Testing the relationship between Vocational Secondary Schooling and Economic Performance

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Abstract:

Theoretically, vocational education is acknowledged to be important for growth, absorptive capacity, innovation and technological diffusion. Yet empirically, little is known about the contribution of vocational education to macroeconomic performance. This paper makes use of a newly constructed dataset of vocational secondary schooling for 129 countries from 1950-2010. By replicating and building upon four classical cross-country analyses, this paper systematically and comprehensively tests whether secondary vocational education contributes to economic performance and how it interacts with other variables known to be important for economic growth and technological change. We find that vocational secondary schooling is consistently related to economic performance. The relationship between vocational secondary schooling and economic growth changes with proximity to the frontier and countries have to be relatively closer to the frontier to see positive growth effects from additional vocation secondary schooling.

Keywords: Vocational Education • Education and Economic Development • Returns to Education • Human Capital • Economic Growth • Industrialisation

JEL Classification Codes: • I25 • I26 •J01 •J24 •O10 •O14

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1.1 Introduction

Education serves many purposes, but vocational education is explicitly designed to educate for a particular job. Therefore, it represents the part of education most directly linked with the labor market in an economy. We hypothesize that vocational education has a distinct relationship from other types of education when related to dependent variables measuring the economic performance of an economy.

In order to test whether this is the case, we start by replicating four classical cross-country analyses of the relationship between education and economic performance. We first reconstruct the original data they used and replicate their results. We then update the data, distinguish between vocational and non-vocational education and test whether vocational education makes a specific contribution to economic performance. Where possible, we explore how vocational education may interact with other variables in our specifications.

We find that the relationship between vocational secondary education and economic performance is quite sensitive to changes in data, specifications, number of countries, and time period. This is also true for other measures of education. In nearly all specifications, however, vocational education helps to explain variation in economic performance and often it offers a more consistent explanation than non-vocational years of schooling. We synthesize the conclusions and formulate our own relationship between the vocational and non-vocational education and economic performance. Our analysis suggests that in order for an economy to take advantage of vocational education, the economy must be closer to the technological frontier than we originally hypothesized.

1.2 Education and Economic Performance

There is a vast literature that, in varying ways, attempts to link education with economic performance. The empirical findings are inconsistent (Sunde, 2015), ranging from no effect to large macro returns (see Patrinos & Psacharopoulos 2011 for a comprehensive review). The relationship between education and economic performance is complicated because of the wide variety of methodologies, dependent variables, other regressors[1], and different samples that are used in different studies (Sianesi & Van Reenen, 2003). Empirical choices often reflect altogether different investigative aims stemming from different theoretical approaches (Savvides & Stengos, 2009).

As a first step we replicate studies with diverse theoretical and empirical approaches to analyzing the role of education in cross-country economic performance over long time horizons. To select studies to analyze we consulted recent reviews of education and macroeconomic growth by Benos and Zotou (2014), Savvides and Stengos (2009), Sianesi and Van Reenen (2003), and also Durlauf et al. (2005) who synthesize growth econometrics more generally. The selected studies capture four distinct dimensions of the relationship between education and economic performance: education as a determinant; education as a structural variable; growth promoting spillovers from education; and education as a conduit for technology diffusion.

Table 1 briefly summarizes key traits of the selected studies and the mechanism that we believe the original authors had in mind for the role of education in their macroeconomic study. The column furthest to the right indicates our hypothesis for the distinct role of vocational education, given the

[1] In a review of growth economics, Durlauf et al. (2005) found well over 60 regressors proposed by the literature as viable determinants of growth. Studies that estimate the relationship between human capital or education and economic performance represent a relatively small subset of these studies.

empirical setting of the original study. For each replication, we introduce our vocational education variable and each time, the research question is as follows: does vocational education reveal a different relationship with macroeconomic performance indicators than non-vocational education?

Table 1 Macroeconomic Studies with Education Selected for Replication

Original Author(s)	Dependent Variable	Empirical Approach	Time Period	Mechanism	Vocational Edu Hypothesis
Barro and Lee (2010)	GDP per Worker	Panel, Fixed and Random Effects	1970-2005	Education is a determinant of GDP	Vocational education is a determinant of GDP and employment
Szirmai & Verspagen (2015)	Growth of GDP per Capita	Hausman-Taylor (preferred specification)	1950-2005	Education is a proxy for absorptive capacity	Vocational education is a better proxy for absorptive capacity
Pritchett (2001)	Growth of GDP per Worker	First, for each variable, log least squares growth is calculated over the entire period. Then, cross-sectional OLS	1960-1985	Education should promote growth externalities beyond aggregation of individual impact	In this empirical setting, if a 10% constant wage increment is assumed we do not expect a big difference between vocational and non-vocational education
Benhabib & Spiegel (2005)	Growth of TFP	Non-linear cross-sectional long-term growth specification. Estimated using maximum likelihood	1960-1995	Education increases capacity for (1) innovation, and (2) imitation	Vocational education is important for imitation and catch up; but its importance changes with the distance to the technology frontier

Source / notes: The dependent variable, empirical approach and time periods are from the original studies.

1.2.1 Determinants – Replication of Barro and Lee (2010)

We begin with replicating Barro and Lee's 2010 NBER working paper, Rate of Return to Schooling. As argued by Durlauf et al. (2005), the baseline of much of growth econometrics starts with what is referred to as 'Barro regressions'. Prompted by Barro's (1991) contribution in which he employed cross-country growth regressions to explore alternative growth theories, Barro's general empirical specification (in various forms) has become the workhorse of empirical work on growth. Empirical studies often take Barro's specification in its general form as the point of departure, rather than deriving a formal expression for steady-state level of output per worker (Savvides & Stengos, 2009). In this empirical setting, researchers often use education as a measure of human capital and they seek to quantify the magnitude of the effect of greater amounts of education on economic growth. A recent meta-analysis highlights measurement as the most important issue inhibiting a consensus on the contribution of education to economic growth, and specifically mentions the omission of empirically accounting for vocational education (Benos and Zotou, 2014).

We hypothesize that since vocational education is more explicitly linked with the labor market than general education it has a direct effect on the efficiency of labor (GDP per worker). Alternatively, a greater presence of vocational education in an economy might facilitate job entry and lead to higher employment levels, indirectly affecting economic performance. In which case, GDP per capita is the more appropriate dependent variable.

1.2.2 Structural Change – Replication of Szirmai and Verspagen (2015)

What if human capital were treated as a structural variable? Where, in a given economy, the structure of the education system is more or less effectively delivering human capital that is 'useful' for the productive structure of the economy. The article by Szirmai and Verspagen (2015) takes the view education can be used as a proxy for absorptive capacity and argues that education increases the ability of a society to absorb and benefit from technological change. For example, when education is interacted with manufacturing, it increases the marginal effect of that sector's ability to drive growth.

Theoretically, absorptive capacity is what developing economies and firms need to catch-up (Abramovitz, 1993; Cohen and Levinthal 1989), and absorptive capacity is part of a self-reinforcing cycle (Soete, 2006) which, together with other factors, leads to greater technological and innovation performance in an economy. As Szirmai and Verspagen point out, the theoretical concept of absorptive capability put forth by Abramovitz in1986, is very broad. It can include elements, such as infrastructure and political stability that go far beyond general education levels in an economy. Education, as a proxy for absorptive capability, captures the efficiency with which catching-up economies obtain and integrate knowledge from more technologically advanced economies.

In the tradition of Abramovitz and Gerschenkron, catching up depends on the extent to which an economy that is technologically backward can grow faster than the economies that are at the technological frontier. One way in which economies can do this is to take advantage of technology and knowledge that has been developed at the frontier in order to catch up or 'leap-frog'. This can be done in a variety of ways, but none of them are costless and they often involve technical know-how (Lee and Kim, 2001) or 'absorptive capacity'.

We hypothesize that vocational education might be a better proxy of absorptive capacity than overall years of schooling. Increasing the number of technically educated people in workforce might lead to the faster introduction and/or diffusion of new technologies (Toner, 2010; Tether et al., 2005). This role for vocational secondary schooling has not been empirically tested in a cross country analyses of economic growth.

1.2.3 Spillovers – A Replication of Pritchett (2001)

In 2001, Pritchett published a famous and highly cited paper that asks 'Where has all the Education Gone?' In this paper, Pritchett argues that since the 1960s, educational attainment has increased in nearly all economies and yet, on average, education has not contributed as much to economic growth as expected. This paper has been identified as a classical reference, because it is the paper people cite for the oppositional view that education is *not* as important for economic output as many think. We revisit Pritchett's analysis 15 years later, and we first replicate Pritchett's original findings as exactly as possible. Then, we update the data and add our vocational variable(s) to see how vocational education may affect the results. Pritchett's empirical approach and even his use of 'years of schooling' is rather dramatically different from the other replications analyzed in this paper.

The construction of what Pritchett calls 'Education Capital' applies a wage increment *r* of 10 percent across all years of schooling, in all countries, and in all time periods to the same 'Years of Schooling'[2] measure from Barro and Lee. Pritchett justifies the assumed *r* of 10 percent by citing surveys of micro-evidence.

Pritchett tests whether 'Education Capital' promotes economic growth. By incorporating the wage increment to education from micro evidence, Pritchett attempts to make micro and macro models

[2] Pritchett uses the variable Years of Schooling in the population ages 25 and over from the 1993 Barro and Lee dataset; we have typically be using a more recent version of the dataset released in 2010 and updated up until 2013.

of the impact of education consistent. From the perspective of this approach, if the gains from education (assumed to be 10 percent per year of education) are incorporated into the adjusted variable 'education capital' at the aggregate (macro) level, then we could expect the coefficient of 'Education Capital' to be zero; or, not statistically different from zero. A positive and statistically significant coefficient on 'Education Capital' supports the notion that the impact of additional schooling has a greater than expected effect, indicating positive externalities from education for economic growth. In fact, in most of his growth regressions, Pritchett finds negative coefficients for 'Education Capital' that are not statistically different from zero. Pritchett subsequently uses TFP as a dependent variable, with assumed factor shares, and concludes that the failure to reject the null hypothesis - that 'Education Capital' is statistically different from zero and positive - is a high-powered failure. He concludes that a more highly educated workforce has not had the positive effect on growth and productivity that would be expected in the macro economic growth context.

Recently Pritchett (2016) has pointed out that part of the reason why macroeconomic growth models may have a difficult time in 'explaining' growth, is that you need variation to explain variation. In many cases, the right hand side education variables that are used to explain growth change very slowly. Measured schooling evolves smoothly and therefore, does not do much to explain changes in growth over time, unless interacted with other variables (page 10). In all of the countries, over time – years of schooling is increasing. This is not the case for vocational secondary schooling, however, where the patterns within countries and between countries tend to show a lot more variation. The question is whether this variation can be used to assess the impact of vocational and non-vocational education.

1.2.4 Technology Diffusion – A Replication of Benhabib and Spiegel (2005)

As Benhabib and Spiegel describe in their 2005 paper 'Human Capital and Technology Diffusion', the way in which education is conceptualized in a model has important implications for policy. When we consider education as a factor of production, the value of an increase in 'years of education (schooling)' is essentially equal to its marginal product. The major limitation to these Solow-inspired growth models is that - eventually - there are diminishing returns (Savvides and Stengos, 2009). In endogenous growth models (á la Lucas 1988 and Romer 1990), the accumulation of knowledge is derived from the features of the model. Therefore, it is not constant, or predetermined. Benhabib and Spiegel's model builds on the Nelson and Phelps (1966) model which explicitly distinguishes between a technological leader and follower in the model. Thus, in Benhabib and Spiegel's model, human capital does not enter directly into the production process. Rather, its role is to facilitate technology diffusion, which means that it affects total factor productivity. When its value is carried over into the future, it affects aggregate growth.

The key difference in the Nelson Phelps-inspired models is that there is a dual role for human capital *and* that dual role is built into the model. That means that there are <u>two</u> channels (or mechanisms) through which education can affect growth (a) innovation and (b) imitation (adoption of technology invented elsewhere), and usually highly-skilled human capital is expected to affect growth through channel (a) whereas other forms of human capital can affect growth through channel (b). Ang et al. (2011) and Vandenbussche, Aghion & Meghir (2006) found that it is possible to empirically test whether the growth enhancing effects of education are mitigated by the composition of education and the proximity to the frontier.

Thus far, studies have tested this by distinguishing human capital measures into higher or lower education groups (to proxy skills). This has never been tested with data that distinguishes human capital measures by *type* of education. We hypothesize that in the context of this model, we can more thoroughly test whether vocational secondary schooling affects technology diffusion through the channel of imitation and whether its effect changes with proximity to the frontier.

1.3 Vocational Secondary Schooling Data

Our analysis of the impact of vocational schooling uses various educational data sets, including one we have assembled. We start with an overview of the data sets used. For the data on vocational secondary schooling, we make use of new internationally comparable variables on vocational secondary schooling now available for 129 countries from 1950-2010 (for the details of the construction of this dataset see Cathles, 2016). The variable on vocational secondary schooling was constructed using UNESCO Statistical Yearbooks (1969 and 1999) and the online UNESCO Institute for Statistics (UIS) data to build a ratio of vocational-to-total secondary schooling enrolments for each country at 5-year intervals. As the vocational education ratio is based on enrolment and the Barro and Lee data on attainment, we apply the ratios to secondary education figures in the subsequent 5-year period (when enrolment presumably has been transformed into attainment). This ratio serves as our measure for vocational attainment at secondary school level of schooling. There are justifications and caveats for the manner in which the vocational secondary schooling variable was constructed.

