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Effects of Male and Female Education on Economic Growth: Some Evidence from Asia Using the Extreme Bounds Analysis

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Working Paper in Economics 10/13

July 2013

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Abstract

This paper uses the Extreme Bounds Analysis (EBA) to examine the comparative growth effects of gender disaggregated and level-specific enrolment ratios in a panel of Asian economies. To test our hypotheses, at first we employ an endogenous growth type framework where education has externality effects and then we compare the results with those obtained from an alternative neoclassical exogenous growth type model where education's effect is transmitted only via total factor productivity (TFP). It is found that the externality effects of education are positive and robust for both male and female and that these are relatively large and significant at the primary, secondary as well as tertiary level. Furthermore, in the endogenous type framework, a gender gap is observed wherein the male growth effect of education is consistently larger than that of female at all levels. Compared to these, in the neoclassical type model we find that only the male and female primary and secondary enrolment ratios have robust growth effects. In contrast to the externality effects, these growth effects are small.

Keywords

education and growth
endogenous growth
Solow growth model
extreme bounds analysis
total factor productivity.

JEL Classification

O11; O15

1. Introduction

This paper examines growth effects of education using a panel of fifteen Asian countries over the period 1970-2009. For this purpose, we use an endogenous as well as an exogenous type growth model to test our hypotheses: whether growth effects of education vary with the levels of enrolment per worker disaggregated by gender. According to Leoning (2005) it is somewhat surprising that there are only relatively few studies at the macro level which have addressed the question of level-specific growth effects of education. The view that the effect of schooling at different education levels does not have the same impact on economic growth is based on the labour economics literature. Psacharopoulos and Patrinos (2004) provide a comprehensive review on the rates of return to education which suggest that returns vary according to the education level as well as by gender among other socio-economic factors. As propounded by the endogenous growth theories, if education has economic externalities, leading to the expansion of economic well-being and the technological frontiers of the economy, the actual benefits of education may thus be better recognised by the study of different education levels – primary, secondary and tertiary – on economic growth. We endeavour to address this gap in the literature and we do so by adding another dimension – gender – to study the effect of male and female enrolments at different levels of schooling on economic growth within the framework of both endogenous and neoclassical growth models.

The economic benefit of education is important as a more educated society translates into higher rates of economic growth. This is evidenced by the large literature that has emerged on education and economic growth: see Mankiw, Romer and Weil (1992), Barro (1991), Hanushek (1995), Temple (2001), Krueger and Lindahl (2001), Gemmel (1996), Benhabib and Spiegel (1992) and Dowrick (1995) among others. The relationship between education and economic growth, with special attention to schooling quality, is examined in Barro (1999), Hanushek and Kimko (2000), Hanushek and Dongwook (1995) and Hanushek and Woessmann (2008) .

Given the current emphasis on education by the United Nations and the Millennium Development Goal (MDG) of achieving education for all by increasing enrolment ratios, this study seeks to investigate empirically, the effect of education, as measured by enrolment ratios, on economic growth. We use primary, secondary and tertiary enrolment ratios disaggregated by gender. Due to the renewed efforts made by the Asian economies to increase enrolment ratios and allocate resources efficiently in an effort to achieve the MDG of education for all, the present study focuses on Asia. The main difference between our paper and a number of previous studies in the literature is as follows. We shall use gender disaggregated and level-specific enrolment data in an endogenous type growth model where the impact of education is captured through externality and later we compare this externality effects within a neoclassical type model where the impact of education on long-run economic growth is only transmitted through total factor productivity (TFP). Secondly, we shall use the extreme bounds analysis (EBA) of Leamer (1985) and its variants to identify and estimate the growth effects of female and male enrolment at the primary, secondary and tertiary levels. Estimates based on the EBA reduce model uncertainty and are claimed to be robust. EBA is especially useful when there are several potential explanatory variables and it is necessary to select a few robust explanatory variables.

The structure of this paper is as follows. Section 2 reviews the literature on education and economic growth. Section 3 discusses some country characteristics of enrolment ratios. Section 4 explains the methodologies. The empirical model is specified and results are presented and discussed with a brief discussion of EBA in Section 5. Section 6 concludes.

2. Review of the Literature

Since the work of Mankiw, Romer and Weil (1992), MRW hereafter, and Barro (1991, 1999) there has developed a large literature on the positive association between human capital and economic growth; see Krueger and Lindahl (2001), Gemmel (1996), Kyriacou (1991), Sala-i-Martin (1997), Romer (1990), Hanushek and Kimko (2000), Hanushek and Dongwook (1995), Hanushek and Woessmann (2007) among many others. Human capital is alternatively measured with several variables including: schooling enrolment ratios (MRW, Barro 1991, Levine and Renelt 1992); the average years of schooling (Hanushek and Woessmann 2007, Krueger and Lindhal 2001, Breton 2011, Lin 2003); adult literacy rate (Durlauf and Johnson 1995, Romer 1990); and education spending (Baladacci *et al.*2008). There are, however, studies that find a weak association between education and growth (Bils and Klenow 2000) or no association (Pritchett 2001). We use enrolment ratios because they are associated with the 3rd MDG.

