) goes to zero at t equals infinity because absenteeism levels off once it reaches a ceiling. In other words, the effect stops getting worse.

$$\frac{\partial a(t)}{\partial t} = \varphi_i \frac{e^{-(t-a)^{\approx}}}{\left[1+e^{-(t-a^{\approx})}\right]^2} = \varphi_i \frac{1}{\left[1+e^{-(t-a^{\approx})}\right].\left[1+e^{(t-a^{\approx})}\right]}, and \tag{21}$$

$$\begin{aligned} \frac{\partial d(t)}{\partial t} &= \varphi_i \frac{e^{-(t-d^{\approx})}}{\left[1+e^{-(t-d^{\approx})}\right]^2} = \varphi_i \frac{1}{\left[1+e^{-(t-d^{\approx})}\right].\left[1+e^{(t-d^{\approx})}\right]}, with \\ \lim_{a^{\approx}\to\infty} \frac{\partial a(t)}{\partial t} &= 0 \; and \lim_{a^{\approx}\to\infty} \frac{\partial d(t)}{\partial t} = 0. \end{aligned} \tag{22}$$

As $a^{\approx}$increase, $a(t)$ across time will be reduced until it reaches 0.

3.3 Each of the two social ingredients includes a minimum level required at recruitment

In this sub-section, we expand our discussion by introducing a minimum level required for each worker in terms of health (h_0) and schooling (s_0) prior to enrol in each industries. This expansion in our reasoning is much more in compliance with job market realities. Each industry has particular set of requirements that need to be met by workers prior to their employment.

$$z_{it} = e^{\gamma(s_t - s_o)+\delta(h_t - h_o)+c_t}, and \tag{23}$$

$$\ln Q_{it} = \ln A_{Ni} + \alpha\left[\gamma(s_t - s_o) + \delta(h_t - h_o) + c_t\right] + \alpha \ln L_{it} + \beta \ln K_{it}. \tag{24}$$

The growth accounting equation is redefined as follows:

$$\begin{aligned} Q^{\bullet}_{it}/Q_{it} &= {}^{\bullet}/A_{Ni} + \alpha\gamma^{\bullet}_t + \alpha\delta^{\bullet}_t + \alpha L^{\bullet}_{it}/L_{it} + \beta K^{\bullet}_{it}/K_{it}, with \\ \overline{s}_t &= s_t - s_o; \\ \overline{h}_t &= h_t - h_o; and \end{aligned} \tag{25}$$

$$G_Q = G_A + \alpha\gamma^{\bullet}_t + \alpha\delta^{\bullet}_t + \alpha G_L + \beta G_K. \tag{26}$$

Using this form of the growth accounting equation it is understandable that, whenever recruitment criteria are tightened, the per capita expenditures need to be increased as well, otherwise a negative effect on growth will be observed.

[5] It is important to note that several forms of drug-resistant HIV virus with more rapid mutation exist and therefore traditional ARV treatment can simply not produce the expected results. However, in this study the concern is much more on the commonly known form of the virus.

3.4 Considering the diffusion process

Using the diffusion[6] process (Bloom, Canning & Sevilla, 2002b) across sectors, the following equation is introduced:

$$\Delta A_{it} = \lambda(\overline{A}_{it} - A_{i,t-1}) + \varepsilon_{it}. \tag{27}$$

Each sector has a 'ceiling' level given by $\overline{A}_{it}$. Recall that A_{it} represents the level of technological factor productivity of country i in period t. The sector adjusts toward this level at a rate λ. λ depends on the sector characteristics and the country's level of technology.

$$\overline{A}_{it} = \delta X_{it} + b_t, \tag{28}$$

with

b_t : time dummy representing the current level of national TFP (Total Factor Productivity).

By including this specific dummy variable, it is assumed that the convergence of sectoral TFPs is analysed in accordance with a national TFP. For the latter reason, this study makes use of fixed effects models. Note that in this subsection, A_{it}, which accounts for all the components of TFP including labour effectiveness, is used instead of A_{Nit}, which only includes the neutral part.