Barro and Lee construct 'years of Schooling' by first calculating the share of the population that has attained three broad educational levels (a) primary, (b) secondary and (c) tertiary and the duration of those levels of school in a given economy in a given year. They use enrolment data to fill-in any gaps in attainment data, which implies that when attainment data are not available, enrolment data (with the appropriate time lag for completion), can be cautiously used as a substitute. After correcting for differing completion ratios and mortality rates, Barro and Lee sum the years of schooling from primary, secondary and tertiary to create their an overall measure for average 'years of schooling'. Our measure of the number of years of vocational secondary schooling is naturally a subset of secondary years of schooling and is distinguished on the basis of the vocational secondary enrolments in the preceding 5 years.

Our calculation absorbs all assumptions and possible measurement errors in Barro and Lee's 'average years of secondary schooling' data plus any that might be present in the UNESCO enrolment data. Furthermore, an **important assumption** is that there are no unobservable differences or attributes that might systematically alter the completion and/or mortality rates of vocational versus general education attainment.

The first question that arises in relating vocational secondary schooling variable to existing macro growth models is; why should we expect this variable to make any difference? Our analysis of the literature on education and macroeconomic performance suggests theoretical reasons for paying attention to vocational education. Different types of educational formation have different distances from the labor market. Vocational education is thought to be most closely linked with the labour market. Therefore we expect it to have a direct influence on economic performance, independently from other forms of education. Vocational educational formation could also play a distinct and an important role in absorptive capacities and what is referred to as acquisition of technology in the context of the innovation literature. Therefore we suspect vocational education could affect economic catch-up in a developing country context.

One might object that our variable of vocational secondary schooling is derived from the overall variable 'years of schooling' typically used in many empirical analyses. So, hasn't it already been captured? While it is part of the overall years of schooling, the distribution of the variables do not behave in the same way. The distribution of total years of schooling is rather far less skewed than years of schooling in vocational secondary education.

The mean ratio of vocational to total secondary schooling in our 128 countries is about 20 percent. The ratio ranges from 1 to 93 percent. Total years of schooling range from 0.01 to 13.42 years. Since 'years of schooling' changes fairly smoothly and its range is rather small, the relative contribution of vocational secondary education depends on the base of secondary education and the base of total years of schooling. There is more variation in the way in which the vocational education variable 'moves' through our dataset, and this is a crucial observation. See Appendix 1 for a full set of descriptive statistics.

Table 2 Descriptive Statistics of the Education Variables

Variable		Mean	S.D.	Min	Max	Observations
Years of Schooling 25 +	overall	5.06	3.32	**0.01**	**13.42**	N = 1572
	between		2.73	0.55	10.79	n = 121
	within		1.92	0.41	10.43	T = 12.99
Years of Secondary Schooling 25 +	overall	1.52	1.43	**0.01**	**6.90**	N = 1565
	between		1.04	0.06	4.39	n = 121
	within		0.98	-1.43	6.07	T = 12.93
Ratio Vocational to Total Secondary 25 +	overall	0.20	0.18	**0.01**	**0.93**	N = 1331
	between		0.14	0.01	0.63	n = 121
	within		0.11	-0.31	0.77	T = 11
Vocational Secondary Schooling 25+	overall	0.35	0.46	**0.01**	**2.43**	N = 1181
	between		0.38	0.01	1.39	n = 121
	within		0.26	-0.74	1.55	T = 9.76
Years of Primary Schooling 25 +	overall	3.32	2.00	**0.01**	**8.99**	N = 1572
	between		1.78	0.38	8.24	n = 121
	within		0.93	0.85	6.52	T = 12.99
Years of Tertiary Schooling 25 +	overall	0.24	0.27	**0.01**	**1.76**	N = 1481
	between		0.18	0.01	0.77	n = 121
	within		0.20	-0.35	1.31	T = 12.24

Source: Own elaboration based on Barro and Lee 2010 and Cathles 2016. The between standard deviation refers to cross country variation in average values of the variables. The within standard deviation refers to the average of the pooled standard deviations with countries. T-bar refers to average number of observations per country.

Examining some maximum and minimums is instructive. The maximum ratio of 93 percent of vocational to secondary school occurred in Romania in 1985. At that time, Romania had an average of 8.41 'years of schooling' of which 1.83 years were of secondary schooling. Since the ratio is based on enrollments, it is applied to the component 'secondary years of schooling 5 years later. In 1990 the total years of schooling in Romania was 9.05, of which 2.16 were of secondary schooling and 2.01 years of this was vocational.

The country with the maximum of 13.42 'years of schooling' in our dataset was Switzerland in 2010, of which 5.94 years were secondary schooling. The ratio of vocational to total secondary five years before (in 2005) was 31.3 percent which means the vocational secondary schooling component was 1.86 years.

The correlation matrix of our educational data (Table 3) shows that, as we would expect, the years of each of the sub-components (primary, secondary, and tertiary) are highly correlated to the overall years of schooling. This has to be true because of the way in which years of schooling is constructed. On the other hand, the ratio of vocational schooling to total years of secondary education is barely correlated, and it is also not highly correlated (only 0.25) with overall years of schooling.

Table 3 Correlation Matrix of the Education Variables

	Years of Schooling 25 +	**Ratio** Vocational to Total Secondary	**Years of Vocational Secondary** Schooling	Years of Secondary Schooling	Years of Primary Schooling	Years of Tertiary Schooling
Years of Schooling 25 +	1					
Ratio Vocational to Total Secondary **Enrolments**	**0.25**	1				
Years of Vocational Secondary Schooling	0.68	**0.58**	1			
Years of Secondary Schooling	0.89	**0.06**	0.64	1		
Years of Primary Schooling	**0.92**	0.38	0.60	0.63	1	
Years of Tertiary Schooling	0.81	0.08	0.57	0.84	0.595	1

Source: Own elaboration based on Barro and Lee 2010 and Cathles 2016.
Notes: The matrix is based on data for all countries for all years.

Using total years of education in empirical analyses, as is customary, therefore disregards differences in the structure of education (e.g., more or less vocational education relative to total education). The implicit assumption is that vocational and non-vocational education have the same, uniform effect on economic performance. As we have argued, it is likely this is not correct. The new vocational secondary schooling variable allows us to examine the effects of more or less vocational secondary education in a systematic fashion.

1.4 Analytical Approach

We start by replicating results of important studies relating years of schooling to economic performance. Although replicability is always an important criterion of scientific method, replication of earlier studies in economics are scarce. In part, this has to do with the fact that replication is difficult and challenging. We should be able to replicate earlier studies with our data set, but since many of the analyses that we replicate were published years ago, our data for all the key variables has been updated and theirs has not. We need to be sure that any changes in results are due to the introduction of our vocational education variable and not to more recent/different data, changes in the number of countries in the sample, differences in econometric procedures, or the use of other measures for explanatory variables (i.e., differences in measures of capital stocks). In each replication we therefore tried to access the original data that the author(s) used. Sometimes we were not able to recover the exact data and had to make do with data from other sources, or from different versions of the same dataset. The description of the data and variables used is presented along with each replication. Then, we modify the replicated models, by distinguishing years of vocational education from years of non-vocational secondary education. In this manner, we examine whether vocational years of schooling make an additional contribution to economic performance. Finally, we develop our own empirical approach based on the experience with these replications.

During the replication process it became clear that seemingly small changes can affect the results rather dramatically. This effect is well known and documented (Dulauf, 2005). Therefore, before introducing our vocational education variable, we have we have to check whether we have been able to replicate the original findings and the original conclusions. Usually, we cannot reproduce the exact same coefficients, but we can check whether the size and significance of the coefficients is consistent with the original study. Only once we are reasonably confident that our results are in line with the original study, do we start using newer datasets and adding our new variable.

1.5 Replications

In this section, we present and discuss results from the replication and extension of four seminal works we have chosen: Barro and Lee (2010), Szirmai and Verspagen (2015), Pritchet (2001) and Benhabib and Spiegel (2005).

1.5.1 Replication of Barro and Lee (2010)

The Barro and Lee specification that we replicate is:

$$\log(y_{it}) = \beta_0 + \beta_1 \log(k_{it}) + \beta_2(s_{it}) + \beta_3 X + \varepsilon_{it} \tag{1}$$

where y_{it} is GDP per Worker. The regressors are the Log of Capital per Worker (k) and Years of Schooling (s) in the adult population above the age of fifteen. The regression includes a set of Xs which are a dummy variable for oil exporters and a period dummy variable which Barro and Lee say represents total factor productivity and is assumed to vary over time. In this specification, Barro and Lee claim that β_1 represents the share of capital in total output and β_2 represents the marginal rate-of-return to an additional year of schooling. This equation is clearly a variation on the classical 'Barro regressions', primarily because the specification does not include a lagged dependent variable. We go ahead with replicating this version, because they extend their analysis to include returns to human capital across regional groups. We suspect regional groups have important implications for the analysis of vocational secondary schooling.

The original results from Barro and Lee (2010) are presented in Appendix 2. In their original study, they have an unbalanced panel of 962 observations at 5-year intervals from 1970-2005 for 127 countries. We follow their use of GDP per worker and Capital per worker data from Penn World Tables (PWT) version 6.3. We follow their procedure to construct a capital stock variable from the 5 year average annual growth of capital flows around the initial year, with a depreciation rate of 0.06, which is assumed to be the same across countries. After discarding the first 5 years, as they do, we use a perpetual inventory method to construct the series of capital stock. We use World Development Indicator (WDI) data to create a dummy variable for 'major oil exporters' that takes a value of 1 if oil represents more than 50% of exports in a given country and roughly follow the methodology described in Ross and Voeten (2015), which we assume to be similar to the approach that Barro and Lee took to create their dummy variable for oil exporters. Following the variables they use as closely as we can, we also drop countries for which there are less than six observations for any variable used in the regression and we arrive at 122 countries and 892 observations.

The results we obtain from our replication are similar enough to theirs to convince us that we can move forward with (1) updating the data and (2) incorporating our vocational education variable. We begin by using a subset of countries for which we have vocational data available (in order to compare with the original results). We lose an additional 19 countries for which we do not have vocational data. This reduces our total number of countries to 103 and either 755 or 670 observations depending on whether the vocational variable is included. The only other change to the replication presented in Table 4 is to modify the years of schooling variable to be the measure for the population 25 years and older (rather than 15 years and older). Our vocational variable is constructed on the basis of the years of schooling for the population 25 years and older and therefore, making this change will facilitate comparison. These two modifications (dropping countries for which we do not have vocational secondary schooling data and changing the years of schooling from 15+ to 25+), do not change the results much. (See Table 15 in Appendix 2 which contains the results from the original study and our first most exact replication).

Table 4 presents the Barro and Lee replication results (on the left) and the results when we include vocational secondary schooling (on the right). We find that introducing vocational secondary schooling has a positive and significant effect in both the random (column 1) and fixed effects settings (column 2). Since the Hausman test suggests that the fixed effects model is preferred over the random effects model, we must rely more on the results from those specifications, but it is understood that variables lose some of their explanatory power when we move from random to fixed effects and are no longer able to compare the 'between country' effects.

Following Barro and Lee's interpretation of the estimates, in the fixed effects setting, holding other factors constant, the output per worker would increase by around 10 percent for each additional year of non-vocational schooling and by 11 percent for each additional year of vocational schooling, on average. We tested whether this difference in the size of coefficients is significant, and it is not. So, in this empirical setting, we cannot say that vocational secondary schooling is more important for economic performance than non-vocational schooling. However, when we standardized the beta coefficients, a one standard deviation increase in non-vocational years of schooling has a larger effect on GDP per worker than a one standard deviation increase in vocational secondary schooling.

It is well known that, when analyzing the relationship between economic output and human capital, there is a potential for reverse causality. Barro and Lee introduce lagged education variables (using a 10 year lag) of the population ages 40-75 to capture parental education. In columns 3 and 4, they use these lags as instrumental variables for 'years of schooling', to address possible simultaneity bias. We follow them, but we simplify the instruments by using just the 10 year lags without restricting the education variables to the age range (40-75), since it is not possible for us to restrict our vocational secondary schooling variable to a range of ages with our current data set. Future research to further develop vocational variables, could address this limitation. In our replication results, the simplification of the instruments does not seem to affect the results for overall 'years of schooling'. When we introduce 10 year lags for vocational secondary schooling in this specification; however, the variable loses its significance. In columns 5-8, we notice that the results for the regional rate of return to vocational secondary schooling do differ from the regional rate of return to overall years of schooling. Typically, the rate of return to any kind of schooling appears to be higher in advanced economies. In the next section, when we change our dependent variable to GDP per capita, we find some more nuanced results and believe these results to have important implications for the relationship between vocational education and economic performance.

