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A model of the impact of government revenue and quality of governance on schooling

Stephen G. Hall [a], Bernadette O'Hare [b,*]

[a] School of Business, University of Leicester, London Road, Leicester LE2 1RQ, UK
[b] Division of Infection and Global Health, The School of Medicine, University of St Andrews, College Gate, St Andrews KY16 9AJ, UK

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ABSTRACT

When governments have more revenue, they spend more on human capital, and spending is more effective in well-governed countries. Here, we use an equilibrium correction model to empirically investigate the relationship between government revenue per capita, six indicators of quality of governance, and school attendance, using an unbalanced panel dataset that includes nearly all countries. The results suggest a strong effect over time: as government revenue increases, school attendance rates increase, and the magnitude of this influence is mediated significantly by a country's quality of governance. Interestingly, the impact of governance is more pronounced in primary education than it is in lower or upper secondary education. This model offers the ability to demonstrate the impact of increases and decreases in government revenue in an individual country while accounting for the impact of revenue on governance and the impact of both revenue and governance on school attendance.

1. Introduction

The 2030 Agenda for Sustainable Development was adopted by all countries in 2015 and has established a framework for the development of all people and the planet. At the centre are the 17 Sustainable Development Goals (SDGs), which build on international human rights treaties and conventions and many years of work by members of the United Nations.

SDG 4 aims to ensure inclusive and equitable education and to promote lifelong learning opportunities. Target 4.1 aims to ensure that by 2030, all boys and girls will complete free, equitable, and high-quality primary and secondary education, leading to effective learning outcomes. Indicator 4.1.2 is the completion rate of primary, lower, and upper secondary education. Indicator 4.1.1 is the proportion of children and young people achieving minimum proficiency in reading and mathematics.

Education is critical for reducing poverty. New technologies mean that there will be very few low-skilled jobs, and that quality education is an urgent requirement for reducing inequality. A meta-regression of 237 estimates demonstrated that government spending on education, as a percentage of GDP, promotes economic growth (Churchill et al., 2017).

Given its importance for sustainable development, it is vital to study how progress to SDG 4.1 can be made. The remainder of this paper is organised as follows: Section 2 reviews the literature on the different measures of educational attainment; Section 3 considers the role of governments and schooling and learning; Section 4 discusses the data and the model; Section 5 presents the results; and Section 6 discusses the results.

2. Measures of educational attainment

It is common to think of the time spent in school as equivalent to educational attainment. However, cross-country comparisons of educational attainment using international surveys have led to questions about the quality of the education provided and the rationale for focusing on attendance if there is limited learning. Hanushek argues that it is important to differentiate between educational attainment (learning) and the time spent in school (schooling) (Hanushek and Woessmann, 2007). We use these terms throughout this study to distinguish between them.

2.1. Returns to schooling

A landmark paper by Mincer established a commonly used approach

* Corresponding author.
E-mail address: bamo@st-andrews.ac.uk (B. O'Hare).

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for estimating returns on schooling, where the independent variable is the log of wages regressed on years of schooling and labour market experience (Mincer, 1974). Montenegro and Patrinos used this approach to study 139 higher- and lower-income countries and found that the returns in terms of labour market earnings to an additional year of schooling are highest in sub-Saharan Africa, higher for males than for females, and higher for primary and tertiary education than for secondary education. On average, an individual's salary increases by ten percentage points for every additional year of primary school, 7% for secondary school, and 15% for tertiary education. They also note that, in an economy, returns to schooling decline as the average level of schooling increases. In view of the gradual increase in schooling globally, there has been a decline in returns between the 1980s and the 2010s (Montenegro and Patrinos, 2014). An important study in India compared districts which participated in a program to extend access to education with those that did not, demonstrate that individual earnings increased by 13.5%, and earnings in the district as a whole increased by 7% (Khanna, 2023). A systematic review of the literature in sub-Saharan Africa found that education is beneficial to the economic well-being of individuals and contributes to the economic growth of a country (Chikoko and Mthembu, 2020).