Lagged technology can be measured by substituting equation 28 into equation 27 so that the following is obtained:

$$\Delta A_{it} = \lambda_i(\delta X_{it} + b_t - A_{i,t-1}) + \varepsilon_{it}. \tag{29}$$

with X_{it} : all set of sector's specific variables that have an impact on A.

The higher λ_i is, the faster the movement towards a complete diffusion process and the lower λ_i, the slower the diffusion process. Complete diffusion is achieved when the difference$\overline{A}_{it} - A_{i,t-1} = 0$. Therefore, if $\Delta A_{it} = \varepsilon_{it}$, technological change will only depend on random shocks. This paper presents estimated figures for the diffusion factor given the five sectors considered. When the diffusion process is complete the growth equation is presented as follows:

$$\frac{Q^{\bullet}_{it}}{Q_{it}} = \left(\frac{\varepsilon_{it}}{A_{it}}\right) + \alpha\gamma s^{\bullet}_t + \alpha\delta h^{\bullet}_t + \alpha\frac{L^{\bullet}_{it}}{L_{it}} + \beta\frac{K^{\bullet}_{it}}{K_{it}}. \tag{30}$$

Including equation 29 into the generic growth accounting equation the following is obtained:

$$\frac{Q^{\bullet}_{it}}{Q_{it}} = \lambda_i\delta\left(\frac{X_{it}}{A_{it}}\right) + \lambda_i\left(\frac{b_t}{A_{it}}\right) - \lambda_i\left(\frac{A_{i,t-1}}{A_{it}}\right) + \left(\frac{\varepsilon_{it}}{A_{it}}\right) + \alpha\gamma s^{\bullet}_t + \alpha\delta h^{\bullet}_t + \alpha\frac{L^{\bullet}_{it}}{L_{it}} + \beta\frac{K^{\bullet}_{it}}{K_{it}}. \tag{31}$$

For a diffusion coefficient λ that tends to zero, the growth equation can be reformulated as follows:

$$\frac{Q^{\bullet}_{it}}{Q_{it}} = \left(\frac{\varepsilon_{it}}{A_{it}}\right) + \alpha\gamma s^{\bullet}_t + \alpha\delta h^{\bullet}_t + \alpha\frac{L^{\bullet}_{it}}{L_{it}} + \beta\frac{K^{\bullet}_{it}}{K_{it}}. \tag{32}$$

The two extreme cases seem to present similar evidence when $\Delta A_{it} = \varepsilon_{it}$. This equality holds when either the speed of adjustment toward the ceiling rate is zero, or when the speed of adjustment is very high and $\overline{A}_{it} - A_{i,t-1} = 0$. The difference in the two cases is therefore that when there is no movement towards the ceiling rate, growth will be hindered by slower shares from both growth in labour and growth in capital. Investment in schooling and education together with a higher level of experience will be even more essential to assist the slow speed of adjustment. However, less additional investment in schooling and education as well as experience will be required when the ceiling rate is achieved, assuming a growth rate that is acceptable and sustainable (such as in the case of developed countries). If there is no technological diffusion among sectors, it is observed that TFP differentials persist among sectors. The latter case can be measured using a fixed effect panel data model. Additionally, in the case where TFPs narrow over time because of high technological diffusion, TFP differentials decrease over time.

[6] From a broad perspective, the diffusion process can be referred to as the outcome (solution) of a system of stochastic differential equations. Several processes such as 'Brownian Motion' can be referred to as being part of a diffusion process.

4 The Data

In order to investigate the role played by social ingredients in South African sectoral growth and to study the diffusion process in the country's economic sectors, this paper has made use of secondary (official) data, from the following sources: (1) the South African Reserve Bank (SARB); (2) Statistics South Africa (SSA); and (3) Quantec Research.

Mainly due to limitations on sectoral employment data, the sample size considered ranges from 1995 to 2006. No reliable data on employment could be located for earlier periods. Other sectoral data such as: capital (with fixed capital stock as the proxy); and output (with gross value-added at basic prices as the proxy); are readily available from official sources. However, data on social ingredients such as s (public expenditures on schooling) and h (public expenditure on health) could not be located at the sectoral level. To overcome this challenge, national estimates have been used here.