Table 4 Returns to Education: Replication and Extension of the Barro and Lee Analysis

Replication of Barro and Lee (B&L, 2010):
Rate of Return to Schooling: Population 25 years and above
Dependent Variable = Log GDP per Worker PWT 6.3

	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log K per Worker PWT 6.3	0.52***	0.49***	0.38***	0.22***
	(0.05)	(0.07)	(0.04)	(0.06)
Average years of schooling 25+	0.06***	0.07**	0.11***	0.07**
	(0.02)	(0.03)	(0.02)	(0.03)
Oil exporter and time dummies	yes	yes	yes	yes
Constant	7.58***	7.66***	8.01***	8.62***
	(0.10)	(0.19)	(0.11)	(0.21)
Observations	755	755	599	599
Countries	103	103	103	103
R-sq. within	0.49	0.49	0.22	0.23
R-sq. between	0.87	0.86	0.85	0.85
R-sq. overall	0.85	0.84	0.83	0.82

B. Rate of Return by Region

	(5)	(6)	(7)	(8)
Log Capital per Worker PWT 6.3	0.49***	0.38***	0.32***	0.10
	(0.06)	(0.08)	(0.04)	(0.07)
Average Years of Schooling (25+)				
Advanced Economies	0.08***	0.10***	0.14***	0.12***
	(0.02)	(0.02)	(0.02)	(0.03)
East Asia and the Pacific	0.10***	0.17***	0.15***	0.19***
	(0.03)	(0.03)	(0.04)	(0.04)
Europe and Central Asia	0.04**	0.11***	0.06*	0.06
	(0.02)	(0.03)	(0.03)	(0.07)
Latin America and the Caribbean	0.04**	0.04	0.08***	-0.01
	(0.02)	(0.03)	(0.02)	(0.04)
North Africa and Middle East	0.05	0.01	0.11***	0.04
	(0.04)	(0.06)	(0.04)	(0.05)
South Asia	0.03	0.08	0.14***	0.18***
	(0.05)	(0.06)	(0.06)	(0.06)
Sub-Saharan Africa	0.02	0.03	0.01	-0.03
	(0.03)	(0.04)	(0.03)	(0.05)
Oil exporter and time dummies	yes	yes	yes	yes
Constant	7.67***	7.90***	8.19***	8.92***
	(0.12)	(0.25)	(0.12)	(0.24)
Observations	755	755	599	599
Countries	103	103	103	103
R-sq. within	0.51	0.54	0.30	0.36
R-sq. between	0.86	0.72	0.83	0.49
R-sq. overall	0.84	0.72	0.82	0.50

Adding Vocational to Barro and Lee (B&L, 2010):
Time period 1960-2005
Dependent Variable = Log GDP per Worker PWT 6.3

	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log K per Worker PWT 6.3	0.38***	0.32***	0.28***	0.16***
	(0.06)	(0.06)	(0.05)	(0.05)
Non-vocational Years of Schooling	0.10***	0.09***	0.15***	0.09***
	(0.03)	(0.03)	(0.03)	(0.03)
Vocational Years of Secondary Schooling	**0.11****	**0.11****	**0.09**	**0.03**
	(0.05)	**(0.05)**	**(0.08)**	**(0.08)**
Oil exporter and time dummies	yes	yes	yes	yes
Constant	7.68***	7.90***	8.14***	8.66***
	(0.11)	(0.17)	(0.11)	(0.15)
Observations	756	756	630	630
Countries	100	100	99	99
R-sq. within	0.62	0.63	0.34	0.37
R-sq. between	0.84	0.83	0.82	0.81
R-sq. overall	0.82	0.80	0.79	0.77

B. Rate of Return by Region

	(5)	(6)	(7)	(8)
Log Capital per Worker PWT 6.3	0.37***	0.29***	0.27***	0.14**
	(0.06)	(0.07)	(0.05)	(0.06)
Average Years of Schooling (25+)	0.10***	0.08**	0.15***	0.07**
	(0.02)	(0.03)	(0.02)	(0.03)
Vocational Years of Schooling				
Advanced Economies	0.20***	0.15***	0.20***	0.09
	(0.05)	(0.05)	(0.07)	(0.07)
East Asia and the Pacific	0.40	0.88	0.43	1.14**
	(0.40)	(0.54)	(0.42)	(0.49)
Europe and Central Asia	-0.01	0.08	-0.11	-0.05
	(0.05)	(0.07)	(0.16)	(0.20)
Latin America and the Caribbean	0.01	-0.13	-0.12	-0.37*
	(0.18)	(0.23)	(0.18)	(0.20)
North Africa and Middle East	-0.01	-0.07	0.01	-0.06
	(0.25)	(0.30)	(0.22)	(0.24)
South Asia	0.72	20.45***	3.39	35.78***
	(7.10)	(4.20)	(11.82)	(3.98)
Sub-Saharan Africa	-1.02	-0.99	-2.07**	-1.55*
	(0.72)	(0.84)	(0.83)	(0.79)
Oil exporter and time dummies	yes	yes	yes	yes
Constant	7.73***	8.00***	8.20***	8.77***
	(0.11)	(0.18)	(0.11)	(0.15)
Observations	756	756	630	630
Countries	100	100	99	99
R-sq. within	0.63	0.65	0.37	0.41
R-sq. between	0.85	0.81	0.82	0.74
R-sq. overall	0.82	0.78	0.79	0.70

Notes: Robust standard errors in parentheses.
K stands for Physical Capital. PWT stands for Penn World Tables 6.3. * p<0.10, ** p<0.05, *** p<0.01.

Modification of the B&L Replication: Changing the Dependent Variable to GDP per Capita

The most important modification we make in this section is to test our vocational secondary schooling variable using GDP per Capita instead of GDP per worker. We use the Maddison project data set (Bolt and van Zanden, 2014) which has GDP per capita data up to and including 2015, although most of our other variables are only available until 2010.[3] In our opinion these data are to be preferred to the PWT data, because of their stronger reliance on national sources. Our strategy is generally to replicate using PWT and then shift to the Maddison dataset. When we switch our dependent variable to GDP per Capita (Table 5), we see that the coefficient on vocational secondary schooling jumps in magnitude. We take this as evidence for an indirect effect of vocational education on economic performance. As noted previously, vocational education could affect economic performance by (a) increasing the efficiency of workers, which would be captured by GDP per worker, or by (b) facilitating smoother linkages between school and work, which is more likely to be captured by GDP per Capita.

That is, rewriting GDP per Capita as a product of GDP per Worker and Worker-to-Population ratio implies: $\log\left(\frac{GDP}{Population}\right) = \log\left(\frac{GDP}{Worker}\right) + \log\left(\frac{Worker}{Population}\right)$ and makes it evident that the effect on GDP per Capita can be larger than the effect on GDP per Worker.

From this replication we learn that changes to other variables and datasets can alter the results (sometimes dramatically). The implications for the relationship between years of schooling and economic performance can be very different. When we include the vocational variable, we find differences and see that the two types of education may also influence each other. Including the vocational secondary schooling variable often gives a 'bump' to the coefficient on non-vocational years of schooling. It seems the two types of education have some complementarities (i.e., the greater the overall levels of education in an economy, the greater the value added of vocational education). The construction of the vocational variable as a partial partition of the years of schooling variable makes the two variables additive in nature. To treat them as a multiplicative term may be stretching the limits of the data. The key takeaway from this first replication is that vocational secondary schooling does make a difference for economic performance and to support the notion that its economic effect is likely to be indirect and therefore, better captured by GDP per Capita than by GDP per Worker.

[3] When we replicate Szirmai and Verspagen (2015) we use the same Maddison (2009) database they use, the differences are small and mainly lie in the fact that the Bolt and van Zanden data set covers a longer period.

Table 5 Converting the Dependent Variable to GDP per Capita in the Barro & Lee Model

Time period 1960-2005				
Dependent Variable = Log GDP per Capita				
	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log K per Worker PWT 6.3	0.34***	0.30***	0.26***	0.18***
	(0.05)	(0.06)	(0.04)	(0.05)
Non-vocational Years of Schooling	0.14***	0.12***	0.15***	0.09***
	(0.02)	(0.03)	(0.02)	(0.03)
Vocational Years of Secondary Schooling	0.22***	0.19***	0.13*	0.05
	(0.05)	(0.06)	(0.07)	(0.08)
Constant	6.29***	6.45***	6.76***	7.18***
	(0.09)	(0.16)	(0.10)	(0.18)
Observations	756	756	693	693
Countries	100	100	99	99
R-sq. within	0.69	0.69	0.55	0.57
R-sq. between	0.85	0.84	0.83	0.82
R-sq. overall	0.82	0.81	0.79	0.76
	(5)	(6)	(7)	(8)
Log K per Worker PWT 6.3	0.32***	0.27***	0.24***	0.16***
	(0.05)	(0.06)	(0.04)	(0.05)
Average Years of Schooling (25+)	0.14***	0.10***	0.15***	0.07**
	(0.02)	(0.03)	(0.02)	(0.03)
Vocational Years of Schooling				
Advanced Economies	0.31***	0.23***	0.21***	0.07
	(0.05)	(0.05)	(0.06)	(0.06)
East Asia and the Pacific	1.08***	1.52***	0.90***	1.46***
	(0.27)	(0.34)	(0.33)	(0.39)
Europe and Central Asia	-0.01	-0.02	-0.11	-0.15
	(0.12)	(0.11)	(0.18)	(0.18)
Latin America and the Caribbean	0.24	0.14	0.14	-0.02
	(0.17)	(0.21)	(0.20)	(0.23)
North Africa and Middle East	0.13	0.16	0.07	0.10
	(0.17)	(0.19)	(0.19)	(0.17)
South Asia	-1.54	23.00***	10.06	43.97***
	(12.94)	(4.17)	(18.30)	(4.10)
Sub-Saharan Africa	-0.97**	-0.91**	-3.00***	-2.59***
	(0.43)	(0.45)	(0.76)	(0.74)
Constant	6.37***	6.62***	6.84***	7.32***
	(0.10)	(0.16)	(0.10)	(0.14)
Observations	756	756	693	693
Countries	100	100	99	99
R-sq. within	0.71	0.72	0.60	0.63
R-sq. between	0.85	0.82	0.84	0.73
R-sq. overall	0.83	0.79	0.81	0.69

Notes: Robust standard errors in parentheses.
K stands for Physical Capital. PWT stands for Penn World Tables 6.3. * p<0.10, ** p<0.05, *** p<0.01.

1.5.2 Replication of Szirmai and Verspagen (2015)

In this sub-section, we move toward a more complex analysis that merges our interest in VET human capital with structural change and closer to the underpinnings of the theories that support the notion that vocational education formation may play a special role in catch-up. Szirmai and Verspagen (2015) already found evidence that when interacting years of schooling (as a proxy for absorptive capacities) with an economy's share of manufacturing while also interacting that same share of manufacturing with the relative distance of the economy to the front-runner (in this case the U.S.), that 'years of schooling' do matter for the pace of growth.

We use the same dataset that Szirmai and Verspagen use and describe in their paper (Table 6). The sector shares are value added shares at current prices and are from UN national accounts statistics; WDI; Groningen Growth and Development Centre 60-industry, 10-industry and EUKLEMS databases; and UNIDO Industrial Statistics database. The data on manufacturing are described in more detail in Szirmai (2015). The openness indicator is in current prices and is expressed as a percent (exports plus imports as a percent of GDP). The climate zone data are from Gallup et al. (1999), where the following two variables were combined: "Dry Temperate (% land area)" + "Wet Temperate (% land area)" to create a dummy variable (following Szirmai & Verspagen) where the variable takes a 1 if >50% of the land area is in the temperate zone. The initial replication uses the same data from Barro and Lee (2010) on the average years of schooling for the adult population above the age of fifteen and supplemented with data from Lutz et al. (2007) and Cohen and Soto (2007). We subsequently switch to the Barro and Lee (2010) dataset on the average years of schooling for the adult population above the age of 25 and introduce our vocational variables. Note that we do not have the same number of countries and observations (N), primarily due to the fact that there are fewer countries for which vocational data are available. The change in N seems to affect some variables more than others, particularly the education variables and the openness variable.

Table 6 Descriptive Statistics of the panel dataset 1950-2015

Variable		Mean	Std. Dev.	Min	Max	Observations	
gr	overall	2.23	2.87	-17.41	13.58	No. of Obs.	818
	between		1.33	-0.26	5.65	No. of Countries	76
	within		2.54	-14.92	13.50	T-bar	10.76
man	overall	17.78	8.12	0.00	44.80	No. of Obs.	724
	between		6.26	5.53	30.66	No. of Countries	76
	within		5.29	-4.26	45.58	T-bar	9.53
ser	overall	48.86	12.33	0.00	86.50	No. of Obs.	721
	between		9.73	24.32	74.03	No. of Countries	76
	within		8.24	-4.46	90.70	T-bar	9.49
relus	overall	30.49	26.74	1.40	115.70	No. of Obs.	818
	between		26.00	2.95	98.35	No. of Countries	76
	within		7.36	-7.65	65.71	T-bar	10.76
edu_15+(S&V dataset)	overall	4.77	2.70	0.10	11.85	No. of Obs.	809
	between		2.42	1.01	10.09	No. of Countries	76
	within		1.31	1.24	8.63	T-bar	10.64
kgatemp	overall	0.28	0.45	0.00	1.00	No. of Obs.	1694
	between		0.45	0.00	1.00	No. of Countries	121
	within		0.00	0.28	0.28	T-bar	14
Openness	overall	69.31	50.66	5.05	446.06	No. of Obs.	1179
	between		46.57	13.91	350.29	No. of Countries	121
	within		22.45	-32.82	228.33	T-bar	9.74
Years of Secondary	overall	0.18	0.26	0.00	2.06	No. of Obs.	1234
Vocational Schooling	between		0.22	0.00	0.93	No. of Countries	121
	within		0.13	-0.57	1.38	T-bar	10.20
Years of Schooling (15+)	overall	5.45	3.21	0.02	13.02	No. of Obs.	1573
Barro and Lee	between		2.62	0.75	10.95	No. of Countries	121
	within		1.88	1.15	10.33	T-bar	13
Years of Schooling (25+)	overall	5.06	3.32	0.00	13.42	No. of Obs.	1573
Barro and Lee	between		2.73	0.52	10.79	No. of Countries	121
	within		1.92	0.41	10.43	T-bar	13
ln(pop)	overall	9.31	1.51	5.69	14.05	No. of Obs.	836
	between		1.48	5.87	13.67	No. of Countries	76
	within		0.36	8.02	10.35	T-bar	11

Source: Own elaboration based on data collected by Szirmai and Verspagen and primary sources described in Section 3 of this paper.
Notes: The between standard deviation refers to cross country variation in average values of the variables. Within standard deviation refers to the average of the pooled standard deviations with countries. T-bar refers to average number of observations per country.[4]

Appendix 3 shows the replication of Szirmai and Verspagen 2015. We ran regressions to make sure that our adjustments (fewer N) do not compromise the original results found by Szirmai and

[4] Recall, kgatemp is a dummy variable that takes a 1 if >50% of the land area is in the temperate zone. Openness is exports plus imports as a percent of GDP (current prices). gr is the growth of GDP per capita per 5 year period. Man and Ser are the value added shares of manufacturing and service sectors in the economy's GDP at the start of the five year period. Relus is the GDP per Capita relative to the U.S. at the start of each five year period. Edu_15+(S&V dataset) is the years of schooling variable that was used by Szirmai and Verspagen. Ln(pop) is the log of the population size at the start of the period.

