Production of educational output: time series evidence from socio-economically heterogeneous populations - the case of South Africa 1910-93.*

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This paper uses the natural experiment South Africa provides in order to examine the impact of educational inputs on educational output in different learning environments. Cointegration analysis is employed in order to establish that inputs into the education process do make a difference to educational output. Such an impact is not only strong, but is present even where variation in the input measures is small. By separately estimating production functions for relatively homogeneous population groups in the socio-economically heterogenous South African population, we control not only for background variables, but establish that the capacity to exercise political control over the decision-making executive implies that institutions matter.

JEL Classification: I21, I22, I20, C22.

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1 Introduction

Findings on the link between inputs into educational production and output fall into two broad categories. The first finds little or unconvincing evidence of a link between inputs and the quality of schooling output as measured by standardized test scores, a result perhaps most consistently associated with the work of Hanushek (see 1995, 1996 by way of example). But a second set of studies does establish a statistical link between schooling quality and earnings - Card and Krueger (1992) being an often cited example.1

A number of competing reasons have been advanced for this divergence of findings: since standardized test scores and earnings are two distinct outcomes, school quality may simply have different impacts on the two outcome measures; earnings studies are frequently argued to have insufficient controls for family background variables, the effects of local labour market conditions, and self-selection effects present in samples; and earnings studies and school achievement studies tend to employ different types of data, with earnings studies tending to rely on historical information, school achievement studies on contemporaneous data. The last of these reasons for divergent results between earnings and standardized test score studies is potentially important in pointing to the significance of lags in the impact of schooling inputs on outputs.2

This paper furthers understanding of the link between inputs and outputs of the educational production process. In contrast to earlier studies, the paper employs time series data in order to investigate the link between educational inputs and outputs, and does so over a relatively long time run, from 1910 to 1993.

Strong results emerge from our analysis. We find that educational inputs matter in the determination of educational outputs in the case of South Africa. In this we confirm the findings of Case and Deaton (1999), but our results further strengthen the result. In a second important departure from earlier findings, the relationship between inputs and outputs is found to be statistically significant and strong even in schooling systems in which variation in inputs is low - and of the same order as earlier studies that found

1 Though Betts (1995) suggests that the appropriate schooling quality measures have shifted over time.
2 Loeb and Bound (1996) argue the impact of data characteristics to be more significant than the use of different outcomes measures, biases for missing background variables, and biases from labour market influences.
inputs to be insignificant.

A third important innovation of the present study is facilitated by the clear separation of the schooling system into racially segregated processes. In estimating separate educational production functions for different racial groupings, we are able to implicitly control for at least some of the omitted background variables that are often argued to bias studies at high levels of aggregation.\(^3\)

Moreover, the separation of racially defined educational production functions allows for the impact of different institutional dimensions governing decision-making in the production of educational output in South Africa to be controlled for. Whites in South Africa had access to a set of strong democratic institutions that allowed them to exercise at least some control over the educational production process. Blacks had no, or at best, very imperfect control over the educational production process in their schooling system. An examination of the differences that emerge between white and black schooling production functions thus holds the prospect of providing some insight into the impact that control over the decision-making processes over educational production carries. To preempt our analysis: the educational production functions for whites and blacks in South Africa show some differences, particularly at an institutional level. We show that institutions matter in at least three senses. First, the political instability variable has a very real impact on the black production function but not on the white. Second, the differential degree of political control resulted in the rising per capita expenditure in black education being associated with a widening of education for the black population, whilst in white education it led to a deepening of the educational process. Third, whilst the evidence shows that real per capita expenditure is associated with a high elasticity for the black educational production function, it is associated with a lower statistical significance indicating a lower de facto effectiveness.

The paper proceeds in four sections. We begin with a brief review of the literature on educational production functions, followed by a discussion of our data sources. A presentation of the empirical methodology outlines the nature and relevance of time series estimation techniques employed for the purposes of the present study. In section four we present our substantive

\(^3\) At the level of aggregation at which the present study will proceed it would be foolish to suggest that within-group heterogeneity will not be present. Nevertheless, there is evidence to suggest that within-group heterogeneity is less significant than between-group heterogeneity - see the discussion below.
findings.

2 The educational production function: reviewing some of the evidence

The Coleman Report (Coleman et al., 1966) was the first influential research which found little association between the quality of schools and student achievement on standardized tests. The finding did not remain uncorroborated. The work of Hanushek (1996:9) provides a good example, arguing that it would appear that variation in resources allocated to schooling are not the primary determinants of scholastic achievement. In the USA strong improvements in the quality of schooling inputs as a result of improved funding, does not appear to have translated into better school outcomes. Hanushek (1995:227) argues that appropriate incentive structures for teaching staff, based on strong performance assessment, and decentralized decision making are likely to be more important determinants of educational attainment.