The impressive rates of return seen in these, and similar studies catalysed a drive towards increasing enrolment of children in school globally. However, some feel this may have compromised learning and suggest that using schooling alone does not account for a child's ability or the quality of the school (Glewwe, 1996). Hanushek and Woessmann argue in a series of influential papers that schooling without learning has limited value in terms of economic growth. Using econometric models which include both schooling and learning, they report that learning has a much greater impact on economic growth than schooling (Hanushek, 2013; Hanushek and Woessmann, 2007). However, this work was conducted using learning data from a limited number of countries, and the findings are different from country-level findings which have led some to question their generalisability (Centre for Global Development, 2022).

2.1.1. Nonmarket returns to schooling

There is extensive literature, including several systematic reviews, which find significant non-market returns to schooling. In their systematic review of the literature, Chikoko and Mthembu find that schooling reduces inequality in sub-Saharan Africa (Chikoko and Mthembu, 2020). Another important contribution is that of Gakidou et al., who systematically reviewed the literature and found that, for every additional year of schooling for women, child mortality decreased by 10% (Gakidou et al., 2010). In terms of health, Grossman found that years of schooling is the most important correlate of good health and a recent systematic review of 603 studies found a 1.9% reduction in the risk of adult mortality for each additional year of schooling (Grossman, 2006; IHME CHAIN Collaborators 2024). Country-level studies are summarised in the comprehensive review by the Centre for Global Development (Centre for Global Development, 2022) For example, research in Indonesia shows that, even at a time when students scored very low in terms of learning, an additional year in school led to 7–11% increase in earnings (Duflo, 2001), and in addition to, and independent of an increase in salary, schooling increases happiness (Sohn, 2013). In Nigeria, one additional year of schooling reduces early fertility by 0.26 births, this is in a country where only 8% of women can read after five years of schooling, reflecting the quality of learning (Osili and Long, 2008).

2.1.2. Learning

It is challenging to identify learning outcomes that are consistent across countries, and there are no test scores that are comparable globally (Rajkumar and Swaroop, 2008). Often surveys do not cover all countries. For example, the Programme for International Student Assessment (PISA), produced by the Organisation for Economic Cooperation and Development (OECD) and administered at age 15. The most recent assessment was carried out in 80 countries in 2022 (PISA, 2024). The International Association for the Evaluation of Educational Achievement (IEA) has produced Trends in International Mathematics and Science (TIMSS), carried out in grades four and eight, and Progress in International Reading and Literacy (PIRLS), carried out in grade four. Seventy-two countries participated in the TIMSS in the 2019 round, and 66 countries in the 2021 PIRLS round (IEA, 2024). The Learning Poverty Global Database, developed by the World Bank, reports the percentage of children who are below minimum reading proficiency at the end of primary school, adjusted for out-of-school children. This database includes 15 SSA countries in the 2019 version updated in August 2023, with data for 47 countries (World Bank, 2024). Using the Learning Poverty data, Richards found that in India, Pakistan, and Bangladesh, most of the next generation will be illiterate (Richards, 2023). However, using data on learning-adjusted years at school from the World Bank (Angrist et al., 2020), researchers have found little relationship between learning in a country and earning gains (Centre for Global Development 2022).

3. Government revenue, governance, schooling, and learning

Education is largely financed by governments and households. In high-income countries, 84% of spending on education is by government, and the rest is by household; in upper-middle-income countries, the figure is 66%, and the remainder by households; in lower-middle income countries, governments spend 58%, households 40% and donors 2%; in low-income countries, governments, households, and donors spend 49%, 35%, and 16%, respectively. In all countries, the main source of government revenue is taxes (UNESCO, 2024). Taxes are largely determined by the country's GDP and the ability of governments to raise taxes. A meta-analysis of 115 studies found that a one standard deviation improvement in corruption is associated with a 0.59% increase in GDP per capita income in low-income countries (Ugur and Dasgupta, 2011). Dreher and Herzfeld quantified the impact of governance on economic growth and GDP per capita, and concluded that corruption negatively affects economic growth, GDP per capita, investment activity, international trade, and price stability (Dreher and Herzfeld, 2006). Several studies have also empirically demonstrated that corruption negatively affects tax revenue and, thus, government revenue (GR)(Arif and Rawat, 2018; Igbinovia et al., 2020).