Many studies using enrolment ratios have found a positive relation between primary and secondary education and economic growth. Barro (1991) uses the initial (1960) enrolment ratio as proxy for the initial stock of human capital. He concludes that the higher the level of initial human capital, the faster the growth rate of per capita income in that country. Augmenting the Solow growth model with a variable for human capital as measured by the secondary enrolment ratio, MRW find that the secondary enrolment ratio explains a large proportion of growth variation in GDP per capita. Gemmel (1996) using a measure of human capital derived from school enrolments and labour force participation rates, shows that primary and secondary enrolment ratios have a greater impact on economic growth in the developing economies, while tertiary enrolment has a greater effect on economic growth in the developed economies. Employing regression tree methods and categorising countries by their levels of output and literacy, Durlauf and Johnson (1995) argue that economies can achieve multiple equilibria depending on the levels of output and literacy in a country.

Studies which disaggregate levels of schooling, find that primary and secondary enrolment have in general a positive effect on economic growth as opposed to tertiary education. Self and Grabowski (2004) in a study of India, find evidence of a strong causal relation between economic growth and primary education, weak evidence of a relationship between growth and secondary education, and no evidence at all between growth and tertiary education. Self and Grabowski (2004) attribute the absence of a causal relation between tertiary education and growth to the low numbers undertaking tertiary education. Petrakis and Stamatakis (2002) similarly, argue that primary and secondary education contribute significantly to growth in developing nations, while tertiary education contributes significantly to growth in OECD developed market economies. They suggest that the impact of education on economic growth depends on the level of development of a country. Similar conclusions are reached by Pereira and St. Aubyn (2009) who find that education at both the primary and secondary levels have a positive effect on economic growth in Portugal, however, tertiary education does not contribute significantly to economic growth. They conclude that tertiary education contributes significantly to growth only when a country is a technological leader. de Meulemeester and Rochat (1995) also find evidence of a relationship between education and growth for some countries in the sample investigated. They argue that education can promote growth only if the curriculum is designed with the needs of the economic system in mind.

Studies which disaggregate enrolment by gender find mixed evidence on growth. Barro and Sala-i-Martin (1995) find that male education is positively related to growth while female education is negatively related to growth. Barro (2001) subsequently finds that female primary education is positively related to growth while male secondary and tertiary education are positively related to growth. Self and Grabowski (2004) on the contrary show that female education has the potential to increase economic growth as opposed to male education.

The relation between schooling and economic growth giving special emphasis to schooling quality is examined in the work of Barro (1999), Hanushek and Kimko (2000), Hanushek and Dongwook (1995), Hanushek and Woessmann (2007), Hanushek (2013), Castelló-Climent and Hidalgo-Cabrillana (2012). The majority of these studies emphasise the importance of education quality for economic growth. Mincer (1974) shows that years of schooling can be used to estimate the returns to education. Castelló-Climent and Hidalgo-Cabrillana (2012) argue that the impact of the quantity and quality of education on economic growth depend to a large extent on the level of development of a country. Fogel (2009) reviews the development of economic growth in the context of the rapid growth experienced by China, India and Southeast Asia observes that a college educated worker is 3.1 times as productive, and a high school graduate is 1.8 times as productive, as a worker with less than a ninth-grade education. Contrary to the conclusions with regard to quantity versus quality, Breton (2011) in a study of test scores versus years of schooling in explaining economic growth finds that years of schooling have greater explanatory power for economic growth.

The robustness of education variables including other variables on economic growth are undertaken in the studies of Levine and Renelt (1992), Sala-i-Martin (1997) and Temple (1998) among others. Investigating the robustness of various variables on economic growth, Levine and Renelt (1992) show support for conditional convergence between the 1960-1989 period when the initial level of human capital is included in the growth equation. Temple (1998) investigating the robustness of MRW's results argues that when outliers are excluded and regional dummy variables are included, the secondary schooling variable loses statistical significance.

Our objective in this study is to explore the influence of education on economic growth in a group of Asian countries employing the EBA of Leamer (1985) and its variants. We contribute to the literature by using the EBA to identify and estimate the growth effects of female and male enrolment at the primary, secondary and tertiary levels for Asia. The use of this technique enables us to identify variables which have a robust effect on economic growth in Asia.

3. Country Characteristics

Table 1 summarises the enrolment ratios at the primary, secondary and tertiary levels disaggregated by gender for the countries under study. The figures indicate that enrolment ratios, particularly at the primary level, have steadily increased in these countries, with the gap between male and female enrolment rates having narrowed significantly over time.

