Does institutional quality lower the effect of education spending on growth? *

William Blankenau† and Jehu Mette‡

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Abstract

We evaluate the interaction of institutional quality (quality) and government education spending (spending) in generating growth. To motivate our empirical investigation, we develop an endogenous growth model where spending affects growth through two channels. First, it is an input in human capital accumulation. Second, spending interacts directly with quality to determine total factor productivity. The model suggests a growth regression including quality, spending, and their interaction as explanatory variables. The coefficient on the interaction term is never found to be significantly positive and is negative and significant in most cases. This suggests that the marginal growth effect of spending is often lower when quality is higher. Results are generally robust to controlling for the government budget constraint, additional controls, and a variety of quality measures.

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†Department of Economics, Kansas State University, 327 Waters Hall, 1603 Old Claflin Place, Manhattan, KS 66506. Email: blankenw@ksu.edu. Phone: 785-532-6340.

‡David D. Reh School of Business, Clarkson University, 8 Clarkson Avenue, Potsdam, NY 13699. Email: jmette@clarkson.edu, Phone: 785-770-6956.

1 Introduction

Countries with higher quality institutions grow faster. This intuitive notion is supported by many empirical investigations.[1] Figure 1 below shows supporting evidence. This is a plot of institutional quality (quality), as measured by average protection from expropriation, against 10-year average growth rates of per capita real gross domestic product (GDP) for groups of high-income, middle-income, and low-income countries.[2] The positive slope of the best-fit line in each case demonstrates a positive relationship.

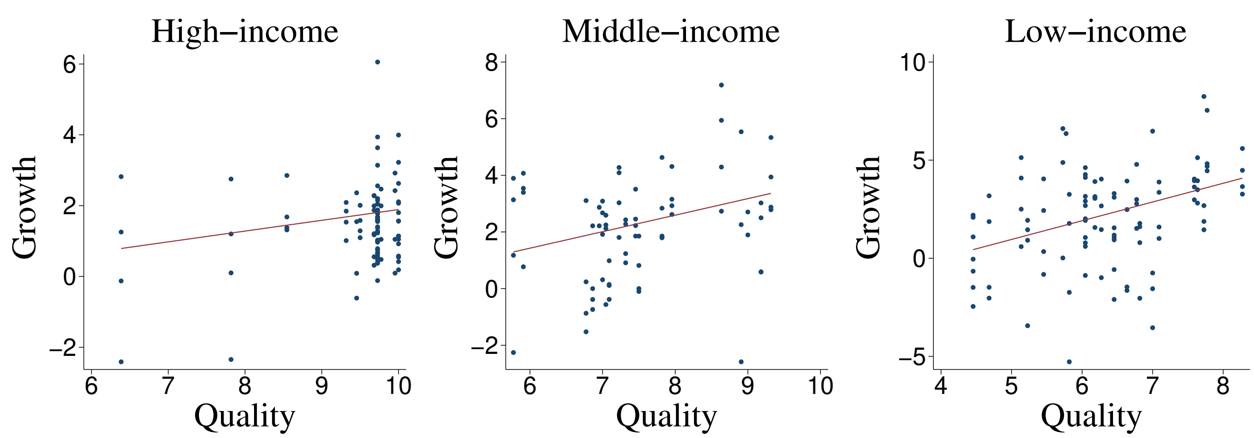

Figure 1: Institutional quality and growth. Growth is the 10-year average growth rate of real per capita GDP for four periods beginning with 1980-89. Institutional quality is average protection from expropriation from 1985-95 as in Acemoglu et al. (2001).

In the class of 'AK' endogenous growth models with K defined narrowly as physical capital, it is natural to consider quality as having a positive effect on A directly and on K only indirectly. For example, quality institutions may create an environment where capital can more freely seek its highest value use. A higher value use of capital translates easily to a larger value of A. While growth ultimately results from capital accumulation, a larger value of A motivates more rapid capital accumulation and is the root cause of the quality/growth relationship.

Countries with more government education spending (spending) may also grow faster. We hedge this statement on both empirical and theoretical grounds. On the empirical side, some researchers find

[1] North and Thomas (1973), Hall and Jones (1999), Acemoglu et al. (2001), Acemoglu et al. (2005) and Hall et al. (2010) are part of a large and growing literature that examines the importance of institutions in economic development.

[2] Details of country inclusion are available in Appendix A.

a relationship between spending and growth while others do not. On the theoretical side, the spending/growth relationship is often positive in available models, but with caveats. For example, public spending may simply crowd out private spending. Even if education spending does generate growth, the relationship is not generally monotonic. If distortionary taxes fund education, these distortions may counter, and even dominate, the positive effects of spending.

Figure 2 shows the relationship between lagged government education spending and growth for the same country groups as Figure 1. The slight positive slope of the best-fit line in the first panel reflects a small, positive correlation for high-income countries, while the correlations are negative for middle-income and low-income countries. In fully specified econometric models, the effect of spending on growth is typically more positive than indicated by Figure 2. The meta-analysis by Churchill et al. (2017) shows a positive effect of spending on growth for developed countries and no statistically significant effect for low-income counties.

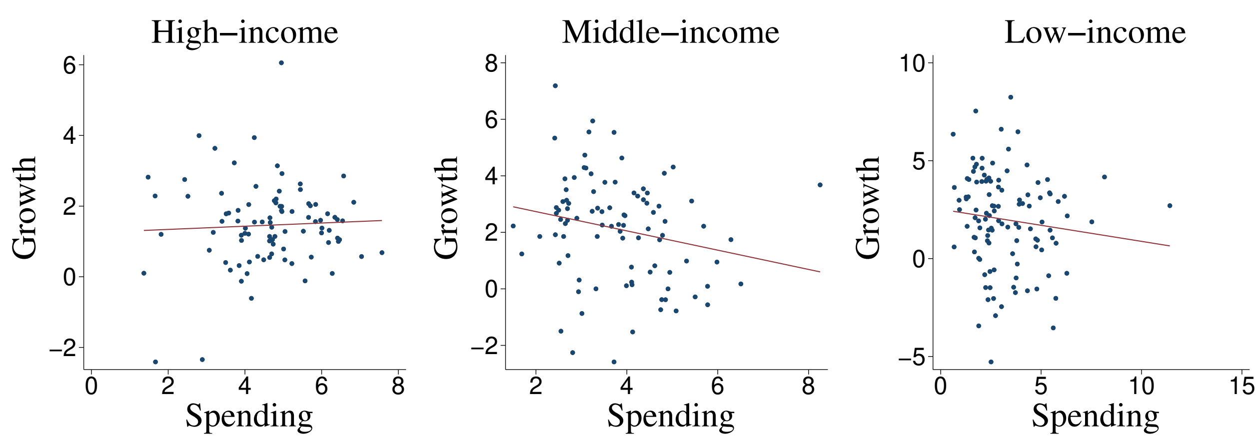

Figure 2: Government education spending and growth. Growth is the 10-year average growth rate of real per capita GDP for four periods beginning with 1980-89. Spending is the average ratio of government education spending to GDP in the preceding 10-year period.

All told, government education spending is a plausible driver of growth. In AK growth models, spending can operate through a different channel than institutional quality. The model developed in this paper makes use of the common notion that government education spending is an input in human capital accumulation. With K defined broadly to include both human and physical capital, government education spending works directly through the K channel, rather than the A channel.

Higher spending also leads indirectly to more rapid physical capital accumulation through its effect on the marginal product of capital. However, its direct impact on K through human capital is the root cause of the spending/growth relationship.

In this paper, we build a simple overlapping generations AK growth model with both human capital and physical capital comprising K. Quality and spending work through A and K as indicated above. The model is consistent with Figures 1 and 2; it predicts a positive quality/growth relationship and an ambiguous spending/growth relationship when only these two channels are included. However, we assign an additional role to education spending. While retaining its role through K, spending also has a role through A. The idea is that the average ability of the workforce might directly influence total factor productivity. The model yields a growth regression with quality, spending, and their interaction as explanatory variables.

We might expect quality and spending to reinforce each other, as would be indicated by a positive coefficient on the interaction term. Higher spending may have a greater growth impact when the resulting human capital operates in a more productive environment; i.e. with superior institutions. Similarly, superior institutions may have a greater growth impact when the resulting superior productivity is applied to a larger stock of human capital; i.e. when spending is higher.

The data, however, generally tell a different story. The focus in the empirical part of our paper is on four regressions, each with the 10-year growth rate as the dependent variable. In the first and second regressions, the only explanatory variables are quality and spending. As these correspond to Figures 1 and 2, it is unsurprising that quality is generally found to have a positive coefficient while education has a coefficient which is either close to zero or negative. With both included, results broadly align with the results of the previous regressions. However, a key empirical result is that when we include the interaction term, its coefficient is typically negative. There is some variability in the results but this coefficient is never found to be significantly positive and is negative and significant in most cases.