Yet many of the studies that find little impact of inputs on schooling output are restricted to a small set of input measures. Hence the impact of other inputs not controlled for in such studies is left indeterminate. Comparisons across countries have shown better schooling achievement in other industrialized countries than in the USA. For instance, Johnson and Stafford (1996:690) suggest the difference to be explicable in terms of academic learning time and the involvement of parents with children and schoolwork. All of these factors are inputs into the educational production process - simply not ones that have been traditionally controlled for in studies of educational production. Japanese high school students average studying time was 61.6 hours per week in 1986 (both in and out of school), while in the USA the average was 31 hours per week. At a more disaggregated level, schools in the USA devoted proportionately less academic learning time than Japan or Taiwan (64.5% in the USA versus 87.4% in Japan and 91.5% in Taiwan). American children both now and historically have devoted a larger share of academic time at school to reading, language arts and social studies rather than math and science. In other words, educational outcomes may be bet-

4 Though note that Hedges, Laine and Greenwald (1994) find that there exist some positive relationships between some school inputs and student outputs, where more than Hanushek’s summary measures are employed. However, such effects are argued to be small and not consistent across studies (see Loeb and Bound 1996).
ter explained by examining factors not directly related to resource inputs. Time on task, parental involvement, emphasis on math and science, school governance, discipline, may all be more important in accounting for student performance than the direct resources devoted to education.\(^5\)

A limitation attached to studies finding no returns to changing pupil teacher ratios and other measures of schooling input, is that variation in the inputs measures is relatively low. Thus while increasing pupil teacher ratios from 20:1 to 30:1 may have little negative impact, studies based on such variations may provide little insight into the impact of increasing the ratio to 70:1 (often the case in less developed countries). The cross-sectional study on schools in the Western Cape in South Africa by Case and Deaton (1999) provides a case in point. Pupil teacher ratios included in their sample range from districts averaging 20 children per teacher in both black and white schools, to others with upwards of 80 children per teacher. Such unusually large variations in pupil teacher ratios fall outside the ambit of studies reported by Hanushek and others. Controlling for household background variables, they find strong and significant effects of increasing pupil teacher ratios on declining enrolment, educational achievement, and test scores for numeracy. Thus whilst Hanushek-type studies may be correct in finding that variation of pupil teacher ratios in the range of 20:1 to 30:1 have insignificant effects, the Case and Deaton results suggest that the result cannot be generalized to larger variations in input quality.\(^6\)

In the present study we extend these insights in a number of important senses. The first is to investigate the impact of schooling inputs on schooling output on the basis of long time series data.\(^7\)

In doing so, by virtue of the unique South African natural social experiment in racial segregation, we are able to separate out two schooling processes in which social background variables are kept relatively homoge-

\(^5\)The argument also suggests that social capital factors, such as those identified in Coleman (1988), may be crucial in determining educational attainment. See Fedderke, de Kadt and Luiz (1998) for some extensions on Coleman’s arguments.

\(^6\)Though they caution that the positive effects of reducing class size would be diminished if the quality of teachers were to be reduced in an attempt to expand the number of teachers.

\(^7\)The use of longitudinal data is particularly significant in the light of the Loeb and Bound (1996) finding that data characteristics (and lack of historical data in particular) are potentially the single most important reason for the lack of significance of inputs into educational production.
nous for “whites” and “blacks”, in terms of indicators of socio-economic development.

In separating black and white schooling, we are further able to distinguish between two educational production functions, in one of which the variation of pupil-teacher ratios is relatively small (for white public schooling, it remains roughly 20:1 for the full 1910-93 period), while for another the variation is relatively large (for black schooling the ratio varies from the mid 30:1 range, to 80:1 and more). The implication of the Case-Deaton study that the extent of the variation in the pupil-teacher ratio input measure may influence the findings of statistical significance of schooling inputs can thus be further examined.

There is a further reason why the separation of the white and black schooling production functions carries the potential of important analytical insights. Whites were the only franchised population group in South Africa, and hence the only group with substantial capacity to influence decisions over the educational production process.

One potential criticism of the present study is that it proceeds at too high a level of aggregation to be useful for policy conclusions. In particular where there exist aggregate effects correlated with excluded explanatory variables of interest, aggregation will exacerbate the bias due to the omitted variables. Of particular importance in a time series context might be changing perceptions of the importance of educational attainment for success in labour markets. Such perceptions of changing incentives may impact on educational attainment, and their omission from estimation would exaggerate the impact of school inputs. But a number of considerations limit the importance of the aggregation problem for this study. For South Africa an important offsetting influence would be the impact of labour market discrimination, which would bias downward the impact of school inputs on job prospects. Moreover, aggregate studies also carry advantages that are particularly useful in

We follow the classificatory conventions employed under the Apartheid system for the sake of consistency with official data sources. Thus “black” refers to “African” persons specifically, rather than the “Coloured” and “Asian” Apartheid racial category.

