An Education Production Function for Botswanan Secondary Schools

Sub-Theme: Education

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Abstract – This study investigates the determinants of educational outcomes in the developing world by estimating an education production function for Botswanan secondary schools. Education plays an essential role in the development process, as a high-quality educational system is the only means by which a developing country expands its stock of human capital. Additionally, education contributes to the improvement of health outcomes and political institutions. Sub-Saharan Africa is perhaps the region of the world for which efficiency in education is most important, as policymakers are faced with the combination of a rapidly growing population, low levels of education, and limited resources. Without an accurate understanding of the determinants of educational outcomes, it will be difficult to enhance efficiency. Panel data from school districts are used to specify a translog production function, using scores from standardized math and science examinations as outputs, while using school inputs, student characteristics, and family background as regressors. The translog function is used in this study because it imposes few restrictions on the underlying production function. The results of this study have important policy implications for Botswana in particular and for all of Africa and the rest of the developing world in general.

Introduction

This study estimates an education production function for Botswanan secondary schools using data obtained from the 2007 Trends in International Mathematics and Science Study (TIMSS). This is done in order to contribute to the economic literature regarding the impact of school inputs on the educational process.

Many economists have argued that education is essential for economic growth (Mankiw, Romer, and Weil, 1992; Lucas, 1988). Moreover, the economic literature suggests that education has a desirable impact on other aspects of development, such as health and population-growth (Shultz, 2002; Strauss and Thomas, 1995). In addition to these benefits, education is also considered to be a good in itself, as is indicated by its inclusion in the United Nations Development Program’s Human Development Index.

Over the past 50 years, access to primary and secondary education in developing countries has improved tremendously. Botswana is no exception to this, as since gaining independence
in 1966 the enrolment and completion rates for Botswanan primary and secondary schools have increased markedly (UNESCO 2002).

Given the fact that many developing countries devote a large share of their limited resources to education, it is imperative that education is produced efficiently. Yet education in developing countries often suffers from a myriad of defects. Among them are high rates of teacher absenteeism, woefully limited amounts of basic supplies, and high grade repetition rates. As education finance systems in developing countries are often weak, there is reason to suspect that the consequent budget distortions result in large inefficiencies. In order to address the sources of these inefficiencies, policymakers must understand the mechanism through which educational outputs are obtained. That is, it must be understood how a bundle of various inputs such as student background characteristics, school/family inputs, etc. are mapped to an educational outcome. With an accurate understanding of this production process, policymakers could then reallocate expenditures away from inputs with relatively low marginal products in favour of those with relatively high marginal products (Glewwe and Kremer, 2006).

I consider education production using Botswanan TIMSS data alone for a number of reasons. First, the amount of work that has been done on education production in Africa is quite limited, and the work that has been done suggests that education production in Africa is very inefficient (Gyimah-Brempong and Appiah, 2004). Second, using just one country helps to eliminate some problems caused by potential country heterogeneity. Third, the TIMSS dataset is very rich in that it features an abundance of panel data from two periods for each student. It provides 4th grade TIMSS outcomes as well as 8th grade TIMSS outcomes, which permits us to use a value-added framework for estimation.

The TIMSS was initiated by the International Association for the Evaluation of Educational Achievement (IEA) for the purpose of comparing educational achievement in participating
countries. The first study was conducted in 1995, and has since been administered every four years. The TIMSS studies 4th and 8th grade students in participating countries, and includes skill tests in Mathematics and Science, in addition to student, teacher, and school surveys. Botswana was chosen as the sample country for this study primarily because the Botswanan dataset features more data than did the datasets for other sub-Saharan African countries. Another reason is that Botswana has been a success story in development among SSA countries, so an understanding of the Botswanan experience could offer valuable insights for other countries in the region.

This study will estimate a transcendental logarithmic (translog) production function. The translog production function was chosen due to its flexible form, which permits us to test for other functional forms (e.g. Cobb Douglas) with the appropriate parametric restrictions.

**Previous Work**

Overall, the results of previous studies on education production are highly ambiguous. While some studies have suggested that school inputs have a positive statistically significant effect on student cognitive achievement (Krueger, 2003; Case and Deaton, 1999; Woessman, 2005), others have suggested that no such effect exists. This has led some researchers (Hanushek, 2003) to argue that many traditional policies implemented to improve the quality of education, such as increasing the general funding of schools, have little prospect for success.

The literature does, however, offer a clearer and somewhat less bleak picture when considering developing countries exclusively. A number of studies have found significantly positive effects on student cognitive achievement for school inputs, including teacher experience, teacher training, facility quality, textbook use, and instruction time (Glewwe et al, 1994; Glewwe et al, 1995; Lavy, 2010). In another study on primary education in 21 sub-
Saharan African countries, Fehrler et al (2009) finds significantly positive effects on student cognitive achievement for a number of pedagogical resources (e.g. textbooks and wall-charts) as well as teacher quality. That additional resources are more effective in developing countries than in developed countries is consistent with economic theory, as the additions to the lower stocks of resources found in developing countries should feature a higher marginal productivity than additions to the higher stocks of resources found in developed countries.

Nevertheless, a significant number of studies on this topic have produced results which bring into question the effectiveness of school inputs. Some have argued that such results may be the consequence of flaws in the econometric techniques used (Gyimah-Brempong and Appiah, 2004; Gyimah-Brempong and Gyapong, 1992; Todd and Wolpin, 2003). In particular, some of these studies could suffer from omitted variable bias and model misspecification. Such problems are often times the result of researchers using inadequate proxies for relevant inputs from both current and previous periods, especially student socioeconomic characteristics.

Given the controversy surrounding these important issues, it is clear that more work needs to be done on this topic.

The rest of this study is organized as follows: part 2 introduces theoretical model and translog production function, part 3 provides a description the TIMSS dataset in greater detail, and the results of the estimation are reported and discussed in part 4. In part 5 conclusions are offered.

Model

Our starting point is that educational output (Y) can be produced with a set of school inputs (X), family background characteristics (W), and student quality (Z). We assume that the underlying production function can be represented by a transcendental logarithmic production function (Christensen et al, 1973). The translog function is a Taylor approximation of the
underlying production technology and it imposes no restrictions on the underlying production technology.

Other production functions can be derived from the translog function as testable hypotheses using appropriate parametric restrictions. For example, the production technology is Cobb Douglas when all second order coefficients are jointly equal to zero and we obtain constant returns to scale when the sum of input coefficients equals zero.

The translog production function is given by:

\[
\ln Y = \alpha_0 + \sum \alpha_i \ln X_i + \left(\frac{1}{2}\right) \sum \sum \beta_{ij} \ln (X_j^2) + \sum \sum \alpha_{ij} X_i X_j
\]

In this study, we have a vector of school inputs \((X)\), a vector of socioeconomic inputs \((W)\) and one student characteristic \((Z)\) proxied by the previous test score of the student at a lower grade level. This allows us to estimate the education production function as a value added proposition.

Another advantage of the translog production function is that it does not impose any restrictions on scale elasticities, which are given as:

\[
E(X_0) = \sum (\alpha_i + \beta_{ij} \ln X_j^*)
\]

This suggests that scale economies vary with the scale of operation.

In addition to the total production function, one can also derive a series of marginal product functions from the total product function:

\[
MP_x = \frac{\partial Y}{\partial X_i} = \sum \alpha_i X_i + \sum X_j
\]

These marginal product equations can then be estimated jointly with the production function to achieve efficiency.

Note

The estimation/result/conclusion sections of the paper are currently being produced.
References