This can be understood in the context of our model. The additional role assigned to education is similar to the role played by quality as both work through A. With quality and education spending playing similar roles through total factor productivity, it is plausible that more of one diminishes the importance of the other in enhancing growth. For example, we can think of good institutions as removing barriers to efficient activity and human capital as useful in navigating remaining barriers. Human capital may be less important with fewer barriers, and removing barriers may be less important when they are more easily navigated.

Quality, arguably, has deep historical roots and is slow to change (Acemoglu et al. (2001)). This makes spending the more relevant policy consideration. As such, in our discussion of the results, we focus on the marginal growth effect of spending at different levels of quality. In our baseline regression we find that for high-income, middle-income and low-income countries, as well as for the set of all countries, the marginal growth effect of spending decreases with quality. For high-income counties, the marginal effect is positive for lower levels of quality and insignificant at high levels of quality. For other sets of countries, the marginal effect is insignificant at low levels of quality and becomes negative at high levels of quality.

Section 2 presents the model. Section 3 develops an empirical methodology for testing some implications of the model and provides results for our baseline regression. Section 4 considers robustness. The first two subsections consider additional controls suggested by the model and the third considers alternative measures of quality. Section 5 summarizes the paper and suggests direction for further investigation.

2 Model

In this section, we build an endogenous growth model to motivate our empirical methodology. The model economy is populated by overlapping generations of homogeneous agents. We consider a representative agent for each generation and normalize the population to one. Each agent lives three periods and is, in turn, a learner, an earner, and a retiree. A representative firm produces the unique final good, and a government imposes taxes to fund education spending and other spending which we model as unproductive. The model is constructed to produce a closed-form solution leading to a growth equation which we later estimate.

The model is most similar to that of Blankenau et al. (2007) and can be seen as generalizing the final goods production function presented there. Antecedents to that paper, in turn, include Glomm and Ravikumar (1992, 1997), Kaganovich and Zilcha (1999), Blankenau and Simpson (2004), and Cassou and Lansing (2006). As the key modeling innovation relative to Blankenau et al. (2007) is in the final goods production function, we begin with a discussion of output.

2.1 Output

Output, Y_t, is produced competitively by a representative firm as a Cobb-Douglas combination of physical capital, $K_{p,t}$, and human capital, $H_t(e_{t-1}, \cdot)$, with share parameter $0 > \alpha > 1$ and productivity scalar $A_t\left(q, e_{t-1}\right)$. Human capital is a function of lagged government education spending as a share of output, e_{t-1}, and other items discussed below. Note that e_{t-1} is spending on period t earners since they were the learners in period $t-1$. Thus the human capital effect of spending arrives with a one period delay. The productivity scalar is a function of both spending and institutional quality, q. We use a fixed measure of q in keeping both with data availability for our primary quality measure and with the notion of persistence in institutional quality (Acemoglu et al. (2001)).

More specifically, the production function is

$$Y_t = A_t\left(\cdot\right) K_{p,t}^{\alpha}(H_t(\cdot))^{1-\alpha}. \tag{1}$$

Both forms of capital are reproducible, so that production is linear in capital, broadly defined. We define this as $K_t \equiv K_{p,t}^{\alpha} H_t^{1-\alpha}(\cdot)$ to allow the AK specification

$$Y_t = A_t\left(\cdot\right) K_t(\cdot). \tag{2}$$

Equation (2) expresses the key point of departure of our model from otherwise similar AK models. A number of papers model education spending as an input to K.[3] We allow for this as well, but spending additionally has a direct impact on productivity.[4] Since institutional quality also affects productivity, this allows that the quantity of one productivity determinant (q or e_{t-1}) may influence the marginal

[3]Examples include papers mentioned in the section introduction and additionally Glomm and Kaganovich (2008), Agénor (2011), Arcalean and Schiopu (2010), Viaene and Zilcha (2013), and Schiopu (2015).

[4]The notion that the education level can have a level effect on productivity reaches as far back as Nelson and Phelps (1966), though they do not model the education level as a function of education spending.

impact of the other. To capture this succinctly, we set

$$A_t(\cdot) \equiv \exp\left(\chi_1 q + \chi_2 e_{t-1} + \chi_3 q e_{t-1}\right). \tag{3}$$

Institutional quality has both a direct productivity effect equal to $\exp(\chi_1 q)$ at $e_{t-1} = 0$ and an additional effect through its interaction with e_{t-1}. Similarly, education has both a direct productivity effect equal to $\exp(\chi_2 e_{t-1})$ at $q = 0$ and an additional effect through its interaction with q.

2.2 Human capital

A period t learner receives an endowment of public education inputs given by E_t. The public input depends on both the share of current output spent by government on education, e_t, and on output itself, Y_t. As in Blankenau et al. (2007), this is not the simple product of these items but rather:

$$E_t = \exp(e_t) Y_t. \tag{4}$$

There are several motivations for this specification. On the empirical side, it leads to a simple functional form and reasonable results for our growth regression. On the modeling side, it allows for positive output absent public education expenditures while keeping a close tie between the size of the education sector and educational inputs.[5] Period t public inputs combine with the human capital of period t workers to provide a period $t+1$ endowment of human capital to period t learners according to

$$H_{t+1} = B E_t^{\mu} H_t^{1-\mu} \tag{5}$$

where $\mu \in [0, 1]$ determines the relative importance of inputs in the formation of human capital and $B > 0$ is a productivity scalar.

[5] If Equation (4) were instead $E_t = e_t Y_t$, we would have zero output and growth with $e_t = 0$. In contrast, the analysis below shows that the current specification allows output and growth with $e_t = 0$.

2.3 Agents, factor markets, and government

In period t, learners passively receive the human capital endowment and make no economic decisions. Retirees pay taxes at rate τ_t on the proceeds of period $t-1$ savings and consume the remainder. For period t workers (born in period $t-1$) consumption as workers and as retirees are defined as $C_{t-1,t}$ and $C_{t-1,t+1}$. Utility is given by

$$\ln C_{t-1,t} + \beta \ln C_{t-1,t+1}$$

with $0 < \beta < 1$. Earners inelastically supply their human capital endowment, receiving wage w_t per unit of human capital. This income is taxed at rate τ_t and the remainder is allocated across consumption and savings. An agent's savings in period t transforms to capital holdings in period $t+1$ which is rented to firms at rate r_{t+1} and then fully depreciates. It is straightforward to show that optimal saving for a period t worker, $s_t = K_{p,t+1}$, is[6]

$$K_{p,t+1} = \frac{\beta}{\beta+1} w_t H_t (1-\tau_t). \tag{6}$$

Let k_t be the ratio of physical capital to human capital. Then with competitive factor markets we have

$$\begin{aligned} r_t &= A(\cdot)\,\alpha k_t^{\alpha-1} \\ w_t &= A(\cdot)\,(1-\alpha)\,k_t^{\alpha}. \end{aligned} \tag{7}$$

Government spends a share e_t of output on public education expenditures and an additional share, g_t, on items other than education which have no impact on productivity. Expenditures are financed through taxes on labor and capital income at rate τ_t. Revenues and expenditures must balance in each period so the government budget constraint is

$$\tau_t(w_t + r_t k_t) = (e_t + g_t) A(\cdot)\, k_t^{\alpha}. \tag{8}$$

[6] Details of the model solution are available in an unpublished appendix available from the authors.

2.4 Equilibrium and balanced growth path

In an equilibrium, each worker optimally chooses savings and two periods of consumption taking factor prices and taxes as given resulting in Equation (6). The representative firm maximizes profits takings factor and output prices as given yielding Equations (7). Government spending satisfies Equation (8). The factors of production evolve according to Equations (5) and (6). Market clearing requires that the firm hires the full stock of each input and that output is either transformed to period $t+1$ capital or consumed by period t workers and retirees.