3.1. Government revenue and schooling

When governments have more income, they spend more on public services, and increased government spending drives the progress of the SDGs, including SDG 4 (Haile and Niño-Zarazúa, 2017; Gupta, Verhoeven, and Tiongson, 2002; Bokhari, Gai, and Gottret, 2007). Public services are critical for the poorest households and quality health and education services are the most effective mechanisms for reducing inequality (Lustig, 2017). Researchers have modelled the relationship between government revenue per capita (GRpc) and several SDG indicators, including school life expectancy. They found the relationship to be highly nonlinear and that additional GRpc has a much higher impact in low-income countries than in high-income countries. There are several reasons for this, including the fact that revenue is so low in many countries that any additional income is relatively high, and interventions to reduce the coverage of several critical SDG indicators, such as school life expectancy, are less costly than those in high-income countries where the coverage of these SDGs is close to 100% (Hall et al., 2021, 2022).

Additional revenue also improves the governance indicators. A study of 31 sub-Saharan African countries demonstrated that a 1% increase in the tax/GDP ratio reduced corruption by 0.04–0.08 points (measured on a scale of 0–6). The authors also empirically demonstrate that this acts by strengthening the fiscal contract, as citizens demand better

governance if they carry a fiscal burden (Baskaran and Bigsten, 2013). Hall and O'Hare empirically showed that an increase in GRpc leads to a steady improvement in governance which drives a virtuous circle (Hall and O'Hare, 2023).

3.2. Governance and schooling

What is also critical is how effectively governments use their resources, as there is considerable variation in the efficacy of government spending between countries. Governance is critical for effective public spending (Makuta and O'Hare, 2015; Rajkumar and Swaroop, 2008) and the quality of governance is positively associated with 19 measures of societal outcomes, including health, ecological, and reduced inequality (Holmberg, Rothstein, and Nasiritousi, 2009). The quality of a country's public institutions is the most critical explanation for variations in social well-being, and how efficiently governments allocate and spend their revenue (Acemoglu and Robinson, 2013). Allocation decisions in the public interest are more likely in countries with good governance (Dreher and Herzfeld, 2006). Poor governance leads to overspending, diversion, and the distorted allocation of public funds. For example, investing in sectors where the opportunity for bribes is increased rather than in sectors which favour public interest. Poor governance diminishes government efficiency and the underuse of human capital because of cronyism, as opposed to meritocracy (Ugur and Dasgupta, 2011). In contrast, good governance reduces corrupt practices downstream at the frontline (civil servants including teachers) which drives the efficient delivery of public services, and low-income households rely most heavily on public services (Arbache et al., 2010). Good governance reduces the chances of debt taken out in the public name and diverted to private accounts and the theft of public funds or 'big time' corruption (Ndikumana and Boyce, 2011).

Better governance drives progress toward SDG targets, including school life expectancy (Hall and O'Hare, 2023). Richards and Vining empirically demonstrated that this is also true for primary school completion. Using panel data, they showed that the quality of governance is critical, and explained the improvement in primary school completion in low-income countries at the beginning of this century. The independent variables include governance, government spending per student, parental literacy rates, and GDP per capita. Governance indicators include effectiveness, voice and accountability, and political stability. They did not include corruption in their model because it was highly correlated with government effectiveness. They found that the most important independent variable is governance, and among the three, government effectiveness is the most important. They focused on low-income countries because primary school completion is almost 100% in middle- and high-income countries; therefore, marginal gains are minimal (Richards and Vining, 2015). Others confirm this finding using student achievement and primary school completion as the dependent variables (Fomba, Talla, and Ningaye, 2023). However, both studies used a functional form that allows the level of schooling to be greater than 100%.

Given the importance of schooling for both market and non-market returns and the current limitations in the coverage of learning data, we focus on schooling. Given the critical role of the government in the provision of schooling, we aimed to answer the following research question: What impact does the GRpc and governance have on schooling? We expect to find that as GRpc increases, out-of-school rates decrease or conversely, in-school rates increase. Thus, we aimed to model the GRpc and governance in an individual country to predict the effect of an increase or decrease on educational outcomes. These findings will allow realistic modelling of losses, such as tax avoidance and debt repayment on education.

4. The data and the model

4.1. Description of the variables

4.1.1. Government revenue

We used the latest update of the Government Revenue Database (GRD). The GRD has both general and central GR; we used the latter because funding for education typically comes from central government. Data which include and exclude grants are available, and we use total general GR, excluding grants, as this variable best reflects the capacity of domestic resource mobilisation (UNU-WIDER, 2023). For the same reason, we used data that included social contributions, although these may have been incomplete. The GRD expresses all data as a percentage of the GDP taken from the World Economic Outlook (WEO) in Local Currency Units. We converted GR as a percentage of GDP into GRpc using the World Development Indicators for GDP per capita in 2015, constant USD.