Additionally, using Cobb-Douglas specifications for the sectoral growth equations, it is simple to compute a TFP (Total Factor Productivity) series for each sector from the ISUR regressions estimations.

5 Empirical Results

5.1 Sectoral output equations: Testing variant 1 in 3.1

5.1.1 Isolated regressions per sectors

After replacing z by its specification that includes s and h, we estimate the growth accounting equation. This helps produce estimates for the impact of h and s per sector for the South African economy. Also, this allows to compute a series of 'effective labor EL' for each sectors. With the exception of 'agriculture', all other sectors portray highly reliable estimation results. The fact that accurate results for the agricultural sector cannot be obtained might be caused by poor data and/or other factors in this sector. For this reason, the final parameters obtained for this sector are not included in the summary table.

This exercise has produced insightful outcomes in terms of the impact of changes in expenditures on health or education on sectoral growth. The modelling process used does not enforce any specific input-output scaling. Regressions are conducted on the basis of varying returns to scale and the input shares estimated here are supported by the underlying theories. There is a major weakness in conducting sectoral regressions individually and in isolation from others. That approach ignores the 'cross-sectoral' effects that exist in every economy. For this reason the ISUR approach is conducted in order to obtain parameters.

5.1.2 A cross-section ISUR model

This sub-section contains our estimation results using the 'Iterative Seemingly Unrelated Regressions' (ISUR) model. This modelling exercise presentss the advantage of providing GLS (Generalised Least Squares) estimates through a correction of contemporaneous correlation and any type of heteroskedasticity related to the cross-sections. Iterative SUR can either be utilised under the form of purely 'cross-section SUR' or 'period SUR'. The 'period SUR' contains the major advantage of correcting for heteroskedasticity related to the period and it also corrects for correlation within cross sections. In this research, a 'period SUR' could not be performed because the number of pool cross-sections (5) does not exceed the number of periods 12). In fact, by using ISUR, a set of sectoral growth equations, allowing for different coefficient vectors, have been estimated. As mentioned earlier, ISURs have the advantage of capturing efficiency observed due to the correlation of cross-section disturbances.

Tables 1,2, and 3 present the results of a cross-section ISUR with output value added per sector as dependent variable. In both regressions (table 1 & 2) EL represents the effective labour series obtained by multiplying our computed z (per capita level of human capital) by L (number of worker). With the exception of agriculture, all sectoral growth regressions are well behaved and the levels of significance of the obtained coefficients do not differ much from expectations. In table 1 the ISUR is run without a constant while table 2 includes a constant. The use of a constant term for each cross section (table 2) produces an improvement to the estimations mainly by correcting for the negative sign obtained for 'Agric-lnK' (the natural logarithm of capital in the agricultural sector). Table 1 does not account for heterogeneity amongst the sectors, i.e. individual effects caused by variables not included as explanatory variables will not be captured.

As mentioned earlier, estimates from 'agriculture' do not always meet theoretical expectations. For this reason another set of ISURs which exclude agriculture have been run (table 3). The results show great improvement with the exception of effective labour (EL) for 'communication and transport' (COMTRS).

5.2 The effects of an increase in h and s on the sectoral growth rates

This sub-section provides a thorough discussion of the size and economic meaning of the parameters $\alpha\gamma$ and $\alpha\delta$. These parameters represent the effects of increasing $h$or s on sectoral output growth rates. The calculation of these parameters is based on the following regression:

$$\begin{aligned} \dot{Q}_{it}/Q_{it} &= \dot{A}_{itN}/A_{itN} + \left[\frac{\partial \ln z_{it}}{\partial T_{it}}.\frac{dT_{it}}{dt} + \frac{\partial \ln z_{it}}{\partial a_{it}}.\frac{da_{it}}{dt} + \frac{\partial \ln z_{it}}{\partial d_{it}}.\frac{dd_{it}}{dt} + \frac{\partial \ln z_{it}}{\partial o_{it}}.\frac{do_{it}}{dt}\right] \\ &+ \alpha\gamma \overset{\bullet}{s_t} + \alpha\delta \overset{\bullet}{h_t} + \alpha \overset{\bullet}{L_{it}}/L_{it} + \beta \overset{\bullet}{K}_{it}/K_{it}, \end{aligned}$$

with:

$$\dot{h}_t = \frac{dh(t)}{dt} = \frac{h_{t+1} - h_t}{dt}; and \frac{\dot{Q}_{it}}{Q_{it}} = \frac{(Q_{it+1} - Q_{it})/dt}{Q_{it}}$$