Moving forward, we consider only the balanced growth path where k_t, factor prices, and policy instruments are constant while human capital and output grow at the same constant rate. As such, we define $\frac{Y_{t+1}}{Y_t} = \frac{H_{t+1}}{H_t} \equiv 1+\gamma$ and drop time subscripts elsewhere. To solve for growth in this setting, we put Equations (1) and (4) into Equation (5) and rearrange to arrive at

$$1+\gamma = (A(\cdot))^{\mu} B \exp(\mu e) k^{\alpha\mu}.$$

Then rearranging Equation (6) and the expression for wages gives

$$k = \left(\frac{1}{1+\gamma} \frac{\beta}{\beta+1} A(\cdot)(1-\alpha)(1-\tau) \right)^{\frac{1}{1-\alpha}}.$$

Together with Equation (3) and defining

$$\begin{aligned}
\Lambda &\equiv \frac{\mu}{1-\alpha(1-\mu)} \\
\lambda_0 &\equiv \Lambda \ln \left(B^{\frac{1-\alpha}{\alpha\mu}} \frac{\beta(1-\alpha)(1-\tau)}{\beta+1} \right)^{\alpha} \\
\lambda_1 &\equiv \Lambda \chi_1 \\
\lambda_2 &\equiv \Lambda (1-\alpha+\chi_2) \\
\lambda_3 &\equiv \Lambda \chi_3
\end{aligned}$$

we arrive at

$$1+\gamma=\exp\left(\lambda_0\right)\exp\left(\lambda_1 q+\lambda_2 e+\lambda_3 qe\right). \tag{9}$$

Note that $\Lambda>0$ scales the λ values.

Using $\ln\left(1+\gamma\right)\approx\gamma$ and taking the log of each side, from Equation (9) we arrive at

$$\gamma=\lambda_0+\lambda_1 q+\lambda_2 e+\lambda_3 qe. \tag{10}$$

We will develop Equation (10) as our baseline model in the empirical investigation. However, this expression relegates taxation to an item in the constant. With the approximation $\ln\left(1-\tau\right)\approx-\tau$, we can alternatively extract $\lambda_4\tau$ from the constant where λ_4 = -$\Lambda\alpha$ yielding

$$\gamma=\lambda_0+\lambda_1 q+\lambda_2 e+\lambda_3 qe+\lambda_4\tau. \tag{11}$$

We make two additional points regarding taxation. First, the government budget constraint in Equation (8) reduces to $\tau=e+g$ making explicit the relationship between taxes and expenditures. In this case, Equation (11) becomes

$$\gamma=\lambda_0+\lambda_1 q+\left(\lambda_2+\lambda_4\right)e+\lambda_3 qe+\lambda_4 g. \tag{12}$$

That is, we can simply reinterpret the coefficient on e to include the distortionary impact of the requisite taxation as well as its impact through A and K. Note in this case, g enters the expression. Given our definition of λ_4, we anticipate that a larger g would decrease growth. This is because such expenditures have no direct growth effect but require a larger distortionary tax.

Finally, we note that due to these distortionary effects, the impact of education spending may not be monotonic. Replacing τ with $e+g$ in Equation (9), for fixed g, growth is maximized at

$$e=e^*=1-g+\frac{\lambda_4}{\lambda_2+\lambda_3 q} \tag{13}$$

if $0<e^*<1$, at $e=0$ if $e^*<0$ and at $e=1$ if $e^*>1$. It is straightforward to show that parameters exist where $0 < e^* < 1$. Consider this case. Then with sufficiently high spending ($e > e^*$), the negative distortionary effects of taxation will dominate the positive growth effects of spending. The approximation methodology used to derive Equation (10) from Equation (9) makes growth monotonic in e. We reintroduce the possibility of a non-monotonic relationship between e and γ suggested by Equation (13) by including spending squared such that

$$\gamma = \lambda_0 + \lambda_1 q + \lambda_2 e + \lambda_3 qe + \lambda_4 g + \lambda_5 e^2. \tag{14}$$

3 Empirical methodology and baseline results

We now turn to our empirical investigation. In this section, we begin by developing a baseline empirical model based on our theoretical model. We then discuss the relevant data and results. In the subsequent section, we conduct a sensitivity analysis which considers budgetary constraints, additional control variables, and alternative measures of institutional quality.

3.1 Baseline model

Our baseline empirical model is motivated by Equation (10). The equation suggests that in a panel data set of countries, growth rates should be influenced by institutional quality, government education spending, and their interaction. As such, we specify the following empirical model

$$\gamma_{n,t} = \beta_0 + \beta_1 q_n + \beta_2 e_{n,t-1} + \beta_3 q_n e_{t-1} + \delta_t + u_{n,t}. \tag{15}$$

Here $\gamma_{n,t}$ is the growth rate in per capita real GDP from period $t-1$ to t for country n. Each $\beta_i \in \{0, 1, 2, 3\}$ is the empirical counterpart to λ_i. We denote the time invariant institutional quality measure for nation n by q_n. Education spending as a share of gross domestic product is represented by $e_{n,t-1}$. The lag on this measure has two motivations. First, though obscured by considering only balanced growth, this is suggested by our model. See, for example, Equation (2). Second, lagged values are often used in such regressions to control for endogeneity.[7]

We control for time fixed effects through δ_t. With a fixed measure of institutional quality, country fixed effects are not feasible. Finally, we account for the stochastic nature of the growth process by including an independent and identically distributed error term $u_{n,t}$. We conduct this baseline investigation for four sets of countries: high-income, middle-income, low-income, and all countries. These groups are presented in Appendix A.

3.2 Baseline regression data

For our baseline regression we need a measure of the growth rate of real GDP per capita, a measure of institutional quality, and a measure of education spending as a share of GDP. Data on real GPD comes from version 10 of Penn World Table (PWT10). As suggested by Feenstra et al. (2015) and Deaton (2005) we measure real GDP from national accounts expressed in 2017 U.S. dollars. We divide by population to put GDP in per capita terms.[8] The growth rate over a period is the difference between the log of real GDP per capita at the end of a period and the beginning of a period divided by the number of years in a period. We take a time period to be ten years in our regressions. Both five- and ten-year periods are common in the literature.[9] However, growth stems in part from human capital accumulation in our model. As both intuition and investigation suggest, education spending should affect human capital with a considerable lag (Atems and Blankenau, 2021). This makes the longer time period appropriate for our investigation.

Our baseline measure of institutional quality is the same measure used by Acemoglu et al. (2001) as their main variable in exploring the relationship between institutional quality and output. Their data comes from Political Risk Services and is the average score for protection against appropriation over the period 1985 to 1995. This index varies between 0 and 10 with higher values associated with higher quality institutions. Data on education expenditure is expressed as a percent of GDP and comes from the World Development Indicators (WDI). The measure includes education expenditures at the

[7] Caselli et al. (1996) and Blankenau et al. (2007) are examples of similar studies that use this same approach.

[8] We use the PWT10 variables $RGDP^{NA}$ and POP for real GDP and its adjustment to per capita values.

[9] For example, Fortunato and Panizza (2015) and Kotschy and Sunde (2017), Brueckner and Lederman (2018) use five-year periods in their analyses while Barro (1997) and Barro (1999) use ten-year periods.

local, regional and central government levels and includes current expenditures, capital expenditures, and transfers.[10]

We use data for the ten-year periods of 1969-79 through 2009-2019. This is five time periods. However, since we use lagged values of education expenditures, we can have only four observations at most for each country. We have at least one period of data for 71 countries. For most of our analysis we break countries into high-, middle-, and low-income groups with 23, 19, and 27 countries in the various groups. See Appendix A for details.

Data on growth, quality, and spending are presented in Figures 1 and 2. We note that institutional quality is unchanged through time. This explains why measured institutional quality appears to clump together. For example, consider that there are four observations at the lowest measure of institutional quality in the first panel of Figure 1. This represents four decadal growth rates for a single country.

Table 1: Descriptive statistics for the baseline regression

Variables	High-income	Middle-income	Low-income	All
Growth rate	1.72	2.41	2.14	2.10
	(1.27)	(2.18)	(2.68)	(2.19)
Institutional quality	9.46	7.56	6.28	7.69
	(0.81)	(1.01)	(1.00)	(1.65)
Education spending	4.64	3.81	3.52	3.95
	(1.29)	(1.17)	(3.23)	(2.27)
Countries	23	19	27	69

Notes: Growth is the average of the 10-year growth rate. Institutional quality is the average score for protection against expropriation over the period 1985 to 1995. Education expenditures are in terms of percent of GDP. Standard deviations are in parentheses.

Summary statistics for this data are given in Table 1. The first row shows the average of the 10-year annualized growth rates in real GDP per capita. For high-income and middle-income countries, this average is 1.72% and 2.41% respectively. Low-income countries have grown less rapidly than

[10] See World Development Indicators for details.

middle-income countries, averaging 2.14% and the average across all countries is 2.10%. The second row shows institutional quality as measured by protection against appropriation over the period 1985 to 1995. The index is between 0 (lowest quality) and 10 (highest quality). This is highest for high-income countries at 9.46 and lowest for low-income countries at 6.28. The third row shows average education spending as a share of output. This is again highest for high-income countries at 4.64% and lowest for low-income countries at 3.52%.