Blacks had limited capacity to influence education in some designated “homeland” areas. However, homelands comprised only about 13% of the total land area of South Africa, and came into existence as constitutionally “independent” entities only from 1976 onwards. Thus black autonomy over education was severely limited.

See for instance the discussion in Betts (1995).
the current context. They avoid the endogeneity problems inherent in micro studies, brought about by parental choice of schools attended by children. Second, bias due to errors in variables is reduced. While micro-level studies can only control for schooling characteristics present for the time point of the study, aggregate studies with time series data can control for the time path of educational experience that may be relevant to performance. Whatever the relative strengths of these arguments, we note that studies appear to find stronger impacts on schooling inputs on educational output the greater the level of aggregation.\(^\text{12}\)

South Africa and the time series data assembled for its schooling system, thus offers the opportunity of improving our understanding of educational production functions quite generally, while the presence of socio-economically heterogenous populations allows for the impact of institutional patterns of governance in educational production to be controlled for.

3 Econometric Methodology and Data

3.1 Data Sources

Given the use of a new data source for this study, we provide some descriptive detail before embarking on the analytical component of the analysis. This section draws substantially on the education time series assembled in Fedderke, De Kadt and Luiz (2000), which reports data sources and descriptive findings exhaustively, and on Fedderke, De Kadt and Luiz (2001) for time series evidence on some variables critical to the institutional context in South Africa.

For purposes of the present study we confine our attention to three measures as reported in Fedderke, de Kadt and Luiz (2000). Pupil teacher ratios show marked differences between whites and blacks over the full 1910-1993 sample period, but also strong variation in the pupil teacher ratio for black public schooling in contrast to the relative stability of the ratio for white schooling. Blacks consistently faced poorer educational opportunities as measured by pupil-teacher ratios than did whites.\(^\text{13}\) Similar strong variation is evident with respect to per pupil expenditure figures between black and white


\(^{13}\)For further evidence on the differential quality of schooling inputs, see Moll (1996).
schools. The divergence between white and black per pupil expenditure persists into the 1990's, confirming the presence of strong patterns of inequality between whites and blacks. Per pupil expenditure and pupil teacher ratios are not the only measures of schooling inputs, of course, nor are they likely to be the only schooling inputs of importance to school output. However, a number of studies have noted strong correlation between different school inputs, suggesting that which precise input measure is employed may be less critical than might appear at first sight.

We note from the outset that the input measures in the white and black schooling systems are potentially likely to operate quite differently. Consider the correlation coefficients between the pupil-teacher ratio and real per pupil expenditure in white and black schooling of $-0.67$ and $+0.54$ respectively. The correlation indicates a point already evident from Fedderke, De Kadt and Luiz (2000), viz. that rising per capita expenditure in black schooling was associated with a widening of education for the black population, such that the rising expenditure was associated with a pupil population that rose more rapidly than did the teachers supplied to black schools. By contrast, rising expenditure in white schools led to teacher numbers rising more rapidly than pupil numbers, suggesting a deepening of the educational process.

Evidence on the outputs of the two schooling systems further confirms the presence of strong differences between white and black schooling in South Africa, but also renders plausible the suggestion that the strong differences in inputs impact on the quality of educational output. While the matriculation pass rates for whites rises steadily over the 1910-93 period, that for black schooling never reaches the rate attained in white schools, shows strong variation, and shows steady decline since 1976. Given that the output measures are pass rates, and hence constrained to the range $(0, 1)$, attempting to fit a linear specification may generate fitted values outside the feasible range, and does not give proper recognition to the fact that improving pass rates from 97% to 98% may not carry the same resource implications as increasing pass rates from 50% to 60% (it presumably gets more difficult). To avoid such problems we use a log ratio as the outcome variable, defined as $\ln Q_t = \ln \left( \frac{\text{PassRate}}{1 - \text{PassRate}} \right)$.

The output measures employed in the current study differ from the mean

\footnote{A number of studies have employed this measure as a proxy for the quality of schooling inputs - see the discussion in Card and Krueger (1992:9).}
\footnote{See Loeb and Bound (1996) by way of one example.}
score measures on standardized tests employed in other studies. This raises
the important concern that the output measures are not standardized across
time. At the outset we suggest that the possibility of changing standards in
the final standardized test in South African schooling is likely to be of limited
importance. This is evident from the fact that universities in South Africa
have employed the performance of pupils in the standardized matriculation
exams as the single most successful predictor of subsequent performance in
university education since 1917.\(^\text{16}\) Moreover, performance in the matricula-
tion examinations has been employed in unadjusted form - with no correction
for either rising or falling standards in matriculation examinations - indicat-
ing the relative reliability of the matriculation examination result.\(^\text{17}\) A final
indication of the relative reliability of the pass rate over time is the evidence
contained in Lam (1999), in which age and schooling alone accounts for well
over 40% of the variance in log earnings in South Africa. The implication is
that the quality of the schooling even across different generations is strongly
associated with the marginal product that beneficiaries of the schooling come
to realize in the labour market. This conclusion is further strengthened by
Lam’s finding on intergenerational human capital transfers. The finding that
sound educational performance of parents is a good predictor of sound edu-
cational performance of children suggests that the screening quality of the
educational system over time has been subject to some degree of consistency.