Verspagen. The results are quite similar, though as expected, with some notable differences with respect to the significance of manufacturing in the Hausman-Taylor and Between Effects estimations (Appendix 2, Table 16, columns 3 and 4). With the larger number of countries they were using, Szirmai and Verspagen found that the effect of the share of manufacturing was significant at the 5 percent level in both the Hausman-Taylor and Between Effects estimations. With a reduced number of countries, we find that the coefficient of the share of manufacturing is only significant at the 10 percent level in the Between Effects estimation, and not significant in the Hausman-Taylor estimation. Interestingly, we find the share of manufacturing to be a significant factor/determinant at the 10 percent level in the Fixed Effects estimation, whereas they did not find it was significant. We have the most similar results for this variable in the Random Effects setting, where we both find it is significant at the 5 percent level and the coefficients are similar in magnitude.

We continue to follow Szirmai and Verspagen and introduce interaction terms and estimate variations on the equation they estimate:

$$GR = \alpha Man + \beta RELUS + \gamma EDU + \phi MANREL + \varphi MANEDU + \nu X \qquad (2)$$

The initial interaction terms are MANREL, which is the interaction between the Manufacturing value added share in the economy's GDP multiplied by the distance of the country to the frontier (the economy's GDP relative to the U.S. at the start of the period). The second interaction term is between the Manufacturing value-added share in the economy's GDP multiplied by the average years of schooling in the population 15 years and above. Hausman-Taylor specification is used in all of the subsequent regressions and Openness and the Population size of the economy are treated as exogenous, and the variable KGATEMP (a dummy variable taking the value of 1 if more than 50 percent of the land in the country is in the temperate zone) is taken as time invariant. Subscripts i and t are suppressed for simplicity.

We also followed Szirmai and Verspagen in introducing slope shift dummies for three relevant sub-periods (1950-1970; 1970-1990; 1990-2005). As they note, by using the slope shift dummies rather than running separate estimations for each of the time periods, we are assuming that the country fixed effects are constant over the entire time period (1950-2005). Results in

Table 7 are comparable with the results they present in their Table 4. In the results presented here the exogenous and time invariant variables are included in all specifications, but are not reported. The slope shift coefficients are likewise suppressed. A full table of results is available upon request.

Column 1 in Table 7 is our replication of their Hausman-Taylor estimation that includes the slope shift dummies (50-70, 70-90 and 90-05), but does not include any interaction terms. Column 2 is our replication of their final specification which incorporates both the slope shift dummies and interaction terms. The results are similar with some notable differences. They find that when both interaction terms are used, education (overall years of schooling 15+) is significant in all the three time periods. Using the same education data as they use, but with a reduced number of countries, we find that education is only significant in the first time period (1950-1970) and not significant after 1970.

Similarly, our results for the interaction terms tend to follow theirs, although we do not find significance for MANREL or MANEDU in the period 1970-1990. Generally speaking, the time period

1970-1990 appears to have different trends from the rest of the periods. It is the period in which the service sector consistently becomes significant across all specifications. The distance to the frontier (RELUS) is robust across the later periods (from 1970 onward).

Table 7 Growth Estimations for 3 Periods using Hausman Taylor: Replication and Extension of Szirmai and Verspagen Analysis

Dependent Variable: Growth of per capita GDP (Maddison 2009)					
	Replication S&V			Add Vocational Secondary	
	No Interactions	Interactions		No Interactions	Interactions
	(1)	(2)		(3)	(4)
Edu 50-70 (S&V)	-0.10	-0.86**	Non-Vocational 50-70	-0.04	-1.48***
	(0.16)	(0.35)		(0.27)	(0.49)
Edu 70-90 (S&V)	0.24	-0.05	Non-Vocational 70-90	0.17	-0.21
	(0.19)	(0.40)		(0.25)	(0.39)
Edu 90-05 (S&V)	0.28	-0.59	Non-Vocational 90-05	0.31	0.12
	(0.18)	(0.48)		(0.22)	(0.38)
			Vocational 50-70	**1.76**	**7.00***
				(1.47)	(3.61)
			Vocational 70-90	-0.57	-8.38***
				(0.90)	(2.37)
			Vocational 90-05	0.17	-2.91**
				(0.66)	(1.36)
manu50_70	-0.03	-0.09	manu50_70	-0.07	-0.20***
	(0.04)	(0.06)		(0.05)	(0.06)
manu70_90	0.04	0.00	manu70_90	0.05	0.01
	(0.04)	(0.07)		(0.04)	(0.07)
manu90_05	0.02	-0.12	manu90_05	-0.01	-0.04
	(0.03)	(0.11)		(0.04)	(0.10)
ser50_70	-0.00	0.00	ser50_70	-0.02	-0.03
	(0.02)	(0.02)		(0.03)	(0.03)
ser70_90	0.07***	0.07***	ser70_90	0.05**	0.06**
	(0.03)	(0.03)		(0.03)	(0.03)
ser90_05	-0.01	-0.01	ser90_05	-0.02	-0.01
	(0.02)	(0.02)		(0.03)	(0.03)
relus50_70	-0.06***	-0.02	relus50_70	-0.08***	-0.07***
	(0.02)	(0.03)		(0.02)	(0.02)
relus70_90	-0.13***	-0.10**	relus70_90	-0.13***	-0.17***
	(0.02)	(0.04)		(0.02)	(0.02)
relus90_05	-0.12***	-0.03	relus90_05	-0.13***	-0.16***
	(0.02)	(0.05)		(0.02)	(0.03)
manrel50_70		-0.002*			
		(0.00)			
manrel70_90		-0.001			
		(0.00)			
manrel90_05		-0.004*			
		(0.00)			
manedu50_70		0.04**	manedu* 50_70		0.05***
		(0.02)			(0.02)
manedu70_90		0.01	manedu* 70_90		0.02
		(0.02)			(0.02)
manedu90_05		0.04*	manedu* 90_05		0.01
		(0.02)			(0.02)
			relvoc50_70		-0.09
					(0.06)
			relvoc70_90		**0.13*** **
					(0.04)
			relvoc90_05		**0.05*** **
					(0.02)
Constant	14.87***	13.77***		10.39*	19.09***
	(4.60)	(4.43)		(6.01)	(5.61)
Observations	679	679		588	588
Countries	76	76		76	76
Rho	0.91	0.90		0.93	0.93

Notes: Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

The next step is to introduce our vocational education variable, which initially does not seem to have a big effect. Column 3 shows the results are qualitatively quite similar to the results in column 1 – the results without vocational secondary schooling. When we introduce the interaction terms, we find that the interaction term between share of manufacturing and vocational secondary schooling appears to be perfectly correlated with the set of other regressors and therefore it is omitted from the regression results in two periods. This result might have been anticipated (especially for the earlier periods), but it lends some credence to the notion that there is a relationship between vocational education and the productive structure of the economy. To test our hypothesis that vocational education plays a crucial role in absorptive capacity and catch-up, we decided to interact vocational secondary schooling with RELUS.

The interaction term between RELUS and Vocational secondary schooling tends to be positive and significant, indicating that more vocational secondary schooling may help countries to 'run faster' to catch the leading economy, but this help comes as countries are already getting closer to the frontier. There is an interesting pattern in how vocational secondary schooling behaves in the different time periods. From 1950-1970, the partial effect of vocational secondary schooling is positively associated with growth, but the interaction term, while negative – is insignificant. This means that vocational secondary schooling in that period had a positive effect on growth, regardless of the economy's distance to the frontier. In the later periods, the partial effect of vocational secondary schooling is negatively associated with growth, but the interaction term is positive and significant. This means that the growth effect of vocational education changes and improves as the economy gets closer to the frontier. These results, coupled with structural argument from Szirmai and Verspagen's original findings, suggest that, as the structure of the economy changes, the relationship between education and growth also changes.

1.5.3 Replication of Pritchett (2001)

In this sub-section, we describe (a) Pritchett's analysis and the steps we took to replicate it, (b) what happens when we update the data and introduce our vocational variable, and (c) the potential contribution his work could make to refining the 'Educational Capital' variable to allow the *r* to vary with levels of educational attainment.

Following Pritchett, we calculate the growth of the stock of education capital as:

$$h\dot{k}(t) \cong dln\left(exp^{RN(t)} - 1\right)/dt \tag{3}$$

Where hk is 'Education Capital', R is the wage increment to a year's schooling which is assumed to be 10 percent[5] and constant across all years of schooling, and N is the number of years of schooling at a given time, *t*. As Pritchett notes in his paper, the growth of each variable is calculated as the logarithmic least squares growth rate over the entire period. We follow the same methodology. This means that the growth rate is estimated by fitting a least squares regression line to the logarithmic annual (or 5-year interval) values of the variable over time:

$$\ln X_t = a + bt, \tag{4}$$

[5] Pritchett defends this assumption on the basis of a survey of wage increments by region, arguing that cross-national differences in the growth rate of educational capital are robust when r is changed.

where X is the variable and t is time. The parameters to be estimated[6] are: a = ln X_0 and b= ln(1+r). We calculate the least squares growth for each variable from 1960-1985. We calculate these growth rates by country[7] and then use OLS to regress the calculated growth of GDP per worker on the Growth of Education Capital and Physical capital. We include the natural log of GDP per Worker in 1960 in all columns labeled (2) in Table 8 below.

Pritchett used Barro and Lee's 1993 data set on Average Years of Schooling in the population aged 25 and older[8] for most of his analysis. We were able to access the 1993 dataset through the Barroandlee.com website. This ensures that we are using the same data as Pritchett used to construct his Educational Capital variable. Pritchett used Penn World Tables (PWT) Mark 5 for the dependent variable of GDP per worker. The Barro and Lee 1993 dataset preserves the PWT 5 data (GDP and Employment) in 5 year intervals. Pritchett may have used annual data from the original source, but we are comfortable with using the 5-year intervals, since Educational Capital is also in 5-year intervals. Pritchett used two series for physical 'capital stock' (King and Levine 1994 and Nehru and Dhareshawr 1993). We were not able to recover those data sets and so we use a measure of capital stock computed using the PWT 6.3 dataset following a Perpetual Inventory Method (PIM) and estimation of Initial Capital to Output ratios that seem to approximate the second PIM methodology described by King and Levine in their 1994 paper. We know that specifications are particularly sensitive to changes in the physical capital variable, so we also try using the most updated and comparable capital variable available from PWT 9.

Our sample consists of 91 countries (the same number of countries as Pritchett), when we use PWT 6.3 for Capital per worker. We lose one country when we include initial GDP per worker. For comparative purposes the results from Pritchett (2001) are presented in the first two columns of Table 8 and are highlighted in grey. In columns 1a and 2a we present our first replication results where we get a coefficient on Education Capital that is very close to Pritchett's. Using PWT 6.3, however, our coefficient for Capital per Worker is much smaller than Pritchett's and smaller than expected in this type of regression.

Table 8 Growth-Accounting of GDP per Worker Growth: Replication of Pritchett Analysis

	PRITCHETT RESULTS		Replication (USING LOG LEAST SQUARES of			
DV: Per annum growth of GDP per Worker (PWT 5)	OLS		K = PWT 6.3		K = PWT 9	
	Pritchett	Pritchett	(1a)	(2a)	(1b)	(2b)
Growth of 'Education Capital' per Worker (B&L 1993)	-0.049	-0.038	-0.004	-0.02	0.038	-0.028
	(1.07)	(0.795)	(0.07)	(0.07)	(0.06)	-0.06
Growth in Capital* per Worker	0.524	0.526	0.205***	0.201***	0.357***	0.392***
	(12.8)	(12.8)	(0.05)	(0.05)	(0.05)	-0.05
ln (initial GDP per Worker)		0.0009		-0.001		-0.006***
		(0.625)		(0.002)		(0.002)
Constant			0.016***	0.026*	0.013***	0.056***
			(0.003)	(0.01)	(0.003)	(0.02)
Countries	91	91	91	90	90	89
R-squared	0.653	0.655	0.307	0.308	0.326	0.391

Notes: Pritchett has t-statistics in parentheses and we have Standard errors in parentheses. *Pritchett calls Capital Cumulated Depreciated Investment Effort 'CUDIE' in his results table. * p<0.10, ** p<0.05, *** p<0.01.