3.3 Baseline results

In this subsection, we present our baseline results. For each country group, we have estimated three restricted versions of Equation (15) as well as the unrestricted model. Table (2) organizes these results for each country group. In each case, column (1) restricts $\beta_2 = \beta_3 = 0$, column (2) restricts $\beta_1 = \beta_3 = 0$, column (3) restricts $\beta_3 = 0$ and column (4) shows results from the unrestricted model. In each regression, clustering is done at the country level.

As outlined in the introduction, our discussion of the results focuses on how quality influences the marginal growth effect of spending rather than how spending influences the marginal growth effect of quality. We begin this discussion by considering the unrestricted model (column (4)) and highlighting a result which is robust across these regressions and across all of the sensitivity analysis in the following section: the marginal growth effect of spending does not increase with quality. One might expect spending to have a greater growth impact when workers enjoy quality institutions. We robustly reject this notion. Throughout Table 2 and our later sensitivity analysis, we find no significantly positive estimate of β_3.

We find, instead, considerable evidence that β_3 is negative; the marginal effect of spending falls with quality. In all country groups, the estimate of β_3 is negative and in most cases is statistically significantly different from 0 at the 1% or 5% level. This finding is consistent with our theoretical model where a dual role is assigned to education spending. The second role of education spending is similar to the role played by quality. The model highlights the possibility that quality might diminish the importance of spending in generating growth. Our empirical results are supportive of this possibility.

Table 2: Baseline results

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	High-income				Middle-income			
Quality	0.35***		0.33***	0.87***	0.49		0.45	1.72**
	(0.08)		(0.11)	(0.18)	(0.31)		(0.29)	(0.71)
Spending		0.06	0.04	1.66***		-0.23	-0.41*	2.33
		(0.09)	(0.07)	(0.29)		(0.40)	(0.20)	(1.55)
Qual*Sp				-0.17***				-0.37
				(0.04)				(0.22)
Observations	92	92	92	92	71	71	71	71
R-squared	0.31	0.51	0.31	0.34	0.11	0.52	0.16	0.19
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	Low-income				All			
Quality	0.90***		0.91***	1.83***	0.14		0.13	0.73***
	(0.25)		(0.24)	(0.53)	(0.10)		(0.10)	(0.25)
Spending		-0.17***	-0.15**	1.73**		-0.15***	-0.18**	0.73**
		(0.04)	(0.07)	(0.84)		(0.04)	(0.08)	(0.28)
Qual*Sp				-0.31**				-0.14***
				(0.14)				(0.04)
Observations	103	102	103	103	320	298	266	266
R-squared	0.22	0.54	0.26	0.29	0.05	0.45	0.05	0.09

Notes: The dependent variable is the average 10-year growth rate of real GDP per capita. Quality is averaged between 1985 and 1995. Spending is expressed as a percentage of GDP. As quality is fixed, we include time fixed effects but not country fixed effects. Column (2) has a larger R-squared because the absence of quality allows for country fixed effects. Clustering is done at the country level. Asterisks indicate significance at the 10% (*), 5% (**) and 1% (***) levels.

We next turn to the full set of results for high-income countries. The first column of Table 2 for high-income countries shows the common result that institutional quality is associated with higher growth when we do not control for education. The second column shows that when we do not account for institutional quality, the coefficient on education is positive, though insignificant. As mentioned above, this is consistent with some of the growth literature. The third column includes both institutional quality and education spending and confirms the findings from columns (1) and (2); institutional quality matters for growth while education spending does not.

The unconstrained model in column (4) tells a more nuanced story. Here we see that the coefficients on institutional quality and education spending are both positive and the interaction term is negative. Each is significant at the 1% level. As such, we cannot consider the effect of spending without reference to quality.

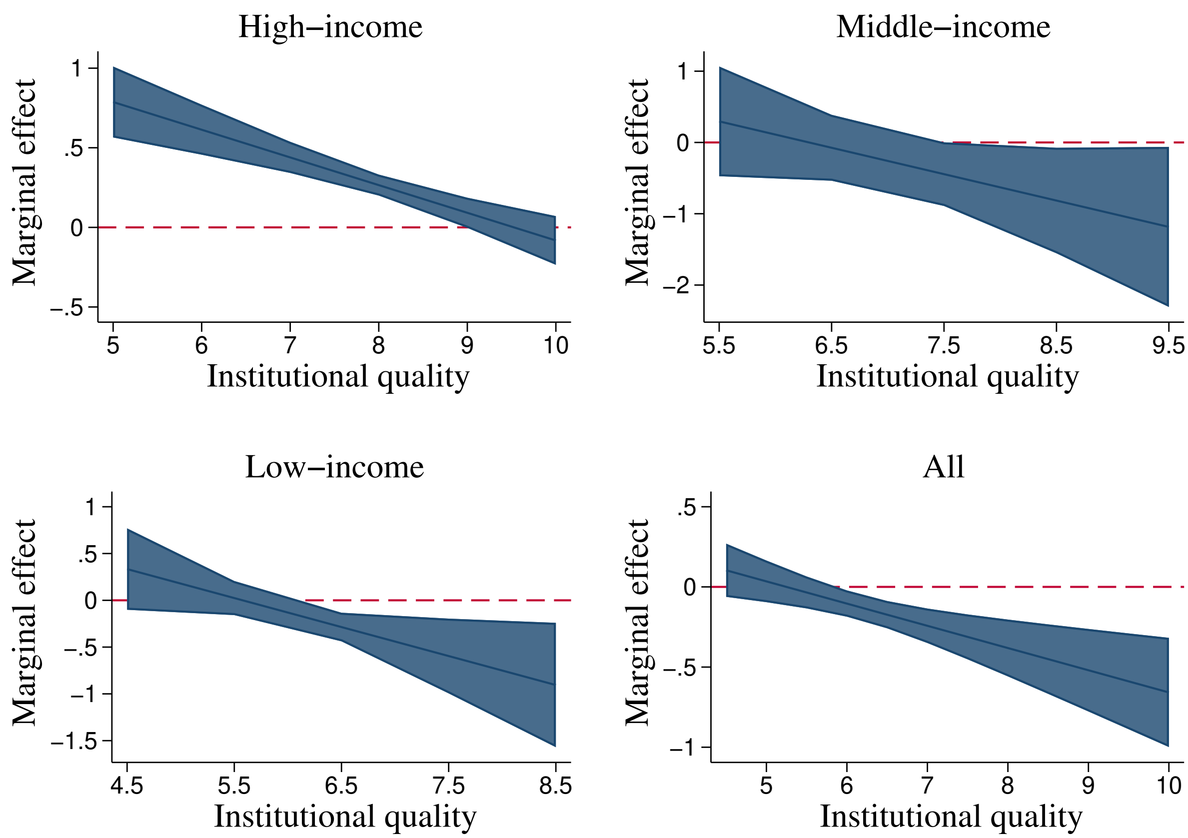

Figure 3: Marginal effects of education spending on growth. Solid lines are estimates of $\beta_2 + \beta_3 q$. Shaded regions represent 90% confidence intervals. The first three panels show marginal effects for high-income, middle-income, and low-income countries. The final panel shows these effects for all countries.

The point is made more clearly in the first panel of Figure 3. From Equation (15), we see that conditional on q, the marginal effect of e on growth is given by $\beta_2 + \beta_3 q$. The downward sloping line in this panel is this estimate for high-income counties; i.e. it is 1.66-.17q. The shaded region shows the 90% confidence intervals. We see that for lower levels of institutional quality, education spending has a significant positive effect on growth. The effect, however is decreasing with quality and has an insignificant effect when quality is sufficiently high. For $q > 9.76$, in fact, the estimated marginal effect of spending is negative (though insignificant).

For the other sets of countries, we again find positive estimates for quality in column (1). However, this is significantly different from zero only for low-income countries. In each of these cases, we find negative estimates for education spending in column (2), with the estimates significant in two of the three cases.[11]

When we include both quality and spending (column (3)), quality is again significant only for low-income countries while spending is negative and significant in each case.

Column (4), again, tells a more nuanced story, one that is largely consistent with the results for high-income countries. In each case, the coefficient on quality and education are positive and the interaction term is negative. For middle-income countries, however, results for spending and the interaction term are not significant.

The second through fourth panels of Figure 3 show estimates of $\beta_2 + \beta_3 q$ for middle-income countries, low-income countries, and the full set of countries. In each case, we see that the estimated effect of spending decreases as quality increases. For $q <$ 6.3, 5.58, and 5.21 for middle-income, low-income, and all countries, the marginal effect of spending is estimated to be positive, but is not significant. For higher levels of quality the effect is estimated to be negative and at sufficiently high levels of quality the effects are statistically significant.