Nevertheless, in order to control for any additional variation in standards
over time, we correct the matriculation pass rate by controlling for up to
two measures of quality of the schooling system. These two variables proxy
for the quality of the output being generated through the pass rates of the
standardized tests completed at the conclusion of the schooling process in
South Africa. The two quality measures proposed are the proportion of
martriculants sitting mathematics as one of their matriculation subjects, and
the proportion of pupils in the schooling system that are in the matriculating
class.

In the case of the maths proportion we hypothesize that a rising propor-
tion indicates improving capacity of the schooling system to teach subjects
with content subject to objective marking standards and to produce the

\(^{16}\) See also the evidence in Edwards (2000), in which the score on the standardized
matriculation examinations constitutes a statistically significant and reliable predictor of
performance in first year economics examinations regardless of the schooling system from
which students originate.

\(^{17}\) See for instance the discussion in FRD (1996:14).
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types of human capital required by modern economic processes. The anticipation should therefore be of a positive impact of the math proportion on the aggregate pass rate maintained by the schooling system. One concern with this quality control might be that falling standards in mathematics education might serve to invalidate it. We believe this not to be the case. In the first instance, the proportion of matric candidates reading mathematics has been falling over time (particularly for white schools).\textsuperscript{18} Moreover, the pass rates in mathematics examinations have not trended over time.\textsuperscript{19} As long as the distribution of ability among matriculation candidates can be assumed to remain constant over time, the math proportion measure may be taken to give an indication of the system to adequately prepare pupils for the final standardized examinations. A falling proportion gives an indication that pupils are self-selecting out of the math stream, in anticipation of poor performance in the standardized examination. Hence, the proportion of matriculants sitting the examinations for mathematics can thus be taken as one indicator of the ability of the schooling system to generate the skills required of quality graduates.

In the case of the matric proportion measure, we note at the outset that the measure is a reliable indicator of quality only in the white schooling system. We have already noted that the increasing per capita resources devoted to schooling were associated with a deepening of the schooling process in the case of white schooling, and of widening in the case of black schooling. The finding of Lam (1999), that the earnings payoff of additional schooling is significantly positive for both whites and blacks, implies that there exists an incentive to progress through secondary schooling for all race groups. In the case of black schooling this resulted in ever greater pressure on existing inputs, with rapidly increasing pupil-teacher ratios. Only for white schooling were rising matriculation proportions (reflecting the incentive to acquire education) associated with constant (even falling) pupil teacher ratios. For this reason, we have potential confidence in the matriculation proportion as a quality measure only for white schooling - and exclude it from the black schooling estimations.

A final consideration is crucial in the South African context. South Africa has been an environment in which political conditions have dominated the activity of economic agents. Particularly for black communities, the level

\textsuperscript{18}See the discussion in Fedderke, de Kadt and Luiz (2000).
\textsuperscript{19}See also the absence of a trend in the mathematics pass rates noted in FRD (1996:19).
and extent of political disenfranchisement, and the level of political unrest and repression have often been particularly severe in schools - as in the 1976 Soweto uprising. Not to control for such factors is to ignore potentially crucial determinants of school performance. In order to do so we introduce a variable providing an index of political instability and repression. The variable is obtained from Fedderke, De Kadt and Luiz (2001). The indicator has been subjected to an independent panel of experts for assessment and validation. However, while political instability was of considerable importance for black schooling, we hypothesize relatively little impact on the functioning of white schools. For this reason, in what follows we control for political instability only in the production function for black schools.

3.2 Empirical Methodology

The expectations of long run relationships in non-stationary data suggests the appropriateness of a VECM estimation framework. We employ that of Johansen.

Johansen techniques of estimation are now standard, so that the discussion here can be brief. We employ a vector error-correction (VECM) framework, for which in the case of a set of $k$ variables, we may have cointegrating relationships denoted $r$, such that $0 \leq r \leq k - 1$. This gives us a $k$-dimensional VAR:

$$ z_t = A_1 z_{t-1} + \ldots + A_m z_{t-m} + \mu + \delta_t \tag{1} $$

where $m$ denotes lag length, $\mu$ deterministic elements, and $\delta$ a Gaussian error term. While in general $z_t$ may contain $I(0)$ elements, given our bivariate association, as long as non-stationary variables are present we are exclusively restricted to $I(1)$ elements. Reparametrization provides the VECM specification:

$$ \Delta z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-k+1} + \mu + \delta_t \tag{2} $$

The existence of $r$ cointegrating relationships amounts to the hypothesis that:

$$ H_1 (r) : \Pi = \alpha \beta' \tag{3} $$

20 Sociologists, political scientists and legal experts familiar with South African history.

where $\Pi$ is $p \times p$, and $\alpha, \beta$ are $p \times r$ matrices of full rank. $H_1 (r)$ is thus the hypothesis of reduced rank of $\Pi$. Where $r > 1$, issues of identification arise. In our case this may arise if more than one long run relationship is present in the data.