We used the six Worldwide Governance Indicators: Control of Corruption, Government Effectiveness, Voice and Accountability, Political Stability, Rule of Law, and Regulatory Quality (WGI) (Kaufmann and Kraay, 2023). Each indicator is a composite score of multiple surveys, and each country is ranked on each indicator relative to the global average, which is zero and ranges from -2.5 to $+2.5$. We analysed all six indicators, and our general approach was to enter all these variables into each equation for our three schooling measures (primary, lower, and upper secondary) and then move from this general specification to a simpler one by eliminating all variables which proved insignificant. Therefore, we were able to determine which of these indicators of government quality were most relevant for each schooling indicator.

4.1.2. Schooling variable

The official age of entry and duration of schooling at each level varies by country. The global average age of official entry is 6 years. The global average theoretical duration in years is 5.8, 3.4, and 3.0, for primary, lower, and upper secondary schools, respectively (UNESCO Institute for Statistics, 2024). Our goal was to measure the impact of government revenue and governance on the proportion of children participating in schooling at the primary, lower, and upper secondary levels.

The United Nations Educational Scientific Cultural Organization (UNESCO) Institute for Statistics (UIS) and the Global Education Monitoring Report has recently begun to use a Bayesian hierarchal cohort-based model to provide estimates of out-of-school rates for all countries using administrative data and household surveys (Dharamshi et al., 2023). The out-of-school rate (SDG indicator 4.1.4) is defined as the "proportion of children and young people in the official age range for the given level of education who are not enrolled in pre-primary, primary, secondary, or higher levels of education". This model is now used by the United Nations to monitor SDG indicators 4.1.4. We employed these estimates of the proportion of children out of school at each school level in each country for our model.

4.2. The Model

In this section, we investigate the relationship between GRpc and the proportion of children in school for each school level, primary, and lower and upper secondary in each country. We used the UIS out-of-school estimates and converted them into the proportion in school by subtracting from 1. The resultant variable is still bounded between zero and 1, as shown in Figs. 1–3. A standard linear model or log-log model with constant elasticities is inappropriate for these data. Such a model suggests achieving rates above 100% for a sufficiently high GRpc which is unacceptable. It is also likely that very low-income countries would be unable to devote sufficient resources, so that, at very low levels of income, an increase in GRpc would have little effect. What we need therefore is a model with a broadly defined 'S' shape which starts with minimal effects for very low levels of GRpc and then has a period of

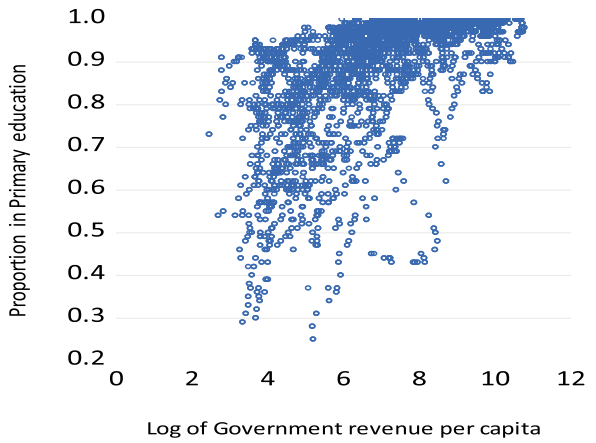

Fig. 1. The non-linear relationship between the log of government revenue per capita and the proportion of children of primary school age in primary school.

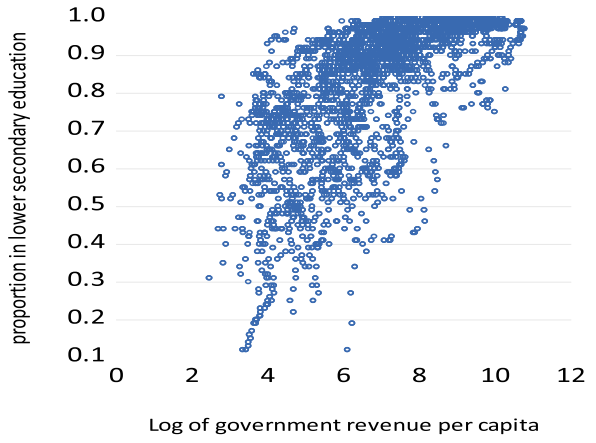

Fig. 2. The non-linear relationship between the log of government revenue per capita and the proportion of children of lower secondary school age who are in lower secondary school.