[6]The World Bank (http://econ.worldbank.org/) describes this method in more detail and explains that equation 2 is equivalent to the logarithmic transformation of a compound growth equation $X_t = X_0 (1+r)^t$ and that if b* is the least-squares estimate of b, the average annual growth rate can be obtained by [exp(b*)-1] and multiplying by 100 for a percent.

[7] We are assuming this is a necessary step in order to run the OLS on the entire sample (as Pritchett indicates in columns 1 and 2 of his regression table); but we also tried using the annualized change in logs as Cohen and Soto (2007) did when they replicated Pritchett and we arrive a similar estimates to theirs which are also close to Pritchett's results.

[8] Pritchett restricted 'Years of Schooling' to age 25-65 (robustness check) and 'instrumented' B&L data by using a similar dataset from Nehru et al. (1995).

In columns 1b and 2b we repeat the same estimations changing only the capital per worker variable to PWT 9. We find, as we have found in other parts of this paper that changing the capital variable changes the results. When we switch to PWT 9 for the Capital per Worker variable, the results have a larger coefficient, not quite as large as Pritchett's, but the coefficients are more in line with expectations.

When we update the data (tables available upon request) we arrive at coefficients for growth of Capital per Worker that are more in line with Pritchett's original findings and the R-squared also shoots up to 0.73 when we use Capital from PWT 9. The results thus far, convince us that we have reasonably approximated Pritchett's methodology and have confirmed his findings. We therefore move on to consider how distinguishing vocational and non-vocational education in the Education Capital variable affects the results. This is done in Table 9. In this table we continue to assume a 10 percent rate of return to all types of schooling. Bear in mind that the part of educational capital that can be attributed to vocational schooling is always much smaller than non-vocational years of schooling, regardless of whether we find differences in how the two education capital variables behave. The coefficient of vocational education capital is positive. It remains insignificant in all cases, except when using PWT 6.3 with initial GDP (column 4a), and even then, it is only significant at the 10 percent level. The coefficient on non-vocational educational capital remains negative and insignificant.

Table 9 Growth-Accounting of GDP per Worker Growth: Extension of Pritchett Analysis

	Distinguishing Non-Vocational and Vocational Education			
DV: Per annum growth of GDP per Worker	GDP and K = PWT 6.3		GDP and K = PWT 9	
	(3a)	(4a)	(3b)	(4b)
Growth of 'Non-vocational Education Capital' per Worker	-0.12	-0.12	-0.06	-0.12
	(0.10)	(0.14)	(0.06)	(0.10)
Growth of 'Vocational Education Capital' per Worker	0.04	0.11*	0.01	0.03
	(0.07)	(0.06)	(0.04)	(0.04)
Growth in Capital* per Worker	0.36***	0.26***	0.63***	0.54***
	(0.08)	(0.06)	(0.06)	(0.08)
ln (initial GDP per Worker)		-0.002		-0.004**
		(0.002)		(0.002)
Constant	0.01**	0.03	0.004	0.04**
	(0.004)	(0.02)	(0.002)	(0.02)
Countries	95	77	95	64
R-squared	0.38	0.40	0.73	0.73

Notes: Pritchett has t-statistics in parentheses and I have Standard errors in parentheses. *Pritchett calls Capital 'CUDIE' in his results table: Cumulated Depreciated Investment Effort. * p<0.10, ** p<0.05, *** p<0.01.

In Table 10 and Appendix 3 Table 17 we make use of data which (somewhat surprisingly) Pritchett did not use himself. Within the Barro and Lee data, it is possible to have Years of Schooling in Primary, Secondary and Tertiary (and it was also possible to have that information in the 1993 dataset). In his first descriptive table Pritchett shows the calculated wage premiums of different levels of educational attainment and changes the assumed constant r to vary with primary, secondary, and tertiary attainment. In the regressions, however, he used only the constant 10 percent rate of return. Something interesting happens when we divide education capital into primary, secondary and tertiary (including a differentiation between non-vocational and vocational at the secondary level). We see that the negative coefficients on primary become significant. This finding may at first seem contrary to the literature. But, as Pritchett himself points out, although the literature often repeats that the greatest returns are highest for primary schooling (for example, in Psacharopolous 1993) this is not because the increment in wages is higher for one year of primary school, but rather because the opportunity cost is lower (Pritchett, 2001: pg 373).

The coefficients on non-vocational secondary schooling are mostly negative and insignificant. The coefficients are positive almost consistently across the board for *vocational* secondary schooling. The coefficients on Tertiary are positive, often large and significant. This is the case when we assume the highest return to primary (as Pritchett does in his first table; adjusting his wage r assumption to account for international evidence from Psacharopoulos 1993), but the results also hold when we assume the highest return to tertiary. This implies that the externalities (at the macro level) vary with the level of education achieved, and that tertiary education does indeed have a higher than expected return (implying positive externalities). Furthermore, when more of the workforce is limited to just a primary education, then there is indeed some evidence of negative externalities (as far as growth is concerned). This just makes sense.

What is interesting is that, although mostly statistically insignificant, the transition from negative to positive coefficients seems to occur with vocational secondary education capital. For now we have kept the assumed return to vocational secondary the same as for non-vocational secondary, but a sensitivity analysis could be performed to see how much changing the assumed rates of return could affect the results.

Table 10 Education Capital Broken down into Primary, Secondary (Non-vocational), Secondary Vocational) and Tertiary | Highest r to Primary

	Split Educational Capital into Primary, Secondary (Vocational and Non-Vocational) and Tertiary			
	GDP and K = PWT 6.3		GDP and K = PWT 9	
	(5a)	(6a)	(5b)	(6b)
Growth of 'Primary Capital' per Worker (r = 0.16)	-0.25**	-0.24*	-0.14**	-0.13
	(0.11)	(0.14)	(0.06)	(0.08)
Growth of 'Secondary Non-Vocational Capital' per Worker (r=0.12)	-0.02	-0.14	0.04	-0.04
	(0.09)	(0.10)	(0.04)	(0.06)
Growth of 'Secondary Vocational Capital' per Worker (r=0.12)	0.03	0.11*	0.02	0.03
	(0.07)	(0.06)	(0.04)	(0.04)
Growth of 'Tertiary Capital' per Worker (r = 0.08)	0.37***	0.24**	0.14*	0.03
	(0.13)	(0.10)	(0.08)	(0.09)
Growth in Capital* per Worker	0.33***	0.25***	0.60***	0.52***
	(0.07)	(0.06)	(0.06)	(0.08)
ln (initial GDP per Worker)		-0.004*		-0.005**
		(0.002)		(0.002)
Constant	-0.003	0.05*	-0.003	0.05**
	(0.01)	(0.03)	(0.004)	(0.02)
Countries	95	77	95	64
R-squared	0.47	0.48	0.75	0.74

Notes: Pritchett has t-statistics in parentheses and I have Standard errors in parentheses. *Pritchett calls Capital 'CUDIE' in his results table: Cumulated Depreciated Investment Effort.
* p<0.10, ** p<0.05, *** p<0.01.

In replicating Pritchett, we find empirical evidence that the social returns to human capital might not be uniform for different educational groups. Ang et al., 2011 argue there is no reason to think a priori that the social returns would be the same, as is assumed when they are combined in one measure in macroeconomic studies. Ang et al. employ a system GMM estimator for a panel of 87 countries from 1970-2004 and divide educational categories into Primary, Secondary and Tertiary. They find growth enhancing effects of tertiary education when countries move closer to the frontier in high and medium income countries. This is something we will continue to explore as we move into the next section and our own empirical approach.

1.5.4 Replication of Benhabib and Spiegel (2005)

The Benhabib and Spiegel model represents our preferred way of looking at the relationship between vocational education formation and economic performance, because it has an explicit theoretical grounding (see section 3.2.4). Nevertheless, this specification is limiting in the sense that it only examines the relationship between human capital and total factor productivity (TFP). TFP is important, but it is only one of the factors driving growth in an economy. So in our own empirical approach we will return to the broader measure for economic performance, GDP per capita.

The Benhabib and Spiegel model is a variation of the original Nelson-Phelps model of technology diffusion:

$$\frac{\dot{A}_i(t)}{A_i(t)} = \mathrm{g}\big(H_i(t)\big) + c\big(\big(H_i(t)\big)\left(\frac{A_m(t)}{A_i(t)} - 1\right) \tag{5}$$

Where $A_i(t)$ is TFP, $\mathrm{g}_i\big(H_i(t)\big)$ is the part of TFP growth that relies on education in country i, and $c\big(\big(H_i(t)\big)\left(\frac{A_m(t)}{A_i(t)} - 1\right)$ is the rate at which the technology diffuses between country m (leader) and country i (follower). This rate at which technology is absorbed from abroad also depends on education in country i.

Benhabib and Spiegel assume that $g_i(\cdot)$ and $c_i(\cdot)$ are increasing functions and they model education as a factor that facilitates technology diffusion in the following non-linear cross-sectional specification:

$$\Delta a_i = \beta_1 h_i - \beta_2 h_i \left(\frac{A_i}{A_m}\right)^s + \varepsilon_i \tag{6}$$

In their specification Δa_i is the average annual growth in TFP in country *i,* and h_i is the log of human capital stock of country *i* which is measured as either the initial human capital stock or its average over the time period. They use maximum likelihood to estimate: β_1 the parameter whose coefficient is meant to capture the country's capacity to conduct innovative activity, and β_2 the parameter whose coefficient represents the catch-up term and is meant to capture the capacity for technology adoption from abroad. In the catch-up term, h_i is multiplied by the ratio of the country's TFP (A_i) to the TFP of the productivity leader nation (A_m). The TFP ratio is a proxy of the distance from the technological frontier. In the logistic model, *s* equals 1, and in the exponential model, *s* equals -1. Since Benhabib and Spiegel favor the logistic specification, we replicate the logistic model (setting *s* equal to 1), and make our modifications from there.

In essence, Benhabib and Spiegel say that they have distinguished human capital a la Romer (1990) within a Nelson-Phelps framework and they abstract from issues regarding the distribution of H_i to innovation or imitation (catch-up) and assume that all of it enters in both terms. Although they do allude to an interest in considering how the distribution between imitative and innovative uses of human capital might change with the distance to the frontier. It is this idea of the different functions of human capital as represented by the two terms that makes their model particularly interesting for exploring how their results might change if we can distinguish vocational and non-vocational education. As we have argued above, vocational human capital can make a special contribution to absorptive capacity, and may thus be related to the technology absorption from abroad (imitation) that contributes to catch up.

In order to assess the importance of the vocational variable from this conceptual vantage point, we first try to replicate Benhabib and Spiegel's results as closely as possible and then we experiment with distinguishing the contributions of vocational and non-vocational human capital.

Table 11 Education and Technology Diffusion: Replication of the Benhabib and Spiegel Analysis

	Dependent Variable: Log Average annual growth of TFP (1960–1995)							
	B&S: Table 2		Replication		B&S: Table 3		Replication (H= 1960-1985)	
$\ln(H_{1960})$	0.0100**	0.0134**	0.0058**	0.0121***				
	(0.0023)	(0.0025)	(0.002)	(0.001)				
$\ln(H_{1960})*(TFP_i / TFP_m)^s$	-0.0089**	-0.0072**	-0.0222***	-0.0416***				
	(0.0036)	(0.0025)	(0.01)	(0.01)				
$\ln(\overline{H}_{1960\text{-}1995})$					0.0184**	0.0159**	0.0066***	0.0095***
					(0.0026)	(0.0017)	(0.001)	(0.0009)
$\ln(\overline{H}_{1960\text{-}1995})*(TFP_i / TFP_m)^s$					-0.0135**	-0.0122**	-0.0260***	-0.0343***
					(0.0031)	(0.0029)	(0.01)	(0.004)
Constant	0.0085**	--	0.0093**	--	-0.0030	--	0.0054	--
	(0.0016)		(0.004)		(0.0024)		(0.003)	
S	1	1	1	1	1	1	1	1
Observations	84	84	80	80	84	84	83	83
Log likelihood	263.9	263.9	212.4	209.2	274.4	273.6	225.7	224.1
Wald P-value	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00

Notes: Following Benhabib and Spiegel (B&S); estimation is by maximum likelihood with standard errors in parenthesis. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01. Results reported from B&S Table 3 calculate the average human capital levels as the simple averages beginning in 1960 and ending in 1995. In the 2 columns furthest to the right, simple averages for human capital begin in 1960 and end in 1985.

For this replication, Benhabib and Spiegel include the TFP data they used in an appendix to their paper, so we are sure that the data for the dependent variable and the TFP ratio are the same as the data they used. The Barro and Lee data that they used for Human Capital are from the 1993 dataset (the same data we used for the Pritchett replication, but updated to 1995). Unfortunately, we could only find data from the 1993 dataset up to 1985 and the updated Barro and Lee dataset from 2010 (which incorporated many changes in the way in which the variable is constructed). Therefore we use the 1993 Barro and Lee data for the first replication, which limits the replications to the years 1960-1985.