Considering a one-year ahead forecast, an increase in h_{t+1} by one Rand will lead to a '$\alpha\delta$' increase of $\frac{\overset{\bullet}{Q}}{Q_{it}}$. Similarly a one Rand increase in s_{t+1} leads to a $\alpha\gamma$ increase in $\frac{\overset{\bullet}{Q}}{Q_{it}}$. Using estimates from this regression analysis the size of $\alpha\gamma$and $\alpha\delta$ in percentage for each of the 4 sectors has been calculated (see table 2.2).

From table 4, several observations may be drawn. A one-Rand increase on health expenditures or schooling expenditures (per capita) in both sectors leads to higher output growth.The sizeof this rise differs from one sector to another. The manufacturing sector together with the construction sector has the highest parameters followed by mining and finally transport and communication. The size of these parameters depends on the role played by effective labour variables in the sectoral growth equations. The contribution that a one-Rand increase in per capita expenditures, at sectoral level, has on aggregate growth depends on the size of the sector's contribution to national economic growth. In the fourth quarter of 2006, South Africa reached an economic growth rate of 5.6 percent with several major contributors: the manufacturing industry which contributed 1.4 percent; the finance, real estate and business services industry which contributed 1.0 percent; the wholesale trade, hotels and restaurant industry which contributed 0.8 percent; the storage and communication industry which contributed 0.5 percent (SARB Quarterly Bulletin). When expenditures on health are categorised according to productive sectors, the return on national growth is much higher than an aggregate increase which disregards sectoral differences.

Additionally, lagging h and s will most likely improve these results assuming that both health and schooling policies take years before their effects become noticeable in the economy.

5.3 Analysis of the technological diffusion process using a fixed effects model

A 'fixed effects model' (table 5) is used to determine the size of TFP across sectors over time and to assess the speed of convergence[7]. This information is needed to comment on the diffusion process.

The values of TFPs are obtained by taking the exponential value of TFP (cross-sectional fixed effects) coupled with TFP (period fixed effects). In fact, a fixed effects specification is found very appropriate in this analysis as it implies the use of orthogonal projections involving the removal of cross-sectional or period-specific means from the dependent variable and exogenous regressors (Baltagi, 2001). This approach indicates that 'demeans' are used in the specific set of regressions performed. The results from the fixed effects model are presented as 'multiple-graph' (see figure 2) and are used to assess the overall convergence tendency of the TFP series in the selected South African industrial sectors.

From this graph, very close trends between the Communication & Transport sector and the Mining sector are observed. However, the general view suggests that the speed of adjustment remains very low. It is a fact that sectoral TFPs converge toward a sectoral steady state, although sector differentials remain considerable.

6 Conclusion

In this paper, five sectors were used for the purpose of generating effective labour variables using a coefficient of effectiveness for each sector. Sectoral production functions were estimated using the obtained effective labour series. The data was difficult to obtain due to the lack of a well disaggregated data warehousing system. Nevertheless, the broadest conclusion from the analysis at this stage can only be that it pays to allocate social expenditures according to sectoral productivity and it also pays to include a coefficient of effectiveness in production functions. In many cases it is evident that the use of an effective labour variable does not reduce the predictive ability of the model and that the introduction of this variable opens new channels for "shocking" the model by means of social variables. Additionally, outcomes from the theoretical models can be used with validity to advise policy makers on the harmful effects that the HIV pandemic has on the economic growth. Simply by controlling absenteeism rates and death rates related to the pandemic, the negative impact of the disease can easily be assuaged. However, this paper does not include other channels through which HIV/AIDS might affect economic growth nor does it consider other types of direct or indirect costs at both the private and national level.