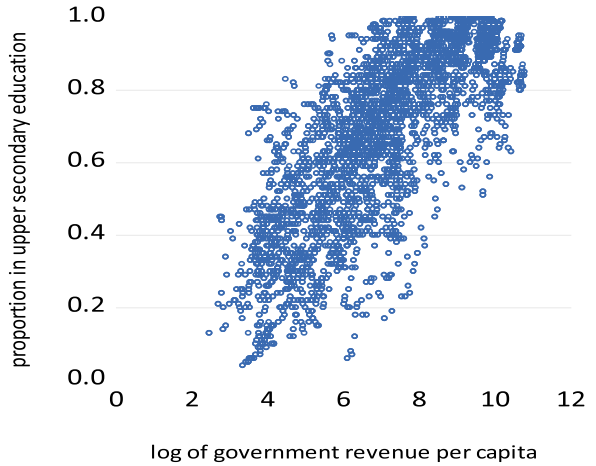

Fig. 3. The non-linear relationship between the log of government revenue per capita and the proportion of children of upper secondary school age who are in upper secondary school.

rapid growth followed by a falling off as saturation is reached. This relationship is described by a broad family of functional forms, called sigmodals. The most widely used function in this family is a logistic function. Verhulst first used this function in a series of papers, culminating in its main one in 1845. He modelled population growth in Belgium; initially, the population was stable with no real change. As development starts, the population begins to grow rapidly, but then growth slows as a saturation point is reached, and eventually, the population stabilises. This approach has been applied in many fields, including medicine, chemistry, physics, linguistics, agriculture, and economics. The basic form of the logistic function is

$$f(x) = M/(1 + e^{-\alpha(x-\beta)}) \tag{1}$$

Where M is the maximum of the curve α *and* β control the steepness and shape of the curve.

Therefore, the initial plan was to fit an unbalanced panel version of this logistic curve for the three measures of school attendance in all countries in our dataset. This model worked reasonably well, but examining the fit for individual countries, we found that it systematically overestimated low- and lower-middle-income countries. This finding suggests that the pooling assumption, that is, that the same curve can explain every country, does not hold in the data. Several options can be considered at this point. A standard approach within the panel data context is to add fixed effects to the model. However, this would violate the bounds of the logistic function, as if a country were to have a positive fixed effect and then GRpc grew to the maximum of the curve, then the total would exceed 100%. Another possibility is to add additional exogenous variables to the model in a linear manner. Again, this could involve violating the bounds of the variables. Therefore, we adapted the basic logistic model by adding a set of exogenous variables to the function itself as follows:

$$f(x) = M/(1 + e^{-((\alpha+\chi w)(x-(\beta+\delta w)))}) \tag{2}$$

Where w is a kx1 vector of exogenous variables and χ *and* δ are 1xk vectors of parameters. This allows the shape of the logistic curve to vary for each country depending on the variables in the w vector.

Another issue which must be discussed is the causal nexus between governance and government revenue. As noted above, both governance and the SDG's and government revenue are interlinked with causality running in all directions. The GRADE model allows for this, as the SDG's and governance are fully endogenous in the complete model. However, in this estimation exercise, we may carry out a valid estimation under the assumption that the governance variables are weakly exogenous in the sense of Engle, Hendry, and Richard (Engle, Hendry, and Richard, 1983). They define three forms of exogeneity: weak, strong, and super exogeneity (a simple discussion of this can be found in Asteriou and Hall (Asteriou and Stephen, 2021). Briefly, a variable Y is said to be weakly exogenous when, over time, it is affected by another variable X, but that there is no contemporaneous feedback from X to Y. A variable Y is said to be strongly exogenous when, even over a period of time, there is no effect on Y from either contemporaneous or past values of X. Moreover, variable Y is said to be super-exogenous if the parameters of the true model generating Y do not vary when X changes. If a variable such as governance is weakly exogenous, we do not need to allow for any feedback effects from government revenue or SDG indicators in the estimation, and we may treat it as an exogenous variable in the single-equation estimation. If a variable is not weakly exogenous, then consistent estimation requires either a system estimator or an instrumental variable approach. Hall and O'Hare demonstrate that while governance responds to government revenue, it does so only slowly and over a long period (Hall and O'Hare, 2023). There is no contemporary effect of government revenue on governance variables. This is entirely intuitive, as governance only changes slowly over time; hence, the governance variables are weakly exogenous, and single-equation estimation is a consistent estimation technique.