4 Robustness checks

In this section, we conduct several sensitivity analyses to demonstrate the robustness of our baseline model. These fall into three categories. First, we consider the consequences of considering the relationship between expenditures and taxation. Specifically, our baseline model is the empirical analog to Equation (10). In Subsection (4.1) we consider additionally the empirical analogs to Equations

[11] As high-income countries generally have higher quality institutions, our findings regarding spending are broadly consistent with Trabelsi (2018) who investigates the non-linear nature of the relationship between education spending and growth using a structural threshold regression method. Results show that education spending has a positive effect on growth only if a country is above a certain governance threshold. Otherwise it is negative.

(11), (12) and (14). In Subsection (4.2) we generalize the intercept term and consider the model with additional controls. Finally, in Subsection (4.3) we consider alternative measures of institutional quality.

4.1 Taxation and government spending

As discussed in Section (2.4), Equation (10) does not consider the tax required to fund education expenditures. As taxation may be a drag on growth, this is a potentially important omission. In this subsection, we consider taxation in two ways. First, we simply add taxation as a share of GDP to the regression above. This is consistent with Equation (11). Next we consider a period balanced budget requirement by including government expenditures aside from education and invoking the relationship derived in Equation (12). Next we add to this regression the square of spending as discussed in the derivation of Equation (14). Finally, we include taxation, government spending and the square of education spending as an additional check. More specifically, we set

$$\gamma_{n,t} = \beta_0 + \beta_1 q_n + \beta_2 e_{n,t-1} + \beta_3 q_n e_{t-1} + \beta_4 \tau_{n,t-1} + \beta_5 g_{n,t-1} + \beta_6 e^2_{n,t-1} + \delta_t + u_{n,t} \tag{16}$$

where $\tau_{n,t-1}$ and $g_{n,t-1}$ are tax revenue and non-education government spending by country n in period $t-1$. We first set $\beta_5 = \beta_6 = 0$, then $\beta_4 = \beta_6 = 0$, next $\beta_4 = 0$ and finally let each of β_4, β_5, and β_6 be non-zero.

For our measure of $\tau_{n,t-1}$ we use OECD data on revenue from government taxes on personal income expressed as a percentage of GDP.[12] We use this measure as it is most closely related to the income tax from our theoretical model. We note that this is an average tax rate rather than a marginal tax rate. While a marginal tax rate would be more appropriate given our model, this data is not available. For other government spending we use WDI data to find total government spending net of education spending as a share of GDP.[13] For both taxes and spending, we use lagged 10-year averages.

[12]This is Tax on Personal Income. For many countries the data starts in 1965, but for later joining members, it starts later. For example, Poland joined the OECD in 1996 and data on income tax began in 1991.

[13]This is General Government Final Consumption Expenditure (% GDP) minus Government Expenditures on Education, Total (% GDP), both from the World Development Indicators (WDI).

Table 3: Descriptive statistics for taxation and government spending

Variables	High-income	Middle-income	Low-income	All
Income tax revenue	13.43	6.15	4.30	8.63
	(5.05)	(2.86)	(2.43)	(5.51)
Other spending	14.15	11.23	10.11	11.75
	(3.93)	(4.49)	(4.77)	(4.73)
Countries	23	19	19	61

Notes: Income tax revenue and other public spending are in terms of percent of GPD. Standard deviations are in parentheses. Low-income countries are missing data on income tax revenue prior 1999. After 2009, 19 of the 27 low-income countries do have data on income tax revenue.

Table 3 provides summary statistics for the tax and expenditure measures. Income tax revenue averages 13.4% of GDP in high-income countries. In contrast, this is 6.15% and 4.3% for middle-income countries and low-income countries. Government spending net of education in high-income countries averages 14.15% of GDP in high-income countries compared 11.2% and 10.1% for middle-income and low-income countries.

Table (4) gives the results of the four regressions discussed after Equation (16) for high-income countries. In column (1), the estimated effect of tax revenue is negative, as expected, but insignificant. Similarly, in column (2), the estimated effect of other government expenditure is negative, as expected, but insignificant.[14]

In column (3), the coefficient on other spending and the square of education spending are both insignificant. Considering also the fourth column, we conclude that none of our controls for the budget constraint are significant for high-income countries. Moreover, including these controls does not changes the sign or significance of our estimates of the effect of quality, spending, or their interaction. Estimates, of course, do change as we change the controls. For example, comparing column (1) of Table (4) with column (4) of Table (2) for high-income countries, we see a larger effect of all three

[14]Previous researchers have included government spending in growth regressions but find mixed results. Lin (1994) conducts a review of the literature and proposes the importance of the time horizon as a possible explanation of the mixed findings. Some researchers have documented a positive link between the two. For example, Cashin (1995), Bleaney et al. (2001), Alexiou (2009), and Ojede et al. (2018) show that non-education expenditures can foster economic growth. In comparison, Landau (1986) and Easterly and Rebelo (1993) find that real government consumption net of education and defense has a significant negative effect on growth.

Table 4: The influence of taxation and government spending (High-income countries)

	(1)	(2)	(3)	(4)
Quality	1.16***	1.01***	1.19***	1.31***
	(0.27)	(0.22)	(0.29)	(0.31)
Spending	2.29***	2.22***	2.23***	2.39***
	(0.54)	(0.52)	(0.50)	(0.51)
Qual*Sp	-0.24***	-0.23***	-0.27***	-0.27***
	(0.06)	(0.06)	(0.07)	(0.07)
Tax revenue	-0.01			-0.01
	(0.02)			(0.02)
Other spending		-0.04	-0.05	-0.01
		(0.03)	(0.04)	(0.04)
Spending^2			0.04	0.03
			(0.05)	(0.04)
Observations	86	92	92	86
R-squared	0.36	0.35	0.35	0.36

Notes: The dependent variable, institutional quality, education spending, and their interaction are as in Table 2. Tax revenue is revenue collected from income, profits, and capital gains. Other spending is government spending net of education spending. Both other spending and tax revenue pertain to all levels of government (federal, state and local) and are expressed as a share of GDP.

items when we include taxation. However, our key result of a significant negative coefficient of the interaction terms is unchanged.

We do not conduct the sensitivity analyses regarding tax revenue (columns (1) and (4)) for other country groups as its inclusion in the regression results in missing data for more than half the observations. We do, however, repeat the analyses in columns (2) and (3) for these country groups. For brevity, we do not present these results, which are available from the authors, but rather describe them. The results are similar in that none of the tax and spending coefficients are significant. Results are also similar in that the signs on coefficients for quality, spending, and their interaction do not change. Moreover, the coefficient on the interaction term is significant and negative throughout. However, spending becomes insignificant for both low-income countries and all countries in column (2), and for low-income countries in column (3).

4.2 Additional controls

It is common in growth regressions to include more controls than we have considered thus far. In this subsection, we consider additional regressors. For consistency with our theoretical model, we note that γ_0 in Equation (10) may vary by country and time. As β_0 is our estimate of γ_0, we generalize this intercept term to vary by country and time. We replace β_0 in Equation (10) with $\beta_{0,n,t}$ and assume m distinct controls influence $\beta_{0,n,t}$. In particular, in we set

$$\beta_{0,n,t} = \bar{\beta}_0 + \sum_{j=1}^{m} \beta_{j+3} x_{j,n,t} \tag{17}$$

where $\bar{\beta}_0$ is a constant common to all countries, $x_{j,n,t}$ is the observation of control j for country n in period t, $j \in \{1, 2, ..m\}$, and β_{j+3} is the coefficient for this control. Time enters $\beta_{0,n,t}$ through potential time variability in the controls. Through most of our discussion, we set $m = 1$ and consider additional regressors one at a time. We then include a regression with all control variables.

Our goal is not to provide a comprehensive accounting of potential controls. Instead, we simply consider several additional items that plausibly influence growth. These are listed in Table 5 where we also provide summary statistics for high-income and low-income countries. We exclude the other country groups for brevity. For high-income and low-income countries, the findings show that our key result is robust to a more full set of controls. This holds also for the excluded country groups.

Perhaps the most obvious omission in our baseline model is the level of GDP as the time period under consideration begins. This is often included in growth regressions to account for different growths rates as a function of the level of development. The neoclassical growth model suggests that among otherwise similar countries, those with lower current output should grow faster. There is some evidence of this conditional convergence (Barro and Lee (1994), Barro (1997), Brueckner and Lederman (2018)). For this reason, we control for the log of real GDP in 1970, denoted y_{1970}. Data on real GPD comes from version 10 of Penn World Table.