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Table 1: Estimates of sectors' production functions using cross-section SUR (no constant)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
_AGRIC--LNK_AGRIC	-2.641124	0.994132	-2.656714	0.0106
_MAN--LNK_MAN	0.653484	0.051183	12.76773	0.0000
_MIN--LNK_MIN	0.839629	0.035988	23.33086	0.0000
_COMTRS--LNK_COMTRS	1.391167	0.201518	6.903428	0.0000
_CONSTR--LNK_CONSTR	0.683151	0.034240	19.95200	0.0000
_AGRIC--LNEL_AGRIC	2.957131	0.829575	3.564634	0.0008
_MAN—LNEL_MAN	0.332578	0.056233	5.914308	0.0000
_MIN—LNEL_MIN	0.079076	0.033303	2.374452	0.0215
_COMTRS--LNEL_COMTRS	-0.524691	0.210324	-2.494678	0.0160
_CONSTR--LNEL_CONSTR	0.292972	0.025089	11.67714	0.0000
Weighted Statistics				
R-squared	0.999995	Mean dependent var		128.4121
Adjusted R-squared	0.999994	S.D. dependent var		437.1014
S.E. of regression	1.067537	Sum squared resid		56.98173
F-statistic	1099021.	Durbin-Watson stat		1.260427

Table 2: Estimates of sectors' production functions using cross-section SUR (with constant)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
_AGRIC--LNK_AGRIC	3.085694	2.109151	1.463003	0.1504
_MAN--LNK_MAN	0.813206	0.420156	1.935487	0.0592
_MIN--LNK_MIN	0.858043	0.153644	5.584618	0.0000
_COMTRS--LNK_COMTRS	2.911776	0.138921	20.95986	0.0000
_CONSTR--LNK_CONSTR	0.689436	0.039532	17.43978	0.0000
_AGRIC--LNEL_AGRIC	22.48967	8.031474	2.800192	0.0075
_MAN—LNEL_MAN	0.346627	0.101458	3.416439	0.0014
_MIN—LNEL_MIN	0.091185	0.036649	2.488031	0.0166
_COMTRS--LNEL_COMTRS	-0.039257	0.053427	-0.734781	0.4663
_CONSTR--LNEL_CONSTR	0.343484	0.079474	4.321955	0.0001
AGRIC—C—AGRIC	-328.4704	129.8093	-2.530408	0.0150
MAN—C—MAN	-2.162191	4.338682	-0.498352	0.6207
MIN—C—MIN	-0.377566	1.932149	-0.195412	0.8459
COMTRS—C—COMTRS	-25.31996	1.812443	-13.97007	0.0000
CONSTR—C—CONSTR	-0.699835	1.040588	-0.672538	0.5047
Weighted Statistics				
R-squared	0.999997	Mean dependent var		265.2649
Adjusted R-squared	0.999996	S.D. dependent var		573.8779
S.E. of regression	1.090217	Sum squared resid		53.48580
F-statistic	1167712.	Durbin-Watson stat		1.549311
Prob(F-statistic)	0.000000			

Table 3: Estimates of sectors' production functions using cross-section SUR with constant excluding Agricultural sector

Variable	Coefficient	Std. Error	t-Statistic	Prob.
_MAN--LNK_MAN	0.758977	0.443535	1.711201	0.0956
_MIN--LNK_MIN	0.899211	0.157137	5.722449	0.0000
_COMTRS--LNK_COMTRS	2.918442	0.136757	21.34036	0.0000
_CONSTR--LNK_CONSTR	0.685548	0.041674	16.45008	0.0000
_MAN--LNEL_MAN	0.359985	0.107256	3.356303	0.0019
_MIN—LNEL_MIN	0.112361	0.038110	2.948304	0.0056
_COMTRS—LNEL_COMTRS	-0.060607	0.053886	-1.124713	0.2682
_CONSTR—LNEL_CONSTR	0.283971	0.088989	3.191078	0.0029
_MAN—C	-1.634881	4.554426	-0.358965	0.7217
_MIN—C	-1.145281	1.947750	-0.588002	0.5602
_COMTRS—C	-25.14415	1.764504	-14.24999	0.0000
_CONSTR—C	0.091927	1.181993	0.077773	0.9384