Our prior discussion leads us to anticipate two possible cointegrating relationships for both white and black schooling. In the case of white schooling we anticipate the presence of a production function with white matriculation pass rates as outcome variable, subject to inputs (real per pupil expenditure), and adjusted for potentially changing quality of the pass rate (controlled for by the math proportion in the matriculation examination, and the proportion of all pupils in the matriculation year). Moreover, we have also noted that rising real per capita expenditure in white schooling was associated with deepening of the schooling process for whites, as measured by pupil teacher ratios. These considerations, lead us to the over-identified structural specification given by:

$$
\Pi z_{t-k+1} = \begin{bmatrix}
\alpha_{11} & \alpha_{12} \\
\alpha_{21} & \alpha_{22} \\
0 & 0 \\
0 & 0
\end{bmatrix}
\begin{bmatrix}
1 & \beta_{12} & 0 & \beta_{14} & \beta_{15} \\
0 & \beta_{22} & 1 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\ln WPRAT \\
\ln WRPERC \\
\ln WPUBPTR \\
\ln WMATHPRP \\
\ln WMATRICPR
\end{bmatrix}
$$

(4)

where $\ln iPRAT$ denotes the log odds ratio of the matriculation pass rate for race group $i$, $\ln iRPERC$ real per pupil expenditure for race group $i$, $iPUBPTR$ the pupil teacher ratio for race group $i$, $iMATHPRP$ the maths proportion for race group $i$, and $iMATRICPR$ the matric proportion for race group $i$. The zero restriction on the pupil teacher ratio in the white production function is dictated by the close association between real per capita expenditure and the ratio. In effect the two measures measure the same dimension: inputs into the schooling process. The second cointegrating vector captures the deepening process.

For black schooling, our prior discussion indicates the lack of relevance of the pupil teacher ratio input over and above the real per pupil expenditure, and the particular importance of a measure of political instability. On the

basis of the preceding discussion we thus specify the just-identified system:

\[
\Pi_{zt-k+1} = \begin{bmatrix}
\alpha_{11} & \alpha_{12} \\
\alpha_{21} & \alpha_{22} \\
0 & 0 \\
0 & 0
\end{bmatrix}
\begin{bmatrix}
1 & \beta_{21} & \beta_{31} & 0 & \beta_{51} \\
0 & 1 & \beta_{33} & \beta_{42} & \beta_{52} \\
0 & 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\ln BPRAT \\
\ln BRPERC \\
\text{BMATHPRP} \\
\text{BMATRICPR} \\
\ln INSTAB
\end{bmatrix}_{t-k+1}
\]  

(5)

where all variables are as defined above, and \( \ln \text{INSTAB} \) denotes the log of our political instability measure. The zero restriction on the BMATRICPR variable in the production function is dictated by the consideration that a rising matric proportion is evidence of widening education in black schooling, rather than a proxy of rising quality in black education. Instead, we anticipate that a rising BMATRICPR is evidence of widening in black schooling, and hence its impact should thus be positive on \( \ln \text{BRPERC} \), with no direct impact on the pass rate.

4 Estimation results and substantive findings

4.1 Univariate Time Series Characteristics of the Data, and Reduced Rank Statistics

The univariate time series characteristics of the data is reported in Table 1. Statistics are augmented Dickey-Fullers. The test statistics confirm that all variables are \( \sim I(1) \), confirming the appropriateness of the VECM estimation framework.

It remains to establish whether the number of cointegrating vectors present in the data conforms to the theoretical priors specified in equations (4) and (5). In Tables 2 and 3 we report the trace and maximal eigenvalue statistics for white and black schooling respectively. In both instances, the test statistics confirm the presence of two cointegrating vectors. In the case of white schooling test statistics are generated under the conditioning assumption that the math and matric proportions are weakly exogenous to the system. In both instances we favor the results of the trace statistics given its more favorable power characteristics in small samples.
### Table 1: Augmented Dickey Fuller Statistics

* denotes significance at the 5 percent level

<table>
<thead>
<tr>
<th>Null</th>
<th>Alternative</th>
<th>Eigenvalue Statistic</th>
<th>95% Critical Value</th>
<th>Trace Statistic Value</th>
<th>95% Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r = 0$</td>
<td>$r \leq 1$</td>
<td>59.36*</td>
<td>27.75</td>
<td>87.54*</td>
<td>46.44</td>
</tr>
<tr>
<td>$r \leq 1$</td>
<td>$r \leq 2$</td>
<td>15.50</td>
<td>21.07</td>
<td>28.17*</td>
<td>28.42</td>
</tr>
<tr>
<td>$r \leq 2$</td>
<td>$r \leq 3$</td>
<td>12.68</td>
<td>14.35</td>
<td>12.67</td>
<td>14.35</td>
</tr>
</tbody>
</table>