Fertility has sometimes been shown to influence economic growth (Brander and Dowrick (1994),

Table 5: Descriptive statistics for additional controls

Variables	High-income	Low-income
y_{1970}	9.66	7.50
	(0.39)	(0.57)
Fertility	2.05	4.52
	(0.56)	(1.54)
Urban population (% of total)	76.84	33.34
	(9.69)	(15.51)
Capital per person	11.91	8.98
	(0.49)	(1.06)
Depreciation	3.46	4.87
	(0.61)	(1.33)
Latitude	0.53	0.19
	(0.12)	(0.11)
Countries	23	30

Notes: Standard deviations are in parentheses. Initial income and capital per person are expressed as logarithms.

Rougoor and Van Marrewijk (2015), Ashraf et al. (2013)). High fertility could lower the savings rate, thus decreasing growth through lower long term investment. On the other hand, Li et al. (2007) and Bloom et al. (2010) demonstrate a long-term trade-off as lower youth dependency rates eventually convert into higher elderly dependency rates when the age pyramid widens at the top. The level of urbanization can also affect economic growth. For example, Henderson (2003) shows that there is an optimal level of urban concentration for productivity growth. The study also shows that this optimal level is different at different levels of development. Our measures of fertility (total births per woman) and urbanization (share of population living in cities) come from the World Bank.[15] As shown in Table 5 low-income countries have higher birth rates and lower rates of urbanization than high-income countries.

In building our theoretical model, we set capital to depreciate fully after one period. This allows a simple exposition of the spending/quality/growth relationship. However, more generally the rate of

[15]Details on the construction of these measures are provided by the WDI database.

deprecation would affect the optimal amount of physical capital per unit of human capital and through this may influence growth. We account for this by including the depreciation rate as measured by 'delta' in the PWT10 data set. We separately control for capital per worker using 'cn, capital stock at current PPPs in (millions $2017)' from the same data set. This is motivated by the notion that the optimal ratio of physical capital to human capital depends not only on current depreciation but also past rates of depreciation. Past depreciation rates are considered in the construction of this variable (Inklaar and Timmer, 2013). Table 5 shows that low-income countries have less capital per person and a higher depreciation rate.

As a final control, we add the absolute latitude of each country's capital to account for geographical differences. Sachs (2012) provides an analysis of the role of institutions and geography in the growth process. The study revisits the Acemoglu et al. (2001) measure of institutions and contributes by showing the role of geography for growth. This measure is the absolute distance of the country's capital from the equator re-scaled to be between 0 and 1 as is common in the literature (Acemoglu et al. (2001)). Low-income countries are closer to the equator.

In Table 6 we add each of these additional controls one at time through the first six columns and in the seventh column include all controls simultaneously. Panel A shows these results for high-income countries, and Panel B repeats the exercise for low-income countries.

Column (1) shows the results when we add initial GPD as an additional control to the regression in column (4) of Table 2. The effect of initial GPD is estimated to be negative, as anticipated, and is significant for low-inomce countries but not for high-income countries. In both cases quality, spending, and their interaction are all estimated to have larger effects upon adding initial GPD, but retain their sign and significance. The coefficient on the interaction terms remains negative and significant.

When we instead include fertility as a control, the estimate is positive and insignificant for high-income counties and negative and significant for low-income countries. For low-income countries, adding this variable causes education spending to no longer be significant. However, again the coefficient on the interaction term is negative and significant for both sets of countries.

As we move through the other controls, we see that in each case estimates are insignificant for both country sets and the interaction term remains significantly less than zero. Each of these, in fact, has a fairly small impact on the estimates for quality, spending, and the interaction term. In the final column, with all controls included, we see larger changes in the estimates of each of these three coefficients. However, in both cases the interaction term remains significantly negative. All controls are insignificant except for the fertility rate, which has a positive estimate for high-income countries and a negative estimate for low-income countries.

Table 6: Additional controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: High-income							
Quality	1.23***	0.94***	0.89***	0.98***	0.86***	0.90***	1.23***
	(0.33)	(0.20)	(0.22)	(0.18)	(0.18)	(0.20)	(0.25)
Spending	1.84***	1.19**	1.93***	1.50***	1.67***	1.81***	1.66***
	(0.44)	(0.52)	(0.56)	(0.37)	(0.29)	(0.42)	(0.50)
Qual*Sp	-0.19***	-0.13**	-0.20***	-0.16***	-0.18***	-0.19***	-0.17***
	(0.05)	(0.06)	(0.06)	(0.04)	(0.04)	(0.05)	(0.06)
y_{1970}	-0.94						-0.72
	(0.66)						(0.51)
Fertility		0.59					0.54**
		(0.35)					(0.25)
Urbanization			-0.02				-0.01
			(0.02)				(0.01)
Capital/person				-0.45			0.10
				(0.40)			(0.47)
Depreciation					0.04		-0.12
					(0.21)		(0.17)
Latitude						0.54	0.28
						(0.66)	(0.75)
Observations	92	92	92	92	92	92	92
R-squared	0.38	0.37	0.35	0.35	0.34	0.34	0.41

Continued on next page

Table 6 – *Continued from previous page*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel B: Low-income							
Quality	1.84***	1.29**	1.81***	2.01***	1.79***	1.91***	1.26**
	(0.49)	(0.52)	(0.48)	(0.51)	(0.53)	(0.48)	(0.47)
Spending	2.05**	1.21	1.70**	1.82**	1.71*	2.02**	1.29*
	(0.77)	(0.72)	(0.82)	(0.83)	(0.84)	(0.84)	(0.67)
Qual*Sp	-0.36***	-0.22*	-0.30**	-0.32**	-0.30**	-0.36**	-0.23**
	(0.13)	(0.12)	(0.14)	(0.14)	(0.14)	(0.14)	(0.11)
y_{1970}	-0.93*						-0.43
	(0.48)						(0.57)
Fertility		-0.53***					-0.83***
		(0.18)					(0.15)
Urbanization			-0.03				-0.01
			(0.02)				(0.02)
Capital/person				-0.52			-0.66
				(0.39)			(0.46)
Depreciation					0.15		-0.13
					(0.20)		(0.15)
Latitude						3.03	0.99
						(2.77)	(1.99)
Observations	103	103	103	103	103	103	103
R-squared	0.32	0.36	0.33	0.33	0.30	0.31	0.46

Notes: The dependent variable in columns (1)-(6) is the average 10-year growth of real GDP per capita. For high-income countries, column (6) includes both lagged government spending and tax revenue, but the estimated parameters are not displayed. For low-income countries, only lagged government spending is added due to data availability.

We further consider the robustness of our results to these additional controls through Figure 4. This is analogous to Figure 3 but shows the marginal effect of e on growth, $\beta_2 + \beta_3 q$, from column (7) of Table 6. Comparing the two figures, the similarities are apparent. For high-income countries, the estimate becomes insignificant at the 90% level at a smaller level of quality. For low-income counties the range of quality where the estimate is significant is quite close in the two cases. Overall, results are qualitatively unchanged.

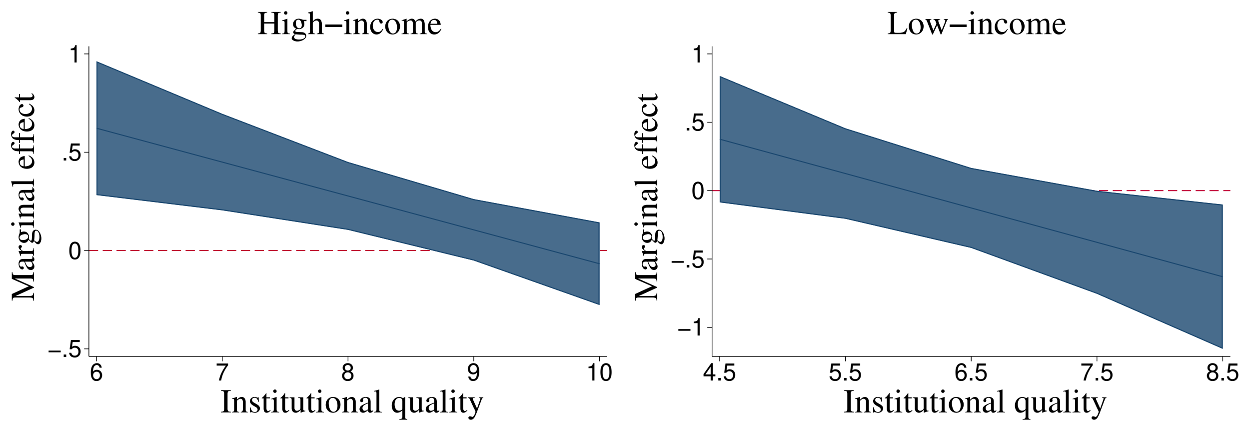

Figure 4: Marginal effects of education spending on growth with additional controls. Solid lines are estimates of $\beta_2 + \beta_3 q$. Shaded regions represent 90% confidence intervals.