The final issue to discuss before turning to the empirical results is that we regard Eq. 2 as a long-run relationship (formerly a nonlinear cointegrating relationship; see Asteriou and Hall (Asteriou and Hall,

2021). This implies that we expect this relationship to hold over time but not instantly. For example, if a poor country was suddenly given a very high level of GRpc, it would not be able to deliver the infrastructure to deliver high-quality education instantly but would have to build this over time. This implies a process of dynamic adjustment, which we model using the following dynamic adjustment equation:

$$Y_{it} = Y_{it-1} + \phi_1 + \phi_2(Y_{it-1} - \widehat{Y}_{it-1}) + \phi_3(Y_{it-1} - Y_{it-2}) + \varepsilon_{it} \quad (3)$$

where Y_{it} is one of the three indicators of education for country i in period t, $\widehat{Y}_{it}$ is the fitted value from Eq. 2 for that indicator, and $\varepsilon_{it}$is a standard error term $N(0, \sigma^2)$. This is a simple form of an equilibrium correction model (ECM) which states that the change in the dependent variable is a function of the change in the last period and the discrepancy between where it was in the last period and the long-run equilibrium it should be moving towards. For stability, we require that ϕ_2 should be negative and bigger than -1, which implies we are moving towards the long run equilibrium.

5. The results

We can see in Figs. 1–3, a clear positive relationship between the various measures of school attendance and the log of GRpc. The upper bound of 1 is very clear, and thus, a linear relationship between these two would not be sensible as an estimation strategy.

Table 1 presents the results of estimating Eq. 2 for each indicator of school attendance. Each column of the tables provides the parameters set out in Eq. 2. α *and* $\beta$are the two basic parameters of the logistic function, and after each of these we show the governance indicators which modify the shape of the logistic curve for each individual country. Overall, all three models seem to work well and have a high explanatory power.

Table 2 provides details of the dynamic model (Eq. 3) for each indicator. The parameter which governs the stability of the equation (ϕ_2) is in all cases negative and significant as required. The effect of the lagged change (ϕ_3) is mostly quite large and highly significant. The R^2 is very high, indicating a very good fit, and the DW statistic clearly showed no sign of serial correlation in the errors. As expected, these results suggest that it takes several years to adjust these indicators to their equilibrium values after a change in GRpc.

Table 1
The results for the logistic model for each learning indicator.

		Primary school	Lower secondary school	Upper secondary school
α		0.59(23.6)	0.67(27.9)	0.47(36.4)
χ	Control of Corruption	0.12(6.2)	0.11(3.8)	-0.02(2.1)
	Political Stability	0.12(9.3)	-	-0.0000002(3.7)
	Regulatory Quality	-0.04(2.9)	-	-
	Rule of Law	-	-0.07(1.9)	-
	Government Effectiveness	-	0.22(7.1)	-0.0000004(4.8)
	Voice and Accountability	-	0.1(6.8)	0.000000(6.3)
β		5.2(87.9)	3.9(35.9)	-28011.9(7.5)
δ	Control of Corruption	0.24(3.3)	0.75(4.7)	-5385.6(3.6)
	Political Stability	-0.15(2.8)	-0.25(4.2)	-5740.5(5.0)
	Regulatory Quality	-	0.1(0.9)	-
	Rule of Law	-	-0.5(2.3)	8537.9(4.6)
	Government Effectiveness	-	0.7(3.2)	-17828.9(4.6)
	Voice and Accountability	-0.29(5.4))	0.5(4.8)	-
R^2		0.64	0.56	0.54

't' statistics in parenthesis

Table 2
The dynamic models for each learning indicator.