### Table 2: White Schooling Cointegration Based on Maximal Eigenvalue of the Stochastic Matrix

* denotes statistical significance at the 95 percent and ** at the 90 percent interval, 67 observations 1927-93; VAR order =10; List of eigenvalues is descending order: 0.58770, 0.20648, 0.17239, .0000, 0.00

<table>
<thead>
<tr>
<th>Null</th>
<th>Alternative</th>
<th>Eigenvalue Statistic</th>
<th>95% Critical Value</th>
<th>Trace Statistic Value</th>
<th>95% Critical Value</th>
</tr>
</thead>
<tbody>
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<td>74.57*</td>
<td>33.64</td>
<td>128.09*</td>
<td>70.49</td>
</tr>
<tr>
<td>$r \leq 1$</td>
<td>$r \geq 2$</td>
<td>26.31**</td>
<td>27.42</td>
<td>53.52*</td>
<td>48.88</td>
</tr>
<tr>
<td>$r \leq 2$</td>
<td>$r \geq 3$</td>
<td>19.73**</td>
<td>21.12</td>
<td>27.21</td>
<td>31.54</td>
</tr>
<tr>
<td>$r \leq 3$</td>
<td>$r \geq 4$</td>
<td>5.78</td>
<td>14.88</td>
<td>7.47</td>
<td>17.86</td>
</tr>
<tr>
<td>$r \leq 4$</td>
<td>$r = 5$</td>
<td>1.70</td>
<td>8.07</td>
<td>1.70</td>
<td>8.07</td>
</tr>
</tbody>
</table>

### Table 3: Black Schooling Cointegration Based on Maximal Eigenvalue of the Stochastic Matrix

* denotes statistical significance at the 95 percent and ** at the 90 percent interval 27 observations 1967-93; VAR order =3; List of eigenvalues is descending order: 0.93683, 0.62266, 0.51848, 0.19270, 0.060920
4.2 The schooling production functions

We present the estimations of educational production functions for the white and black schooling systems in South Africa in Tables 4 and 5 respectively. In both instances the first cointegrating vector provides an educational production function, in which real per pupil expenditure generates an increase in the associated matriculation pass rate. Moreover, the quality measure provided by the mathematics proportion in the matriculation year generates an increase in both matriculation pass rates. As anticipated in the preceding discussion, the proportion of matriculation candidates to total pupil numbers enters the educational production function only for white schooling, while the political instability measure has a significant negative impact on the matriculation pass rate in black schooling.

Again as anticipated above, the second cointegrating vector is distinct between the two schooling systems. In the case of white schooling, rising per pupil expenditure leads to a falling pupil teacher ratio, confirming the hypothesis of a deepening of the educational process in white schooling advanced above. For black schooling, widening of the schooling process precludes the existence of a reliable link between real per pupil expenditure and the pupil teacher ratio. Instead, the widening process has led to a positive relationship between both the matric proportion and real per pupil expenditure, and between the math proportion variables and real per pupil expenditure, while political instability exercises a negative impact on per pupil expenditure also. Both sets of relationships are readily explained. A rising matric proportion in black schooling is associated with the widening of the schooling process, indicative of larger numbers of pupils moving through all 12 years of schooling. The math proportion can continue to be interpreted as a quality measure as explained in the data section above. In both instances, the positive sign on the variables follows. For the political instability measure, the negative sign is explicable in terms of the substitution between different forms of government expenditure that followed as a response to political agitation. Expenditure shifted from social services to security expenditure as pressure on the political system rose.

Finally, note that the error correction terms confirm the presence of coherent equilibrating mechanisms for all cointegrating relationships.

\[\text{\footnotesize \textsuperscript{23}See the more extensive discussion in Fedderke, De Kadt and Luiz (2000).}\]
\[\text{\footnotesize \textsuperscript{24}See for instance the discussion in Lipton (1985:245-7) and Du Toit (1995).}\]
\[\text{\footnotesize \textsuperscript{25}Full details of the dynamics are available from the authors on request.}\]
### White Schooling: Estimated Long Run Relationship

**CV1:**
\[ \ln WPRAT = 0.67 \ln WPERC + 2.41 \text{WMATHPRP} + 26.83 \text{WMATRICPR} \]
\[ (0.13) \quad (0.75) \quad (9.46) \]