4.3 Alternative measures of institutional quality

Thus far, we have considered only protection against expropriation to measure institutional quality. While this measure is well established in the literature, other measures exist. In this subsection we consider the robustness of our results to a set of alternative measures of quality. In particular, we use data from the Fraser Institute database on legal systems and property rights, legal enforcement of contract, protection of property rights, impartial courts, and judicial independence. These are also measured on a scale from 0 to 10.[16] The Fraser data is longitudinal. However, to make this comparable with our earlier quality measure, we use the average value of each quality measure over the period 1985 to 1995.

Table 7 provides summary statistics for the five additional measures. In each case, the high-income countries have the highest values and low-income countries have the lowest values. The final column shows the correlation of each measure with the baseline protection against expropriation measure. Each is highly correlated with our baseline measure, with correlations ranging from .65 for legal enforcement of contracts to .79 for legal systems and property rights.

Table 8 shows the results of this sensitively analysis. Each column represents a regression analogous to our our baseline regression in column (4) of Table 2. The only difference is the quality measure

[16] Detailed exposition of their construction is available in the Economic Freedom Database. This site provides additional indices, but we focus on those most closely pertaining to the quality of government.

Table 7: Descriptive statistics for alternative institution measures

Variables	High-income	Middle-income	Low-income	Correlation with baseline measure
Legal systems	7.69	5.30	3.81	0.79
and property rights	(1.17)	(1.03)	(0.84)	
Legal enforcement	6.99	4.70	3.77	0.65
of contracts	(1.00)	(1.41)	(1.15)	
Protection of	6.93	4.63	4.04	0.74
property rights	(0.88)	(1.10)	(0.83)	
Impartial	8.18	6.23	4.58	0.74
courts	(1.15)	(1.23)	(1.16)	
Judicial	7.93	5.91	4.83	0.67
Independence	(0.96)	(1.14)	(1.21)	
Countries	23	22	30	75

Notes: The measures are from Economic Freedom Database and are indexed between 0 and 10 where larger levels indicate stronger institutions. We show sample means and the associate standard deviations. The final column is correlation with our baseline measure of institutional quality.

as indicated by the column title. For high-income countries, results are little changed with the new measures of institutional quality. For quality and the interaction term, the baseline estimates lie in the range of estimates for the various alternative measures. For spending, each estimate is smaller than the baseline measure. However, qualitative findings are unchanged in each case and quantitative changes are not large.

For middle-income countries, results are more supportive of a negative interaction term than in the baseline model. The interaction term is negative in all cases and significant in three of five cases whereas it is negative but insignificant in the baseline case. Estimates for each of quality, spending, and the interaction term lie in the range of estimates for the various alternative measures.

Table 8: Baseline with alternate measures of institutional quality (1979-2019)

	(1) Legal systems & property rights	(2) Legal enforcement of contracts	(3) Protection of prop. rights	(4) Impartial courts	(5) Judicial independence
		Panel A: High-income countries			
Quality	0.67***	0.92***	1.02***	0.68***	0.83***
	(0.19)	(0.28)	(0.30)	(0.19)	(0.24)
Spending	0.96***	1.24***	1.41***	0.81***	1.13***
	(0.23)	(0.38)	(0.36)	(0.25)	(0.33)
Quality*Sp	-0.12***	-0.18***	-0.20***	-0.10***	-0.14***
	(0.04)	(0.06)	(0.06)	(0.04)	(0.05)
Observations	92	92	92	92	92
R-squared	0.33	0.33	0.33	0.34	0.34
		Panel B: Middle-income countries			
Quality	1.36***	0.98**	0.19	1.72***	1.76***
	(0.36)	(0.45)	(0.61)	(0.38)	(0.47)
Spending	1.32**	0.57	-0.46	2.54***	2.33***
	(0.53)	(0.49)	(0.81)	(0.67)	(0.70)
Quality*Sp	-0.32***	-0.20	-0.01	-0.46***	-0.46***
	(0.10)	(0.12)	(0.17)	(0.12)	(0.12)
Observations	92	74	85	92	92
R-squared	0.13	0.17	0.12	0.16	0.17
		Panel C: Low-income countries			
Quality	0.91	0.47	0.09	0.78	0.08
	(0.54)	(0.38)	(0.62)	(0.48)	(0.54)
Spending	-0.21	-0.59	-0.59	-0.14	-0.95
	(0.59)	(0.42)	(0.65)	(0.63)	(0.70)
Quality*Sp	0.01	0.08	0.11	-0.01	0.14
	(0.12)	(0.08)	(0.15)	(0.11)	(0.12)
Observations	115	114	110	115	115
R-squared	0.22	0.22	0.18	0.25	0.19

Notes: The dependent variable is the average 10-year growth rate of GDP per capita. Education spending is expressed as a percentage of GDP. Institutional quality is different in each column as indicated by column titles and each is averaged between 1985 and 1995. Clustering is done at the country level. Standard errors are in parentheses. Asterisks indicate significance at the 10% (*), 5% (**) and 1% (***) levels.

For low-income countries, results are considerably different from our baseline model. There we find quality and spending to be positive and significant, while the interaction term is negative and significant. In Table 8 we see that for each alternative measure of quality, estimates for each of quality, spending, and the interaction term are insignificant. For spending and quality the signs are the same as in Table 2 but estimates are very small relative to standard errors. For the interaction term the estimates are now generally positive, but again are not significant and are small relative to standard errors.

Overall, our finding of a negative estimate of the interaction term is robust to alternative measures of quality for high-income countries and more strongly supported for middle-income countries. For low-income countries, the negative coefficient is not robust to these alternative measures. However, our broader claim that this value is not positive continues to hold.

5 Conclusion

We investigate how institutional quality influences the impact of government education spending on growth. It is reasonable to expect that such spending would be more effective in generating growth when the resulting human capital is employed in an economy with strong institutions. However, it is also reasonable that government education spending may be less important for growth in an environment with quality institutions if the two factors affect growth through similar channels. To clarify these possibilities, we build a growth model which generates a simple growth regression. Results are decidedly in favor of the second possibility. That is, we find evidence that the marginal effect of government education spending is smaller when institutional quality is higher.

We find, in fact, that when quality is sufficiently high, the marginal effect of spending on growth may be near zero or even negative. Of course government education spending has motivations beyond growth. As such, we do not see our results as arguing against spending when institutional quality is high. It is likely that higher income countries can prioritize economic improvements along other dimensions by spending on education beyond the level which maximizes growth.

Rather we take our results as providing two important insights. First, the growth argument for education is often valid, but weakens when institutional quality is high. Second, the results refine our understanding of the importance of institutions for growth. An equivalent interpretation of our result is that institutions are relatively important for growth when spending is low. In this sense, our results are complementary to Compton and Giedeman (2011). They show that the growth effect of national banking development is lower when institutional quality is higher. An equivalent interpretation is that when banking development is poor, institutional quality is relatively important for growth. Such findings suggest that quality in general carries a bigger load in generating growth when other factors are lacking.

We have kept both our model and our empirical investigation quite simple. This has the advantage of providing a close mapping between the two which is helpful in both the development and interpretation of our empirical strategy. Of course, this comes at some cost. On the theoretical side some obvious omissions include private funding of education, different levels of education (such as primary, secondary, and college) and heterogeneity across agents. We feel that a fuller model may provide additional insights into the quality/spending relationship. Our current work could prove useful in calibrating such a model.

A fuller empirical evaluation may also prove useful. Some of the growth literature moves beyond simple regressions in part to control for endogeneity. While our method of lagging expenditures is a common strategy to deal with potential endogeneity regarding expenditures, future work could go beyond this. Moreover, we have followed Acemoglu et al. (2001) in taking institutional quality to be exogenous. However, they also instrument for quality using colonial death rates. We do not use this approach because it severely limits the countries we can include in our regression and because they found results to be similar upon instrumenting for quality. However, to the extent that concerns remain regarding the endogeneity of institutions, future work might use a similar approach to further explore the quality/spending relationship.

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A Appendix: List of countries by group

We follow the classification of Blankenau et al. (2007). High-income countries had more than $4000 in real per capita GDP in 1960 (in 1995 $), middle-income countries had between $800 and $4000, and low-income countries had less than $800. We employ this classification because it reflects the relative status of countries at the initial time in our dataset. Using the latest World Bank classifications would not be appropriate for our purpose (a study of growth) because countries may have moved up and down across categories.[17]

High-income countries (23)

Argentina, Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, United States.

Middle-income countries (19)

Barbados, Cyprus, Portugal, Seychelles, Singapore, South Africa, St. Kitts and Nevis, Uruguay, Venezuela, Bolivia (Plurinational State of), Bulgaria, Chile, Colombia, Costa Rica, Hungary, Iran (Islamic Republic of), Jamaica, Jordan, Republic of Korea, Malaysia, Malta, Mauritius, Mexico, Panama, Paraguay, Peru, Romania, Eswatini, Turkey.