	Primary school	Lower secondary school	Upper secondary school
ϕ_1	0.0008(6.8)	0.002(8.8)	0.003(8.9)
ϕ_2	-0.04(15.0)	-0.07(17.6)	-0.09(19.9)
ϕ_3	0.6(44.5)	0.59(42.7)	0.6(38.9)
R^2	0.64	0.57	0.48
DW	2.3	2.1	1.96

5.1. The shape of the curves and the importance of governance

The estimates presented above seem reasonably satisfactory, but it is difficult to obtain a clear understanding of exactly what is going on purely from these estimates. This is partly because we have many countries and every country will be different, and space constraints make it impossible to show the behaviour of each country individually. Therefore, to help understand both the importance of governance effects and that of GRpc, we conducted a simple set of experiments. We begin by setting all governance indicators to -1, which is generally a poor level of governance. We then calculate the long-run relationship between revenue and the three measures of education. We then reset all governance indicators to zero, the midpoint of the range, and calculated the relationship between GRpc and the in-school proportion for primary, lower, and upper secondary school education. We then conducted a further experiment in which we set all governance indicators to $+1$. We do not go all the way to setting the governance indicators at $+2.5$, as we recognise that this is a highly unrealistic goal. We then graphed each set of relationships to observe the effect of an improvement in both governance and revenue. Figs. 4–6 shows the graphs for this experiment for primary, lower secondary, and upper secondary education for GRpc between 40–100 in real US$ at 2015 prices.

6. Discussion

We set out to answer the following question: What impact does GRpc and governance have on the proportion of children in school (SDG 4.1.2), expecting that as GRpc and governance increase, in-school rates will increase. We aimed to establish a model to predict the effect of an increase or decrease in GRpc on governance and in-school rates in individual countries.

6.1. Key findings

We found that an increased GRpc is associated with an increase in in-school rates and that the size of this influence is mediated by the governance indicators in each country. This model provides a unique ability to realistically predict the impact of increases and decreases in GRpc at the country level, while controlling for the quality of governance. The results answer our research question and are in line with our

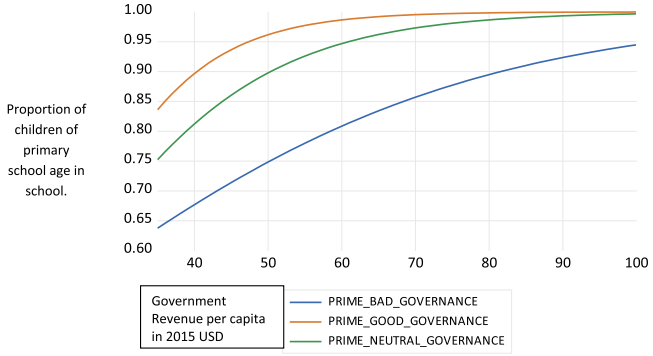

Fig. 4. The effect of governance and revenue per capita in 2015 USD on the in-school rate of primary school age children.

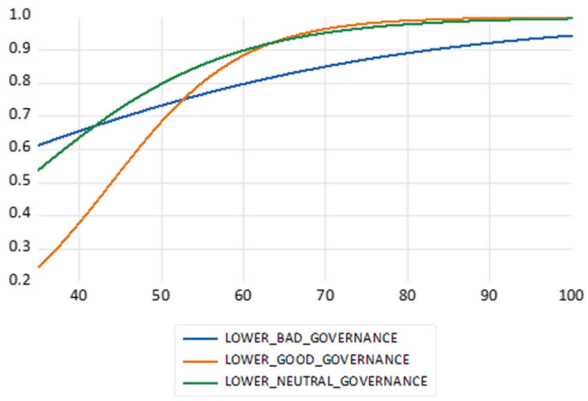

Fig. 5. The effect of governance and revenue per capita in 2015 USD on the in-school rate of lower secondary school age children.

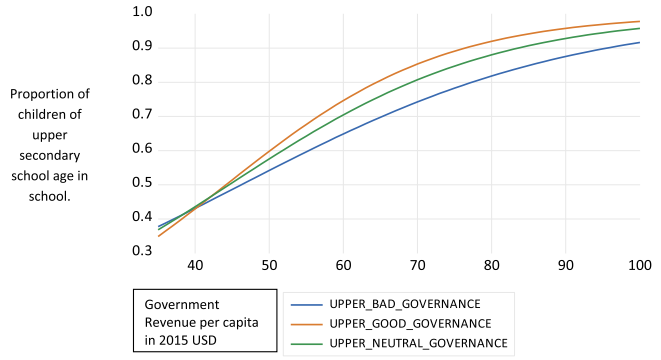

Fig. 6. The effect of governance and revenue per capita in 2015 USD on the in-school rate of upper secondary school age children.

hypothesis that, as GRpc and governance improve, more children attend school. Additionally, the influence of governance is more critical for primary schools than for lower or upper secondary school attendance. To our knowledge, no researchers have studied the impact of government revenues on governance and school attendance. Furthermore, this study is novel from the perspective of the choice of variables used for revenue or spending, and schooling, the levels of education included, the model used, the income level of the countries, and the potential practical use of the models.