In the model which uses initial levels of human capital, ln (H_{1960}), this should not make any difference. In fact it does, because we have fewer observations (countries). The explanation for this is probably that the 'updated 1993 dataset' included some countries which were not yet included in the original 1993 B&L dataset. Nevertheless, our results are similar to those of Behabib and Spiegel in terms of signs and significance. We conclude that we have a close enough approximation to move forward with updating and modifying the data.

In Table 12, we first update the data for TFP to cover the full time period 1960-2010. In the first three models we leave the human capital variable as the Barro and Lee Years of Schooling (either initial or simple average over the time period) in both the first term and second term. Using the extended time period, when the constant term is incorporated (Models 1 and 2) the model as a whole is no longer fitting well. We can see that the p-values for the Wald are 0.26 and 0.24

respectively. Although Benhabib and Spiegel initially say that they are agnostic about including a constant term for *b*, later they state that their theory does not call for "a constant term independent of human capital to account for total factor productivity growth" (page 955). Nevertheless, they dutifully report all of their results with both with and without a constant term (as a kind of robustness check). In our case, since there is no theoretical reason that demands the inclusion of the constant term, we decided to drop the constant term for the rest of the models. We find that (Model 3) dropping the constant term improves the Wald p-value and makes the results qualitatively similar to those obtained from 1960-1995.

In Models 4 and 5 we replace years of schooling by non-vocational years of schooling (25+) in the first term representing innovative Human Capital. We use our vocational portion of years of schooling (at the secondary level) as a second catch-up term. We can see that qualitatively the results are similar.

Table 12 Vocational Education: Extension of the Benhabib and Spiegel Analysis

Dependent Variable = Average annual log growth of TFP (1960–2010)							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
$\ln(H_{1960})$ (Year of Schooling 25+)	-0.0003						
	(0.0003)						
$\ln(H_{1960})*(TFP_i / TFP_m)^s$	0.0008						
	(0.001)						
$\ln(\bar{H}_{1960\text{-}2010})$ Years of Schooling 25+		0.0005	0.001***				
		(0.0003)	(0.0001)				
$\ln(\bar{H}_{1960\text{-}1995})*(TFP_i / TFP_m)$ Years of Schooling $25+)^s$		-0.002*	-0.003***				
		(0.001)	(0.0005)				
$\ln(H_{1960})$ Non-vocational years of Schooling				0.0004***			
				(0.0001)			
$\ln(H_{1960})*(TFP_i / TFP_m)^s$ Vocational Secondary schooling				-0.001***		-0.001***	
				(0.0002)		(0.0001)	
$\ln(\bar{H}_{1960\text{-}2010})$ Non-vocational years of Schooling					0.0004***		
					(0.0001)		
$\ln(\bar{H}_{1960\text{-}1995})*(TFP_i / TFP_m)^s$ Vocational Secondary schooling					-0.0009***		-0.001***
					(0.0002)		(0.0002)
$\ln(H_{1960})$ Tertiary Schooling (25+)						0.03***	
						(0.004)	
$\ln(\bar{H}_{1960\text{-}2010})$ Tertiary Schooling (25+)							0.008***
							(0.0010)
Constant	0.003***	0.002*					
	(0.0007)	(0.001)					
S	1	1	1	1	1	1	1
Observations	89	89	89	73	89	89	89
Log likelihood	390.43	390.90	387.68	315.52	385.48	378.20	372.17
Wald P-value	0.26	0.24	0.00	0.00	0.00	0.00	0.00

Notes: Following Benhabib and Spiegel (B&S); estimation is by maximum likelihood with standard errors in parenthesis. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

In Models 6 & 7 we decided to enter years of tertiary schooling in the first term instead of total years of schooling, together with a catch up term for vocational education. We obtain similar results. The specifications with tertiary schooling seem to 'fit the data' at least as well as specifications with total education. The interpretation of columns 4 through 7 is that vocational education contributes significantly to absorptive capacity and catch up.

The results of the Benhabib and Spiegel replications, combined with our analysis of the role of vocational human capital in a catch-up incorporating the role of sectoral changes (Szirmai and Verspagen 2015), leads us to the conclusion that including vocational education in regressions of economic performance is a promising approach towards a better specification of the relation between education and the dynamics of production.

1.6 Own Empirical Approach

This section further investigates the mechanism through which vocational secondary schooling affects economic performance. Following systematic testing of the vocational variable in a variety of theoretical and empirical contexts, we reached the preliminary conclusion that vocational secondary schooling affects economic performance through the role it plays in equipping economies with the absorptive capacity needed for technology diffusion and catch-up. We already found some evidence that this role is mitigated by the economy's distance to the technological frontier. We have tested the vocational variable in settings that allow for some between country variation and treated some of our explanatory variables as endogenous (i.e., the Hausman-taylor specification in section 3.3). However, we have not addressed autoregressive dynamics, or the likely persistence of our variables. In other words, we have not specified models where y is a function of its own lag, our Xs, and lags of some of our Xs.

GMM offers a methodology to deal with explanatory variables that are not strictly exogenous and are persistent over time (Bond, 2002). Even if some scholars remain skeptical of a methodology which uses lags as instruments, GMM is now the most common alternative to a fixed effects model in the growth literature (Durlauf et al., 2005). So, it is useful to test our vocational variable using the GMM methodology. In our final specification, we are interested in explicitly assessing the joint relationship between vocational secondary schooling and the relative distance to the frontier.

In Table 13 we revisit the relationship between vocational secondary schooling and economic performance as measured by GDP per capita in levels (Panel A) and growth of GDP per capita (Panel B). For the sake of comparison, we include OLS fixed effects models in columns 1 and 2, without and with lags of our explanatory variables, respectively. When we initially introduce a lag of GDP per capita (see Appendix 5) the effects of most other explanatory variables are washed out. This is a common consequence of including the lagged dependent variable in OLS, regardless of whether the true causal effect of lag is strong, weak or impotent (Achen, 2001).

The GMM analysis shows that vocational secondary schooling is clearly associated with a contemporaneous positive and significant increase in GDP (columns 3 and 4) and growth of GDP per capita (column 6). The lagged coefficients, however, are negative and (often) significantly associated with economic performance. There appears to be a dynamic relationship between vocational education and economic performance over time. When we hold contemporaneous vocational secondary schooling constant, the marginal effect on economic performance of an increase in vocational secondary 5 years prior (t-1) is negative. This suggests that for two countries with the same amount of vocational secondary schooling in time t, the country with more vocational secondary schooling 5 years before (t-1) is associated with lower economic performance. In other words, countries with less vocational secondary schooling 5 years prior (t-1), but the same vocational secondary schooling in time t, accumulated vocational secondary schooling more rapidly and thus, reaped higher growth rates 5 to 10 years[9] later. Our results show that the backward trajectory of vocational secondary schooling matters for its effect on economic performance. Vocational secondary schooling always appears to be more relevant for economic performance than non-vocational years of schooling.

[9] Recall that the growth rate in time t, projects forward (t+1) and that each period represents 5 years.

Table 13 Vocational Secondary Schooling: GMM Results & Interaction with Distance to the Frontier

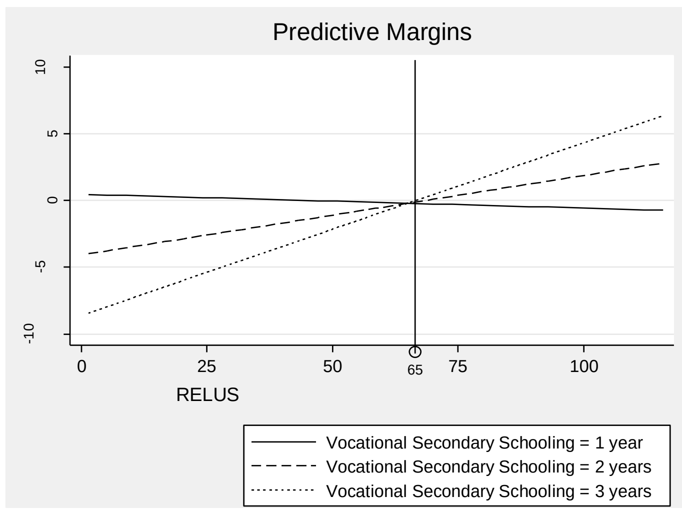
	Panel A LEVELS:				Panel B GROWTH:			
Dependent variable:	**Log GDP per capita 1960-2010**				**Growth of GDP per capita* 1960-2005**			
	OLS FE	OLS FE	GMM DIF	GMM SYS	GMM DIF	GMM SYS	GMM SYS + interactions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-vocational Years of Schooling	0.02	0.01	-0.004	-0.01	-0.16	1.10***	0.67*	0.95**
	(0.02)	(0.03)	(0.02)	(0.02)	(0.83)	(0.22)	(0.39)	(0.37)
Vocational Secondary Schooling	**0.07**	**0.10***	**0.07****	**0.08****	**1.78**	**1.56*****	**4.03****	**5.99*****
	(0.06)	(0.06)	(0.03)	(0.04)	(1.41)	(0.56)	(1.58)	(1.80)
Lag (1 period) Non-vocational Years of Schooling		0.02	0.005	0.02	-0.12	-0.66***	0.10	-0.10
		(0.03)	(0.02)	(0.02)	(0.73)	(0.23)	(0.44)	(0.41)
Lag (1 period) Vocational Secondary Schooling		**0.02**	**-0.05**	**-0.11*****	**-0.73**	**-1.81*****	**-7.17*****	**-10.53*****
		(0.06)	(0.04)	(0.04)	(1.60)	(0.53)	(1.48)	(2.19)
Log K per Worker PWT 9.0	0.52***	0.83***	0.35***	0.53***	1.16	2.53***	2.57***	2.24**
	(0.08)	(0.12)	(0.10)	(0.07)	(3.82)	(0.38)	(0.82)	(1.01)
Lag (1 period) Log K per Worker PWT 9.0		-0.34***	-0.24***	-0.49***	1.16	-3.39***	-3.27***	-3.57***
		(0.12)	(0.09)	(0.06)	(3.10)	(0.35)	(0.73)	(0.81)
Initial Log GDP per capita (start of 5 yr period)					-6.88***		0.83**	1.69***
					(2.26)		(0.34)	(0.50)
Lag (1 period) Log GDP per capita			0.70***	0.95***				
			(0.03)	(0.03)				
Lag (1 period) Growth of GDP per capita					0.08	0.10***	0.02	0.02
					(0.06)	(0.01)	(0.03)	(0.06)
RELUS							0.04*	0.02
							(0.03)	(0.06)
Lag (1 period) RELUS							-0.11***	-0.10
							(0.02)	(0.07)
Non-vocational # Relus								-0.01
								(0.01)
Lag (1 period) Non-vocational # Relus								0.01
								(0.01)
Vocational # Relus							**-0.04****	**-0.07*****
							(0.02)	**(0.02)**
Lag (1 period) Vocational # Relus							**0.09*****	**0.14*****
							(0.02)	**(0.03)**
Oil exporter, time dummies and constant included	y	y	y	y	y	y	y	y
Observations	901	774	657	774	384	467	467	467
Countries	105	105	99	105	70	76	76	76
R-sq.	0.76	0.74						
sarganp			0.00	0.01	0.00	0.01	0.01	0.00
hansenp			1.00	1.00	1.00	1.00	1.00	1.00
ar1p			0.00	0.00	0.00	0.00	0.00	0.00
ar2p			0.63	0.71	0.23	0.46	0.38	0.49

Notes: Growth of GDP per capita is per 5-year period (i.e. t+1, where each period represents 5 years). Robust Standard errors are in parentheses, with the exception of the two-step System GMM, where the co-variance matrix is already robust in theory (adding 'robust' requests Windmeijer's finite-sample correction for the two-step covariance matrix). Results for column 8 with Windmeijer's finite-sample correction are qualitatively similar for our vocational schooling variables. For columns 1-7 the GMM system instruments are the lags from t-2. For column 8, the GMM instruments are the lags from t-3.

We include results from both the first-differenced GMM and system GMM in Table 13 to illustrate the relatively consistent results for vocational secondary schooling using both approaches. The literature notes that first-differenced GMM may be downward biased, especially if the estimate is below or close to the within groups estimate (Bond et al., 2001). Therefore, we adopt the system GMM approach when we include the interaction terms in columns 7 and 8 to test whether the effect of vocational secondary schooling on growth depends on the economy's relative distance to the frontier.

In column 7, we introduce an interaction term between vocational secondary schooling and the distance to the frontier. The distance to the frontier is defined as the GDP per capita relative to the United States (RELUS) at the beginning of the 5 year period based on Maddison (2009). In column 8, we include an interaction between non-vocational schooling and the relative distance to the frontier. The relationship between contemporaneous vocational secondary schooling and growth of GDP per capita is positive and significant and the interaction between contemporaneous vocational secondary schooling and RELUS is negative and significant. The partial effect of lag of vocational secondary schooling is negative and significant, and the lagged interaction with RELUS is positive and significant. When coefficients for the partial effects are summed and tested for significance, the lagged effect dominates. The same is true of the coefficients of the interaction terms between vocational secondary schooling and RELUS. Taking everything together, the relationship suggests that there can be significant growth gains from additional vocational secondary schooling, but these gains tend to occur when the economy is already relatively close to the frontier and when levels of vocational secondary schooling are high and have accumulated relatively quickly in the previous period. Figure 0.1shows the distance from the frontier at which vocational secondary schooling contributes more to the predicted growth rate of the economy in the subsequent 5 years.