Low-income countries (27)

Bangladesh, Botswana, Burkina Faso, Burundi, Cameroon, China, Congo, Côte d'Ivoire, Dominican Republic, Egypt, Ethiopia, Ghana, India, Indonesia, Kenya, Lesotho, Madagascar, Malawi, Morocco, Myanmar, Nepal, Nicaragua, Pakistan, Philippines, Sri Lanka, Syrian Arab Republic, Thailand, Tunisia, Zambia, Zimbabwe.

[17] For example, in 2021, this was the case with Haiti (from low-income country up to lower middle-income based on the World Bank classification) and Indonesia (from upper middle-income countries down to lower middle-income country).

B Appendix : Model details (Not intended for publication)

In this appendix (not intended for publication) we provide additional detail on solving the model. For convenience, some items are repeated from the paper.

B.1 Equations (6), (7), and (8)

We begin by deriving the equilibrium conditions in Equations (6), (7), and (8) from Subsection 2.3. A period t earner chooses $C_{t-1,t}$, $C_{t-1,t+1}$, and $K_{p,t+1}$ to maximize

$$\ln C_{t-1,t} + \beta \ln C_{t-1,t+1} \tag{18}$$

subject to

$$C_{t-1,t} + K_{p,t+1} \leq (1-\tau_t)\, w_t H_t$$

and

$$C_{t-1,t+1} \leq (1-\tau_t)\, r_t K_{p,t+1}.$$

As these hold with equality in equilibrium, we rewrite Equation (18) as

$$\ln\left((1-\tau_t)\, w_t H_t - K_{p,t+1}\right) + \beta \ln\left((1-\tau_t)\, r_t K_{p,t+1}\right).$$

The first order condition with respect to $K_{p,t+1}$ is

$$\frac{1}{(1-\tau_t)\, w_t H_t - K_{p,t+1}} = \frac{\beta}{K_{p,t+1}}.$$

Solving for $K_{p,t+1}$ gives Equation (6).

We next solve for factor prices in Equation (7). To economize on notation, we use $K_{p,t}$ and H_t to denote both the quantity supplied and quantity demanded of physical and human capital. The firm chooses $K_{p,t}$ and H_t to maximize

$$Y_t = A_t K_{p,t}^{\alpha} H_t^{1-\alpha} - w_t H_t - r_t K_{p,t}.$$

First order conditions are

$$w_t = (1-\alpha)\, A_t K_{p,t}^{\alpha} H_t^{-\alpha} \tag{19}$$

and

$$r_t = \alpha A_t K_{p,t}^{\alpha-1} H_t^{1-\alpha}. \tag{20}$$

Setting $k_t = K_{p,t}/H_t$ gives the result.

To derive Equation (8) we note that the period government budget constraint is

$$\tau_t \left(w_t H_t + r_t K_{p,t}\right) = \left(e_t + g_t\right) Y_t.$$

Using Equation (1) for Y_t, dividing each side by H_t, and setting $k_t = K_{p,t}/H_t$ gives Equation (8).

B.2 Equations (10), (11), and (12)

We now turn to deriving the steady state relationships in Equations (10), (11), and (12) in Subsection 2.4. We rewrite Equation (5) as

$$\frac{H_{t+1}}{H_t} = B\left(\frac{E_t}{H_t}\right)^{\mu}.$$

Then from Equation (4)

$$\frac{H_{t+1}}{H_t} = B\left(\frac{\exp(e_t) Y_t}{H_t}\right)^{\mu} = B\exp\left(\mu e_t\right)\left(\frac{Y_t}{H_t}\right)^{\mu}.$$

Using Equation (1), $k_t = K_{p,t}/H_t$, $H_{t+1}/H_t = 1+\gamma$ and dropping time subscripts in a steady state gives one of two equations in γ and k:

$$1+\gamma = A^{\mu} B \exp(\mu e) k^{\alpha\mu}. \tag{21}$$

To find the second such equation, we put the expression for wages into Equation (6) yielding

$$K_{p,t+1} = \frac{\beta}{\beta+1} A\,(1-\alpha)\, k_t^{\alpha} H_t (1-\tau_t).$$

Dividing each side by H_{t+1} setting $K_{p,t}/H_t = K_{p,t+1}/H_{t+1} = k$, $H_{t+1}/H_t = 1+\gamma$, dropping time subscripts, and solving for k we find

$$k = \left(\frac{1}{1+\gamma}\frac{\beta}{\beta+1} A\,(1-\alpha)\,(1-\tau)\right)^{\frac{1}{1-\alpha}}. \tag{22}$$

Putting Equation (22) into Equation (21) gives

$$1+\gamma = A^{\mu} B \exp(\mu e) \left(\frac{1}{1+\gamma}\frac{\beta}{\beta+1} A\,(1-\alpha)\,(1-\tau)\right)^{\frac{\alpha\mu}{1-\alpha}}$$

and solving this for $1+\gamma$ gives

$$1+\gamma = \left(A^{\mu} B \exp(\mu e) \left(\frac{\beta}{\beta+1} A\,(1-\alpha)\,(1-\tau)\right)^{\frac{\alpha\mu}{1-\alpha}}\right)^{\frac{1-\alpha}{1-\alpha(1-\mu)}}$$

or

$$1+\gamma = \left(A \exp((1-\alpha)\,e) \left(B^{\frac{1-\alpha}{\alpha\mu}} \frac{\beta}{\beta+1}\,(1-\alpha)\,(1-\tau)\right)^{\alpha}\right)^{\frac{\mu}{1-\alpha(1-\mu)}}.$$

Using Equation (3) and rearranging gives

$$1+\gamma = \left(\exp\left(\chi_1 q + (1-\alpha+\chi_2)\,e + \chi_3 q e\right) \left(B^{\frac{1-\alpha}{\alpha\mu}} \frac{\beta}{\beta+1}\,(1-\alpha)\,(1-\tau)\right)^{\alpha}\right)^{\frac{\mu}{1-\alpha(1-\mu)}}. \tag{23}$$

Setting

$$\Lambda \equiv \frac{\mu}{1-\alpha\left(1-\mu\right)}$$

$$\lambda_0 \equiv \Lambda \ln\left(B^{\frac{1-\alpha}{\alpha\mu}}\frac{\beta(1-\alpha)(1-\tau)}{\beta+1}\right)^{\alpha}$$

$$\lambda_1 \equiv \Lambda\chi_1$$

$$\lambda_2 \equiv \Lambda\left(1-\alpha+\chi_2\right)$$

$$\lambda_3 \equiv \Lambda\chi_3$$

and taking the log of each side, this is

$$1+\gamma = \lambda_0 + \lambda_1 q + \lambda_2 e + \lambda_3 qe.$$

The approximation $\ln\left(1+\gamma\right) \approx \gamma$ gives Equation (10).

To arrive at Equation (11) we redefine $\lambda_0 \equiv \Lambda \ln\left(B^{\frac{1-\alpha}{\alpha\mu}}\frac{\beta(1-\alpha)}{\beta+1}\right)^{\alpha}$ and define $\lambda_4 = -\alpha\Lambda$ so that logging Equation (23) gives

$$1+\gamma = \lambda_0 + \lambda_1 q + \lambda_2 e + \lambda_3 qe - \lambda_4 \ln(1-\tau). \tag{24}$$

The approximation $\ln\left(1-\tau\right) \approx -\tau$ gives Equation (11).

To arrive at Equation (12), we first simplify the government budget constraint. Putting (7) into Equation (8) gives

$$\tau_t(A\left(1-\alpha\right)k_t^{\alpha} + A\alpha k_t^{\alpha-1}k_t) = (e_t+g_t)Ak_t^{\alpha}$$

and in a steady state this reduces to

$$\tau = e+g. \tag{25}$$

This expression into Equation (11) and collecting terms gives Equation (12).

B.3 Equation (13)

To find the growth maximizing level of spending in Equation (13) we put Equation (25) into Equation (24) to get

$$1 + \gamma = \lambda_0 + \lambda_1 q + \lambda_2 e + \lambda_3 q e - \lambda_4 \ln(1 - e - g). \tag{26}$$

Setting the derivative of this with respect to e equal to zero, gives

$$\lambda_2 + \lambda_3 q + \frac{\lambda_4}{1 - e - g} = 0$$

Solving for e gives

$$e^* = 1 - g + \frac{\lambda_4}{\lambda_2 + \lambda_3 q}$$

It is straightforward forward to show that parameterizations exist where

$$0 < e^* < 1.$$