**CV2:**
\[ WPUBPTR = -1.27 \ln WPERC \]
\[ (0.76) \]

### Error Correction Specification Details

<table>
<thead>
<tr>
<th>[\Delta \ln WPRAT]</th>
<th>ECM on CV1:</th>
<th>(-0.85^*)</th>
<th>(0.27)</th>
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<tr>
<td>[\Delta WPUBPTR]</td>
<td>ECM on CV1:</td>
<td>1.39</td>
<td>(0.75)</td>
</tr>
<tr>
<td></td>
<td>ECM on CV2:</td>
<td>-0.24*</td>
<td>(0.10)</td>
</tr>
</tbody>
</table>

### Black Schooling: Estimated Long Run Relationship

**CV1:**
\[ \ln BPRAT = 0.32 \ln BRPERC + 0.27 \text{BMATHPRP} - 0.52 \ln INSTAB \]
\[ (0.51) \quad (4.36) \quad (0.15) \]

**CV2:**
\[ \ln BRPERC = 7.88 \text{BMATHPRP} + 402.05 \text{BMATRICPR} - 0.45 \ln INSTAB \]
\[ (1.49) \quad (202.5) \quad (0.23) \]

### Error Correction Specification Details

<table>
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<th>[\Delta \ln BPRAT]</th>
<th>ECM on CV1:</th>
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<th>(0.16)</th>
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<td>[\Delta \ln BRPERC]</td>
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<td>(0.12)</td>
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<tr>
<td></td>
<td>ECM on CV2:</td>
<td>-0.29*</td>
<td>(0.13)</td>
</tr>
</tbody>
</table>

Table 4: White Schooling Estimations Figures in parentheses are standard errors

Table 5: Black Schooling Estimations Figures in parentheses are standard errors
4.3 Discussion and Evaluation

The results carry three core implications.

The results from the long run equilibrium relationships estimated confirm the presence of a schooling production function for both white and black schooling in South Africa, despite the considerably different institutional setting in which the two schooling systems operated. Thus the first important implication that emerges from this study is that even at the very disparate levels of inputs devoted to education that were evident in white and black schooling, resources make a difference. While it may be correct to say that the impact of rising inputs may be greater at low absolute levels of inputs into education (such as the high pupil-teacher ratios Case & Deaton 1999 report), this does not preclude the possibility of an impact at the high levels of inputs featured in South Africa’s white schooling system.

As a second finding we confirm that the quality dimension enters the educational production functions with the anticipated sign.

Third, while a production function is present in both schooling systems, the institutional setting exercises a strong influence on the nature of the production function. Given the use of a log odds ratio as dependent variable, and the semi-logarithmic specification used in the educational production function, the coefficients reported above are difficult to interpret directly. For purposes of comparison of the two production functions we therefore compute the variable marginal impact of changes in real expenditure per pupil, and the implied variable elasticity of real per pupil expenditure.

In Figure 1 we report the marginal impact of real expenditure on the matriculation pass rate for both black and white schooling. At very low levels of per pupil expenditure, the percentage point increase in the matriculation pass rate with rising expenditure in white schools exceeds that in black schools. The marginal impact of real expenditure for both schooling systems declines very rapidly with rising expenditure, though the impact remains positive. While the marginal impact of rising real expenditure may appear negligible, note that the increases in real expenditure are relatively modest over the domain considered, and of course marginal increases ignore

\[ \frac{\partial iPR}{\partial iRPERC} \]

where \(iPR\) denotes the matriculation pass rate of race group \(i\) (not as log odds ratio but in raw form), and \(iRPERC\) denotes the real per pupil expenditure for race group \(i\). The computation set all other determinants of the matriculation pass rate at their average values in the sample period. The computed marginal impact is thus on the quality adjusted matriculation pass rate.

\[ \text{We report } \frac{\partial iPR}{\partial iRPERC} \text{, where } iPR \text{ denotes the matriculation pass rate of race group } i \text{ (not as log odds ratio but in raw form), and } iRPERC \text{ denotes the real per pupil expenditure for race group } i \text{. The computation set all other determinants of the matriculation pass rate at their average values in the sample period. The computed marginal impact is thus on the quality adjusted matriculation pass rate.} \]
the proportionality of changes that elasticities convey.

For this reason Figure 2 reports the real expenditure pass rate elasticities for both white and black schooling. In this instance we also report the sensitivity of the elasticity to changes in the quality proxy variable common to both production functions: the mathematics proportion. We do so by reporting the elasticity for the average, minimum and maximum in-sample math proportion for each schooling system. The evidence adds two important modulations to our understanding of the impact of inputs on matriculation pass rates. The first is that the elasticity in black schooling is higher than that in white schools. Moreover the higher elasticity in black schooling is present even over ranges in real per pupil expenditure that the two schooling systems had in common. The second is that the impact of the maths proportion is what we would anticipate if the maths proportion was a control for the quality dimension. Higher maths proportions lower the elasticity (for both schooling systems), consistent with a more rapid onset of diminishing returns to real expenditure.