Weighted Statistics

R-squared	0.999996	Mean dependent var	323.3420
Adjusted R-squared	0.999994	S.D. dependent var	455.5017

Table 4: The size of the calculated parameters of health ($\alpha\delta$) and schooling ($\alpha\gamma$) on sectoral output growth

Variable	Mining	Construction	Transport & Communication	Manufacturing
Health	0.023 %	0.08566 %	0.00155 %	0.08657 %
Schooling	0.00422 %	0.01549 %	0.00028 %	0.015657 %

Table 5: Fixed effects model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.937235	1.805991	1.072671	0.2895
LNK	0.494892	0.109752	4.509205	0.0001
LNL	0.257374	0.107738	2.388886	0.0215
Fixed Effects (Cross)				
AGRIC	-0.851961			
MAN	0.903629			
MIN	-0.157423			
COMTRS	-0.114270			
CONSTR	0.220025			
Fixed Effects (Period)				
1995	-0.156320			
1996	-0.101010			
1997	-0.069780			
1998	-0.065816			
1999	-0.042143			
2000	0.001738			
2001	0.013244			
2002	0.048587			
2003	0.062101			
2004	0.093687			
2005	0.113865			
2006	0.101848			

R-squared	0.992211	Mean dependent var	10.92981
Adjusted R-squared	0.989058	S.D. dependent var	0.740116
Sum squared resid	0.251744	Schwarz criterion	-1.407508
Durbin-Watson stat	0.472393	Prob(F-statistic)	0.000000

Figure 1: HIV Prevalence over time

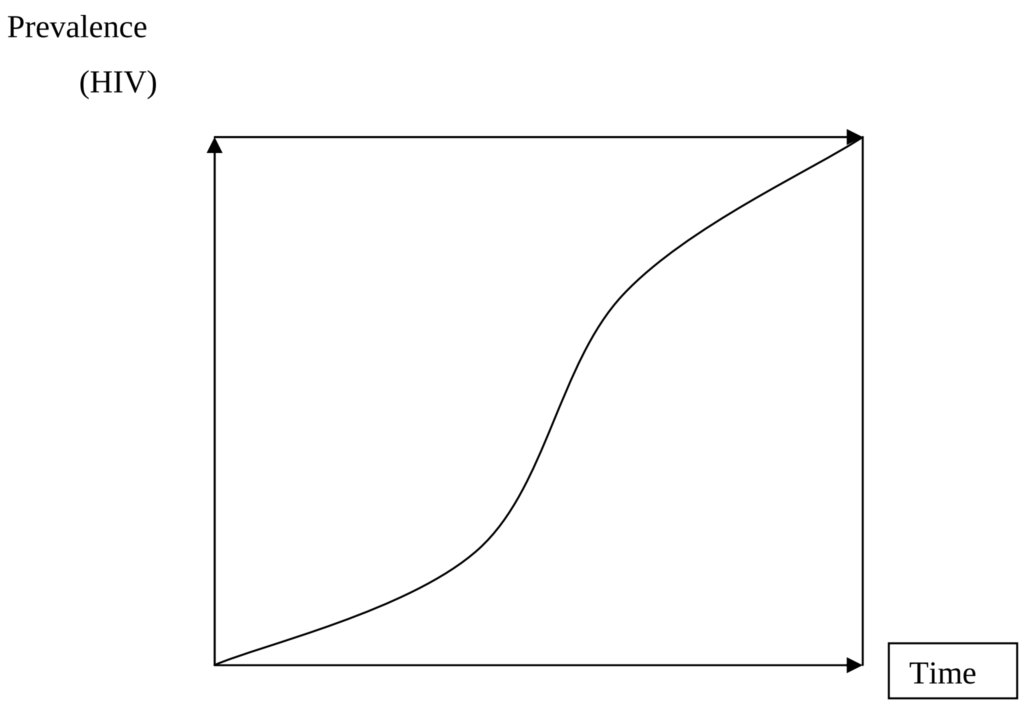

Figure 2: TFP across sectors over time