6.2. Limitations

The main limitation of this research is data availability; however, using UIS and the Global Education Monitoring Report data which have been modelled from out-of-school estimates using administrative data and household surveys to derive in-school rates, has improved our data on education. Educational attainment is a function of both schooling and learning, and future research could model the impact of GRpc on learning.

6.3. Interpretation in relation to relevant publications

6.3.1. Revenue or spending indicator

Our findings are consistent with those of Rajkumar and Swaroop, who interacted a public spending variable with a governance indicator to study the effects of public spending on schooling and found that spending in countries with good governance improved schooling (measured as primary school completion). By contrast, spending in poorly governed countries has virtually no impact (Rajkumar and Swaroop, 2008). However, rather than GRpc, they use primary education spending (ln of the share of GDP), which indicates the priority which a given government places on schooling, whereas an absolute amount such as GRpc depends on the size of the budget and GDP. Fomba et al. also used government spending as a percentage of the government budget, again indicating priority (Fomba et al., 2023). Vining and Richards used spending per pupil, allowing modelling of the impact of governance, and found it to be the most important determinant of schooling (measured as primary school completion) (Richards and Vining, 2015). The use of GRpc allows us to model the impact of global and national factors on GRpc and on schooling,whereas global factors are less likely to influence government spending. The realistic estimates of the impact of losses from GR, for example, due to debt services or tax abuse on a child's schooling at the individual country level, can be used by advocates and policymakers.

6.3.2. Schooling indicator

We employ new data from the UIS and the Global Education Monitoring Report to produce estimates of the proportion of children who are in school, and because it is modelled, the data are available for more years. In addition, other studies using primary school completion do not provide information about children who attend primary school, but do not complete it (Fomba, Talla, and Ningaye, 2023; Richards and Vining, 2015; Rajkumar and Swaroop, 2008). As we have seen, schooling, even without completion, has significant market and non-market benefits to individuals and society (Centre for Global Development, 2022).

This work also builds on previous research, which used only primary schooling, whereas we included primary, lower, and upper secondary schooling and demonstrated the difference in the importance of governance at different levels.

6.3.3. The model

Previous research has used a functional form that would allow the level of school attendance to exceed 100% (Richards and Vining, 2015; Fomba, Talla, and Ningaye, 2023), whereas we used a sigmoidal form that reached a plateau at 100%, as the proportion of children in school cannot exceed this value, and we model the long-run impact of additional revenue on governance. In addition, we modelled for all countries and not just low-income countries.

6.4. Concluding summary

We found that increased GRpc was associated with increased schooling, and the magnitude of this influence was mediated significantly by a country's quality of governance. This model offers the ability to predict the impact of increases and decreases in GR in an individual country while accounting for governance and the long-run impact of revenue on governance. The online visualisation based on this model[1] uses school-age populations from UIS in each country to provide realistic predictions of the additional number of children who will attend school if governments have additional revenue.[2] This is a valuable addition to the armamentarium for those who advocate for reduced losses from government revenue.

Disclosures

During the preparation of this study, we used Open Paperpal software to edit the manuscript. The author reviewed and edited the content

[1] This online tool is called Government Revenue and Development Estimations (GRADE) https://medicine.st-andrews.ac.uk/grade/ (O'Hare, Murray, and Hall 2024).

[2] UIS defines school-age population as the number of persons at the age defined in a country's regulations or laws to attend a given grade or level of education in that country. This number is determined based on the official entrance age and duration of a specific grade or level of education.

as needed and took full responsibility for the final content.

CRediT authorship contribution statement

Bernadette Ann-Marie O'Hare: Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Data curation, Conceptualization. **Stephen G Hall:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no conflict of interests.

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