Thus while we have found that the long run relationships provided by the estimated cointegrating relationships identify real per student expenditure as an input in the schooling production function for both schooling systems, the magnitude of the implied impact in the two systems is quite distinct. While the marginal impact of real expenditure in black schooling is smaller than for white schooling at low levels of real expenditure, the proportional impact in black schooling is higher than in white schooling at all levels of expenditure.

Noteworthy as a difference between the two schooling systems are the higher probability levels at which the input and quality proxies find statistical significance in the black schooling system than in the white - note the standard errors on the real per capita expenditure coefficients in the two production functions. Despite the higher elasticities found for black schooling, the two systems are thus distinct in the importance that can be attached to the real expenditure input measure for policy purposes. What dominates the determination of the black schooling system’s output measure is the level of political instability - with a statistically significant negative impact on the matriculation pass rate.

A final difference between the two schooling systems is evident from the estimated production functions in terms of the different roles played by pupil teacher ratios. In white schooling rising real per pupil expenditure lowers pupil teacher ratios discernibly. In black schooling, expenditure was associ-
ated with the fixed costs of widening the schooling system rather than deepening an already existing schooling system with greater teaching resources for the school population. For this reason the expenditure measure is statistically associated with pupil teacher ratios with intuitively appealing signs in white schooling, while it is impossible to find the symmetrical result for black schooling.

We can thus conclude that institutions matter and this is reflected in the three dimensions discussed above. The political instability variable has a very real impact on the black production function but not on the white one. The differential degree of political control resulted in the widening of education for the black population, whilst in white education it led to a deepening. Lastly, whilst the evidence shows that real per capita expenditure is associated with a higher elasticity for the black educational production function than for the white, it is associated with a lower statistical significance indicating a lower de facto effectiveness.

5 Conclusions and Policy Implications

Inputs matter in the production of educational output. But the efficiency with which such inputs are used matters at least as much - and the governance structures of the educational system may be an important determinant of efficiency. These are the two central conclusions to emerge from our study.

Previous work on South African educational production functions has relied on OLS estimation in time series contexts and cross-sectional studies (see Wakeford (1997) for a review). Databases have been inadequate, rendering previous results doubly questionable. The current study, in using a new database, over a long time run from 1910-93, and employing cointegration estimation in estimating the educational production function, therefore represents a considerable advance over previous results.

But the study represents an advance for an understanding not only of South African educational production functions, but of educational production functions more generally. The study is the first that to our knowledge is able to apply time series estimation to an educational production function using cointegration techniques of analysis. Our findings demonstrate that schooling inputs matter in the determination of educational output (here measured by matriculation pass rates in which quality is controlled for by math proportions in the output and throughput rates), and matter even
where variation in the input measures is low in absolute terms. At the very least, therefore, the findings of the current study provides an important modulation of the findings that emerge from cross-sectional studies, that returns from improved inputs in schooling are negligible.

The second general finding of the present study emerges from the natural experiment that South African history provides, and which allows us to implicitly control for background variables, and different institutional dispensations governing policy making, simply by estimating separate educational production functions for the white and black schooling systems. We note that the background variable (the level of political instability), and the institutional dispensation appear to significantly impact on the educational production function for blacks. While the educational production functions in white and black schooling systems manifest a similar structure in terms of the variables that load in each, the estimated results obtained for the two schooling systems are dramatically different.

First, while real per pupil expenditure has a higher elasticity in black education than in the white schooling system, the input measure lacks the degree of statistical significance it enjoys for white schooling. Second, for the black schooling system the dominant determinant of educational output in this study is the background variable controlled for: the level of political instability.

Such findings nuance our initial conclusion that inputs into the educational process matter in the determination of output. Inputs in and of themselves are not enough. The institutional structures that govern policy formulation within the schooling system appear to be crucial also. Where parents have the capacity to influence policy, the use of inputs in education appears to be more efficient than where they do not. The labour market gives agents a stake in the educational process - what governance structures of schooling should reflect are adequate means allowing agents to realize such stakes in their own best interests. Decentralized decision making, and above all incentive systems that emphasize performance-rated reward structures for teachers, are further likely to be important in eliminating inefficiency.

Understanding the nature of the education production function is particularly important in developing countries given the resource constraints faced in development. South Africa, for example, already spends over 7% of its GDP on education, compared to the average for other upper-middle income
countries of 4.2%, and 5% for industrialized countries. Nevertheless, the state of education in South Africa leaves much to be desired. What this study has shown is that matters can be improved through a judicious use of inputs in education - but equally that inputs into education will be used effectively only where the institutional dispensations governing the decisions on resource use are such as to allow parents to force decision makers to be effective. Money alone is not the answer.

References


\textsuperscript{27}See the discussion in Luiz (1995).


Lipton, M., *Capitalism and Apartheid*, Cape Town: David Philip.


Figure 1: Marginal Impact of Real Per Pupil Expenditure on Matriculation Pass Rate
Figure 2: Elasticity of Matriculation Pass Rate with respect to Real Expenditure per Pupil