Figure 0.1 Predicted Growth Effects of Vocational Education at Different Distances to the Frontier



When the per capita GDP of the economy is roughly 65 percent of the per capita GDP of the U.S., an increase in vocational secondary schooling is associated with a positive and significant effect on the subsequent 5 year growth rate. The predicted marginal effects presented in Figure 0.1 are the post-estimation effects from our specification in column 8 of Table 13. Therefore the predict margins reflect both the contemporaneous and the lagged effects of the interaction between vocational secondary schooling and the relative distance to the frontier.

To summarize, we hypothesized that vocational secondary schooling is important for absorptive capacity. GMM analysis shows this hypothesis this to be credible, but in order to take advantage of gains from absorptive capacity developed through vocational secondary schooling, the economy already has to be relatively close to the frontier. In our dataset, the mean for RELUS is 31 percent, but the median is 21 percent. That means that most of the economies in our dataset have not yet reached the distance at which they can take advantage of additional vocational secondary schooling. We believe that we can link this finding to our regional analysis in the first part of this paper. In those results the regions that benefited most from additional vocational secondary schooling, were Advanced economies and the East Asian region. In sub-Saharan Africa, additional vocational secondary schooling was found to be negatively associated with economic performance. Economies closer to the frontier gain more from increased vocational secondary schooling.

1.7 Discussion, Conclusions and Implications for Future Research

This paper comprehensively and systematically tested vocational secondary schooling and we found that it is consistently related to macroeconomic performance. Through the process of replicating four studies that are emblematic of distinct theoretical and empirical approaches, we covered much of the scholarly ground that analyzes the relationship between education and macroeconomic performance. In the first replication of Barro and Lee, we found that vocational secondary schooling has a stronger relationship with GDP per Capita than GDP per worker. We argue that since vocational education is linked with the labor market, it facilitates an 'employment effect' which boosts GDP per Capita in contemporaneous periods. In our second replication of Szirmai and Verspagen, we found evidence to support the notion that education and economic structure work together to affect per capita GDP growth. We consider education could be a structural variable which contributes more or less to growth when it is 'well matched' with the economy. We find evidence that vocational secondary schooling is a good proxy for absorptive capability and we also note that the returns to these capabilities vary with the distance to the frontier. These results are supported in our final replication of Benhabib and Spiegel, using a different methodology, dependent variable and estimation strategy. In our replication of Pritchett, we similarly find that, once a wage return is embedded in education (i.e., once it is converted to education capital), we do not see macro returns that are over and above what are assumed to be recouped by the people who invest in further education. When we further divide schooling levels, we find preliminary evidence that there may be spillovers to tertiary education that are not found at other levels of schooling. Since this is not part of our primary objective for this paper, we do not dwell or delve further into this finding.

Synthesizing the results from our replications, we look to fill the methodological and theoretical gaps in our own empirical approach. The most important piece of ground not covered in our replications, is the possible persistence of our variables. In our own empirical approach we handle this persistence with GMM models and reach the conclusion that the true effect of vocational secondary schooling should be understood by its contemporaneous ***and*** its lagged effect. That means that, for growth, not only is the amount of vocational schooling in an economy today important, but how fast it has increased its vocational secondary schooling over the past 5 years is also important. Countries that accumulated vocational secondary schooling more rapidly see a higher growth payoff. We also find that while vocational secondary schooling does seem to be important for catch-up, the economy already has to be close to the frontier to benefit from additional vocational secondary schooling.

There are several possible reasons why being closer to the frontier means that an increase in vocational secondary schooling would be more beneficial for growth. The first has to do with the quality of the vocational education. In this paper we have always analyzed vocational secondary schooling at the secondary level that is part of the formal education system. The data do not include vocational training programs or vocational education at the tertiary level. This means that if, in some economies, the vocational track is neglected in terms of funding, or weak in terms of its linkages to the true needs of the labor market, we could not expect it to be as effective in delivering a better 'match' for the productive sector than alternative education pathways. In this paper, we cannot and have not addressed the issue of the relative quality of vocational education in different economies. Another explanation could be that, as Szirmai and Verspagen point out, the theory of absorptive capacity is a broad concept that encompasses many elements that facilitate knowledge transfer from the frontier to catching-up economies. Examples include, but are not limited to: infrastructure, political stability, and other elements of the national innovation system. These might need to be 'healthy' in order for an economy to be able to take advantage of knowledge developed at the frontier for the sake of its own growth. If these other elements are weaker, it may mitigate the role of vocational education to facilitate knowledge transfer, and thus limit its relationship with growth to negligible, nil, or even negative effects.

This paper has taken a big step toward identifying and analyzing the relationship between vocational secondary schooling and macroeconomic performance over long time horizons. By exploiting the value of the scientific method we have systematically replicated and tested our hypotheses in different empirical settings. By doing this, we have established that vocational secondary schooling has a clear impact on macro-economic performance, but that gains from additional vocational schooling are only realized once an economy is already pretty close to the frontier. We identified the threshold at which vocational secondary schooling has a positive growth payoff is when an economy already has a per capita GDP of 65 percent of the per capita GDP of the United States. Future research could investigate more deeply into the issue of whether it is the quality of vocational education or other elements known to be important for absorptive capacity that are the most relevant for getting an economy to this crucial threshold. After an economy reaches 65 percent, vocational education does help economies grow faster to catch-up and maybe even surpass the frontier. Since we noticed considerable regional differences for the relationship between vocational education and economic performance, another avenue for future research could be to explore different and possibly multiple frontiers at which the threshold for the positive growth effect of vocational education can change.

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Appendix 1 Descriptive Statistics Table

Table 14 Full Descriptive Statistics Table

Dependent Variables		Mean	S.D.	Min	Max	Observations		Analysis
GDP per Worker PWT 6.3	overall	21538.11	25101.85	415.71	320639.30	No. of Obs.	1068	
	between		22217.58	1314.63	131385.70	No. of Countries	121	Barro and Lee & Pritchett
	within		12058.84	-45808.34	216714.50	T-bar	8.83	
GDP per Capita Maddison	overall	6149.34	6513.02	214.16	36985.71	No. of Obs.	1259	
	between		5534.33	517.20	21491.60	No. of Countries	121	Barro and Lee & Pritchett
	within		3314.86	-6057.43	22266.11	T-bar	10.41	
Growth Rate (5-year) of Per Capita GDP (Maddison)	overall	2.23	2.87	-17.41	13.58	No. of Obs.	818	
	between		1.33	-0.26	5.65	No. of Countries	76	Szirmai and Verspagen & Own Approach
	within		2.54	-14.92	13.5	T-bar	10.76	
GDP per Worker (Mark PWT 5)	overall	8465.14	8131.593	486.6133	38796.21	No. of Obs.	684	
	between		8523.373	584.9958	38796.21	No. of Countries	120	Pritchett
	within		2415.544	-747.4309	17240.45	T-bar	5.7	
TFP growth 1960-1995	x-section	0.002	0.003	-0.007	0.011	No. of Countries	89	Benhabib and Spiegel
TFP growth 1960-2010	x-section	0.002	0.002	-0.005	0.008	No. of Countries	89	

Capital Variables		Mean	S.D.	Min	Max	Observations		Analysis
Log Capital per Worker PWT 6.3	overall	3.07	1.65	-1.94	7.51	No. of Obs.	948	
	between		1.55	-0.41	6.22	No. of Countries	120	Barro and Lee & Pritchett
	within		0.51	-1.20	6.07	T-bar	7.90	
Log Capital per Worker PWT 8.0	overall	10.40	1.34	7.18	13.67	No. of Obs.	1126	
	between		1.27	7.50	13.01	No. of Countries	121	Barro and Lee & Pritchett
	within		0.43	8.62	12.20	T-bar	9.31	
Log Capital per Worker PWT 9.0	overall	10.92	1.34	7.18	13.70	No. of Obs.	1132	
	between		1.28	7.47	13.14	No. of Countries	121	Barro and Lee, Pritchett & Own Approach
	within		0.45	8.40	12.71	T-bar	9.36	

Full Descriptive Statistics Table (*continued*)

Education Variables		**Mean**	**S.D.**	**Min**	**Max**	**Observations**		**Analysis**
Years of Schooling (25+)	overall	5.47	3.31	0.01	13.42	No. of Obs.	1330	
	between		2.81	0.63	11.09	No. of Countries	121	All
	within		1.77	0.71	10.30	T-bar	10.99	
Years of Schooling minus Vocational (25+)	overall	5.24	3.01	0.12	11.82	No. of Obs.	1096	
	between		2.70	0.54	11.15	No. of Countries	121	All
	within		1.58	0.85	9.67	T-bar	9.06	
Vocational Secondary Schooling (25+)	overall	0.36	0.48	0.01	2.43	No. of Obs.	1096	
	between		0.40	0.01	1.48	No. of Countries	121	All
	within		0.25	-0.82	1.45	T-bar	9.06	
Ratio Vocational to Total Secondary (25+)	overall	0.19	0.17	0.01	0.93	No. of Obs.	1275	For Reference: Not used as a Variable in Regressions
	between		0.14	0.01	0.63	No. of Countries	121	
	within		0.10	-0.23	0.72	T-bar	10.54	
Years of Primary Schooling (25+)	overall	3.51	1.95	0.01	8.99	No. of Obs.	1330	
	between		1.77	0.45	8.38	No. of Countries	121	Pritchett
	within		0.85	1.31	6.44	T-bar	10.99	
Years of Secondary Schooling (25+)	overall	1.70	1.46	0.02	6.90	No. of Obs.	1326	
	between		1.14	0.07	4.75	No. of Countries	121	Pritchett
	within		0.92	-1.32	5.93	T-bar	10.96	
Years of Tertiary Schooling (25+)	overall	0.26	0.28	0.01	1.76	No. of Obs.	1281	Pritchett & Benhabib and Spiegel
	between		0.20	0.01	0.86	No. of Countries	121	
	within		0.19	-0.41	1.29	T-bar	10.59	
Years of Schooling (15+)	overall	5.88	3.16	0.04	13.02	No. of Obs.	1331	For Reference: Not used as a Variable in Regressions
	between		2.68	0.86	11.24	No. of Countries	121	
	within		1.69	1.45	10.14	T-bar	11	
Edu (15+) S&V dataset	overall	4.77	2.7	0.1	11.85	No. of Obs.	809	
	between		2.42	1.01	10.09	No. of Countries	76	Szirmai and Verspagen
	within		1.31	1.24	8.63	T-bar	10.64	

Full Descriptive Statistics Table (*continued*)

Education Variables (continued)		**Mean**	**S.D.**	**Min**	**Max**	**Observations**		**Analysis**
Years of Schooling (25+)	overall	3.96	2.73	0.04	12.14	No. of Obs.	607	
B&L 1993 dataset	between		2.61	0.32	10.70	No. of Countries	111	Pritchett
	within		0.75	1.55	6.20	T-bar	5.47	
Log of 'Educational Capital'	overall	1.51	0.43	1.00	3.18	No. of Obs.	607	
	between		0.41	1.03	2.79	No. of Countries	111	Pritchett
	within		0.13	1.08	2.02	T-bar	5.47	

Full Descriptive Statistics Table (*continued*)

Other Explanatory Variables		**Mean**	**S. D.**	**Min**	**Max**	**Observations**		**Analysis**
Oil Exporter (Dummy)	overall	0.12	0.32	0	1	No. of Obs.	1243	
	between		0.28	0	1	No. of Countries	121	Barro and Lee & Own Approach
	within		0.16	-0.79	1.03	T-bar	10.27	
Relus	overall	31.28	33.14	0.43	306.22	No. of Obs.	1069	
(GDP per Capita Relative to the U.S.)	between		30.80	2.49	178.67	No. of Countries	121	Own Approach
G-K method PWT 6.3	within		11.36	-69.40	158.83	T-bar	8.83	
Manufacturing	overall	17.78	8.12	0	44.8	No. of Obs.	724	
(Value-added Share at Current Prices)	between		6.26	5.53	30.66	No. of Countries	76	Szirmai and Verspagen
	within		5.29	-4.26	45.58	T-bar	9.53	
Services	overall	48.86	12.33	0	86.5	No. of Obs.	721	
(Value-added Share at Current Prices)	between		9.73	24.32	74.03	No. of Countries	76	Szirmai and Verspagen
	within		8.24	-4.46	90.7	T-bar	9.49	
RELUS	overall	30.49	26.74	1.4	115.7	No. of Obs.	818	
(GDP per Capita relative to the U.S.)	between		26	2.95	98.35	No. of Countries	76	Szirmai and Verspagen
	within		7.36	-7.65	65.71	T-bar	10.76	
kgatemp (Dummy)	overall	0.28	0.45	0	1	No. of Obs.	1694	
	between		0.45	0	1	No. of Countries	121	Szirmai and Verspagen
	within		0	0.28	0.28	T-bar	14	

Other Explanatory Variables (continued)		Mean	S. D.	Min	Max	Observations		Analysis
Openness	overall	69.31	50.66	5.05	446.06	No. of Obs.	1179	
	between		46.57	13.91	350.29	No. of Countries	121	Szirmai and Verspagen
	within		22.45	-32.82	228.33	T-bar	9.74	
Log of Population	overall	9.31	1.51	5.69	14.05	No. of Obs.	836	
	between		1.48	5.87	13.67	No. of Countries	76	Szirmai and Verspagen
	within		0.36	8.02	10.35	T-bar	11	
TFP ratio 1960 (Relative to the U.S.)	x-section	0.83	0.12	0.59	1.09	No. of Countries	89	Benhabib and Spiegel

Sources: Barro and Lee 2010 and 1993; Szirmai and Verspagen, 2015; Maddison 2009; Penn World Tables 9.0, 8.0 and 6.3; World Development Indicators; and Gallup et al. 1999.
Notes: Recall that 'kgatemp' is a dummy variable that takes a 1 if >50% of the land area is in the temperate zone and openness is in current prices and is expressed as a percent (exports minus imports as a percent of GDP). 'Relus' is the measure for the distance of the economy to the frontrunner of productivity and is the GDP per Capita relative the U.S. at the start of the period. 'Edu (15+) S&V dataset' is the years of schooling variable that was used by Szirmai and Verspagen and is described in more detail in Section 4.3. Log of the population is the log of population size at the start of the period.

Appendix 2 Additional Tables for the Barro and Lee (2010) Replication

Table 15 Original Barro and Lee Results and Our 'Most Exact' Replication Results

Original Barro and Lee (2010) OLS and IV Regression Results (pg 38)

A. Rate-of-return to Schooling: Total Population, 15 years and above

Dependent Variable: ln (Real GDP per worker)				
	OLS		IV	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
ln (capital stock per worker)	0.652	0.65	0.58	0.544
	[27.3]***	[20.1]***	[18.3]***	[12.3]***
Ave. years of schooling	0.017	0.019	0.055	0.121
	[1.77]*	[1.74]*	[3.26]***	[3.16]***
Oil Exporter Dummies	yes	yes	yes	yes
Time Dummies Included	yes	yes	yes	yes
Constant	Included but not reported			
Observations	962	962	962	962
Number of countries	127	127	127	127
R-squared	0.87	0.61	0.86	0.55

B. Rate-of-return to Schooling by Region

	(5)	(6)	(7)	(8)
ln (capital stock per worker)	0.625	0.596	0.56	0.492
	[23.0]***	[15.1]***	[16.4]***	[8.55]***
Ave. years of schooling (15+)				
Advanced countries	0.031	0.047	0.066	0.133
	[3.27]***	[3.90]***	[3.75]***	[3.39]***
East Asia	0.032	0.052	0.052	0.103
	[2.52]**	[3.91]***	[2.43]**	[2.53]**
Europe and Central Asia	-0.012	0.008	0.015	0.085
	[0.94]	[0.38]	[0.75]	[1.56]
Latin America	0	-0.001	0.034	0.065
	[0.02]	[0.05]	[1.81]*	[1.82]*
North Africa and Middle East	0.008	-0.001	0.057	0.078
	[0.57]	[0.04]	[2.91]***	[2.43]**
South Asia	-0.015	0.001	0.035	0.113
	[0.57]	[0.05]	[1.09]	[1.97]**
Sub-Saharan Africa	0.006	0.004	0.038	0.066
	[0.51]	[0.27]	[1.76]*	[1.78]*
Oil Exporter Dummies	yes	yes	yes	yes
Time Dummies Included	yes	yes	yes	yes
Constant	Included but not reported			
Observations	962	962	962	962
Number of countries	127	127	127	127
R-squared	0.87	0.62	0.87	0.58

Replication of Barro and Lee (2010) OLS and IV Regression Results

Dependent Variable: ln (Real GDP per Worker PWT 6.3)				
	OLS		IV (2 Period Lags)	
	Random	Fixed	Random	Fixed
	(1)	(2)	(3)	(4)
Log (ln) Capital per Worker PWT 6.3	0.54***	0.49***	0.38***	0.20***
	(0.05)	(0.07)	(0.04)	(0.06)
Average years of schooling 15+	0.04**	0.04	0.08***	0.00
	(0.02)	(0.03)	(0.02)	(0.03)
Oil Exporter Dummies Included	yes	yes	yes	yes
Time Dummies Included	yes	yes	yes	yes
Constant	7.59***	7.76***	8.09***	8.93***
	(0.11)	(0.20)	(0.12)	(0.22)
Observations	892	892	704	704
Countries	122	122	122	122
R-sq. within	0.46	0.46	0.16	0.19
R-sq. between	0.85	0.84	0.83	0.82
R-sq. overall	0.83	0.82	0.81	0.79

B. Rate-of-return to Schooling by Region

	(5)	(6)	(7)	(8)
Log (ln) Capital per Worker PWT 6.3	0.51***	0.42***	0.32***	0.11*
	(0.05)	(0.07)	(0.04)	(0.06)
Average Years of Schooling (15+)				
Advanced Economies	0.07***	0.09***	0.12***	0.09***
	(0.02)	(0.03)	(0.02)	(0.03)
East Asia and the Pacific	0.08***	0.14***	0.11***	0.13**
	(0.02)	(0.04)	(0.03)	(0.05)
Europe and Central Asia	0.02	0.10***	0.04	0.04
	(0.02)	(0.03)	(0.03)	(0.07)
Latin America and the Caribbean	0.02	0.02	0.04	-0.06
	(0.02)	(0.03)	(0.02)	(0.04)
North Africa and Middle East	0.03	-0.01	0.07*	-0.01
	(0.03)	(0.05)	(0.04)	(0.05)
South Asia	0.01	0.07	0.09***	0.14***
	(0.03)	(0.05)	(0.03)	(0.04)
Sub-Saharan Africa	0.01	0.01	-0.03	-0.07
	(0.03)	(0.04)	(0.03)	(0.05)
Oil Exporter Dummies Included	yes	yes	yes	yes
Time Dummies Included	yes	yes	yes	yes
Constant	7.69***	7.86***	8.30***	9.07***
	(0.12)	(0.24)	(0.12)	(0.24)
Observations	892	892	704	704
Countries	122	122	122	122
R-sq. within	0.48	0.50	0.25	0.32
R-sq. between	0.84	0.70	0.80	0.38
R-sq. overall	0.82	0.70	0.78	0.39

Notes: In the left hand panel Barro and Lee report T statistics in parentheses. In the right hand panel, we report robust standard errors in parentheses. PWT stands for Penn World Tables. * p<0.10, ** p<0.05, *** p<0.01.

Appendix 3 Additional Tables for the Szirmai and Verspagen (2015) Replication

Table 16 Our 'Most Exact' Replication of Table 2 in Szirmai and Verspagen

	Dependent Variable = Growth of per capita GDP (Maddison 2009)			
	Random	Fixed	HT	BE
	(1)	(2)	(3)	(4)
Value added share of Manufacturing (% of GDP)	0.0489**	0.0578*	0.0370	0.0967*
	(0.02)	(0.03)	(0.02)	(0.05)
Value added share of Services (% of GDP)	0.0249	0.0020	0.0139	-0.0189
	(0.02)	(0.02)	(0.02)	(0.03)
GDP per capita relative to the US at the beginning of the 5 yr period	-0.0461***	-0.1035***	-0.0844***	-0.0306*
	(0.01)	(0.02)	(0.01)	(0.02)
Taken from Barro and Lee (avg years of schooling 15+)	0.3217***	0.0524	0.0741	0.2487
	(0.11)	(0.19)	(0.14)	(0.17)
Dummy variable =1 if more than 50% of the land is in the temperate zone	1.1100***	Omitted	3.2684**	0.4724
	(0.42)		(1.45)	(0.52)
Openness in Current Prices	0.0067	0.0104	0.0094*	0.0191**
	(0.01)	(0.01)	(0.01)	(0.01)
log population UN 2009 from the structural change dataset	0.0969	-2.5358***	-0.5383	0.3487*
	(0.17)	(0.86)	(0.35)	(0.19)
D1955-60	0.4037	1.3400***	0.8805*	-21.3633**
	(0.36)	(0.45)	(0.46)	(8.16)
D1960-65	0.5191	1.7699***	1.1013**	10.0150
	(0.34)	(0.47)	(0.47)	(9.08)
D1965-70	-0.0665	1.7611***	0.8110	-19.5978***
	(0.45)	(0.64)	(0.52)	(7.07)
D1975-80	-0.4739	1.7455**	0.5534	2.0976
	(0.53)	(0.79)	(0.54)	(9.31)
D1980-85	-2.7809***	-0.1266	-1.5585***	-8.9756
	(0.46)	(0.80)	(0.59)	(7.43)
D1985-90	-2.0662***	0.9658	-0.6857	-11.2206
	(0.46)	(0.85)	(0.64)	(7.19)
D1990-95	-2.1498***	1.1976	-0.6439	-7.1322
	(0.47)	(0.98)	(0.70)	(6.46)
D1995-00	-2.2119***	1.5917	-0.5241	9.3833
	(0.61)	(1.18)	(0.77)	(6.87)
D2000-05	-1.8757***	2.2129*	-0.0619	-22.1960***
	(0.59)	(1.20)	(0.81)	(6.48)
Constant	-0.4697	26.0982***	6.9249**	3.6039
	(1.71)	(7.73)	(3.38)	(5.68)
Observations	679	679	679	679
R-squared Overall	0.17	0.001		
R-squared Between	0.15	0.19		0.51
R-squared Within	0.17	0.02		

Source: Own elaboration based on data collected by Szirmai and Verspagen and primary sources described in Section 3 of this paper.

Appendix 4 Additional Tables for the Pritchett (2001) Replication

Table 17 Extension of the Pritchett Analysis: Split Education Capital Primary, Secondary (Non-vocational and Vocational) and Tertiary | Highest r to Tertiary

	Split Educational Capital into Primary, Secondary (Vocational and Non-Vocational) and Tertiary			
	GDP and K = PWT 6.3		GDP and K = PWT 9	
	(7a)	(8a)	(7b)	(8b)
Growth of 'Primary Capital' per Worker (r = 0.08)	-0.27**	-0.27*	-0.14**	-0.14
	(0.11)	(0.14)	(0.06)	(0.09)
Growth of 'Secondary Non-Vocational Capital' per Worker (r=0.12)	-0.02	-0.14	0.04	-0.04
	(0.09)	(0.10)	(0.04)	(0.06)
Growth of 'Secondary Vocational Capital' per Worker (r=0.12)	0.04	0.11*	0.02	0.04
	(0.07)	(0.06)	(0.04)	(0.04)
Growth of 'Tertiary Capital' per Worker (r = 0.16)	0.36***	0.24**	0.13*	0.03
	(0.13)	(0.10)	(0.08)	(0.09)
Growth in Capital* per Worker	0.32***	0.24***	0.60***	0.52***
	(0.07)	(0.06)	(0.06)	(0.08)
ln (initial GDP per Worker)		-0.005*		-0.005**
		(0.002)		(0.002)
Constant	-0.003	0.05*	-0.003	0.05**
	(0.01)	(0.03)	(0.004)	(0.02)
Countries	95	77	95	64
R-squared	0.47	0.48	0.75	0.74

Notes: Pritchett has t-statistics in parentheses and I have Standard errors in parentheses. *Pritchett calls Capital 'CUDIE' in his results table: Cumulated Depreciated Investment Effort. * p<0.10, ** p<0.05, *** p<0.01.

Appendix 5 Introducing the Lagged Dependent Variable in the OLS FE effects setting

In general, introducing the lagged dependent variable (log of GDP per capita) in the OLS fixed effects levels regression seems to wash out the effects of the other variables. In column 1, while the education variables become negative and slightly significant, the coefficient on Capital per worker, which usually is robust and stable across almost any OLS FE specification, shrinks remarkably to 0.09 (although it is still statistically significant). The lagged dependent variable has a huge coefficient, which illustrates how it is dominating the regression. We are reminded that when exogenous variables are heavily trended themselves, the fact that a lagged dependent variable dominates the regression may be a statistical artifact, rather than any evidence of a causal relationship (Achen, 2001).

In column 2, when we introduce lags of the explanatory variables, the schooling variables, the coefficient on the contemporaneous effect of capital per worker is restored to a value within an expected range, and the coefficients on the schooling variables are insignificant. Column 3 drops the contemporaneous explanatory variables and includes only their lags. The result is that all the effects are washed out, even the effect of capital per worker.

Table 18 Further Assessing Vocational Secondary Schooling: Introducing Lagged log GDP per Capita

	Panel A LEVELS:		
Dependent variable:	**Log GDP per capita 1960-2010**		
	OLS FE	OLS FE	OLS FE
	(1)	(2)	(3)
Non-vocational Years of Schooling	-0.01*	-0.01	
	(0.01)	(0.01)	
Vocational Secondary Schooling	-0.04*	0.01	
	(0.03)	(0.03)	
Lag (1 period) Non-vocational Years of Schooling		0.01	-0.01
		(0.02)	(0.01)
Lag (1 period) Vocational Secondary Schooling		-0.01	-0.04
		(0.03)	(0.03)
Log K per Worker PWT 9.0	0.09**	0.45***	
	(0.04)	(0.06)	
Lag (1 period) Log K per Worker PWT 9.0		-0.38***	-0.01
		(0.05)	(0.03)
Lag (1 period) Log GDP per capita	0.79***	0.77***	0.86***
	(0.04)	(0.03)	(0.03)
Oil exporter and time dummies included	y	y	y
Constant	0.85***	1.11***	1.40***
	(0.26)	(0.22)	(0.25)
Observations	840.00	774.00	814.00
Countries	105.00	105.00	105.00
R-sq.	0.88	0.90	0.88

Notes: Robust Standard errors in parentheses. * $p<0.10$ ** $p<0.05$ *** $p<0.01$

The results presented here are for the sake of comparison. Otherwise, applying OLS to dynamic models with issues of persistence and (potential) endogeneity is not advisable. That is why we focused our own empirical approach on GMM techniques.