Table 1 shows that there have been significant increases in the primary enrolment ratio in Bangladesh, Bhutan, Cambodia, India, Laos, the Maldives and Nepal, particularly that of female enrolment. The primary enrolment ratio has increased at a much slower pace in Pakistan, while China, Indonesia, Korea, Malaysia, Myanmar, Philippines, Sri Lanka, Thailand and Vietnam have relatively high primary enrolment ratios from the 1970s onward. Secondary enrolment is much lower in all economies in the 1970s, however, have increased to over 70% by 2008 in China, Indonesia, Korea, Malaysia (for females), Philippines, Sri Lanka and Thailand. Cambodia, Laos and Pakistan face very low secondary enrolment ratios of below 50% as of 2008. The tertiary enrolment ratio is exceptionally high in Korea compared to the rest of Asia, while China, Indonesia, Malaysia and Thailand have reasonably high tertiary enrolment ratios compared to the other Asian nations. Unfortunately enrolment data are not available for Singapore.

Table 1: Enrolment Ratios 1970-2008 for the Selected Asian Countries

Country	1970		1980		1990		2008	
	Female	Male	Female	Male	Female	Male	Female	Male
	Primary Enrolment Ratio							
Bangladesh	33.9	67.5	60.8	81.2	69.2	84.8	97.9	90.8
Bhutan	20.1	37.3	24.6	46.5	46.9	61.3	106.3	106.2
Cambodia	26.0	34.6	-	-	-	-	112	119.7
China	-	-	105.4	121.4	122.1	135.1	115.5	111.2
India	60.4	93.0	67.9	96.5	80.6	104.9	111.8	114.6
Indonesia	77.9	88.8	102.4	115.7	116.4	117.0	117.8	121.1
Korea	-	-	105.5	104.8	106.6	105.3	103.5	105.5
Laos	43.8	73.5	87.2	111.5	89.0	112.1	101.9	119.5
Malaysia	83.4	93.9	92.0	93.2	92.0	93.8	96.4	96.8
Maldives	28.7	37.5	35.2	54.3	108.6	114.4	134.8	141.4
Myanmar	84.0	93.9	-	-	92.1	98.4	116.5	117.2
Nepal	7.5	40.4	40.9	124.5	75.6	104.8	106.2	106.9
Pakistan	23.4	61.5	29.0	58.5	33.6	63.3	76.6	92.6
Philippines	-	-	-	-	108.0	110.3	109.1	110.9
Sri Lanka	86.8	88.6	92.5	92.4	107.2	99.6	108.9	106.0
Thailand	75.4	83.5			91.6	92.8	92.3	94.4
Vietnam	-	-	106.5	112.1	-	-	-	-
	Secondary Enrolment Ratio							
Bangladesh	9.0	22.0	9.0	25.0	14.0	29.3	44.6	42,9
Bhutan	-	-	-	-	-	-	-	-
Cambodia	5.9	13	-	-	-	-	36.2	44.4
China	-	-	43.3	59.1	32.5	44.0	78.1	74.3
India	16	37	21.3	41.2	29.4	45.8	51.1	60.2
Indonesia	12.2	22.6	23.0	33.2	43.7	52.1	74.1	74.7
Korea	-	-	70.6	82.6	90.3	94.7	95.2	98.9
Laos	2.2	6.1	14.2	22.5	19.2	28.1	28.4	40.4
Malaysia	27.9	40.7	45.7	49.7	57.7	54.3	70.5	66.0
Maldives	-	-	-	-	-	-	-	-
Myanmar	16.3	25.3	-	-	19.5	25.8	-	-
Nepal	3.0	14.0	7.7	31.0	18.5	43.3	-	-
Pakistan	6.0	23	8.7	24.3	13.2	29.5	27.6	36.9
Philippines	47.2	49.8			71.9	69.6	86.1	70.0
Sri Lanka	52	49	58.0	53.8	74.2	66.6	87.9	85.6
Thailand	14.6	20.2	-	-	30.6	31.0	77.4	71.3
Vietnam	-	-	-	-	63.9	69.7	-	-
	Tertiary Enrolment Ratio							
Bangladesh	0.4	3.3	0.8	4.7	1.3	6.5	5	8.9
Bhutan	-	-	0.4	1.3	-	-	4.8	8.2
Cambodia	-	-	-	-	-	-	4.9	9.1
China	-	-	0.55	1.6	-	-	23.1	22.2
India	-	-	2.7	7.0	4.1	7.8	11.0	15.7
Indonesia	1.3	4.1	-	-	7.8	11.6	20.4	22.1
Korea	-	-	6.0	19.2	23.4	49.3	79.1	115.3
Laos	-	-	0.2	0.5	0.7	1.5	1.9	3.5
Malaysia	-	-	3.1	5.2	-	-	36.2	28.1
Maldives	-	-	-	-	-	-	-	-
Myanmar	-	-	-	-	4.8	3.9	12.4	9.1
Nepal	-	-	-	-	2.8	8.4	-	-
Pakistan	-	-	1.2	3.1	2.1	4.0	4.8	5.8
Philippines	-	-	25.9	22.3	30.4	20.6	31.8	21.7
Sri Lanka	0.8	1.4	-	-	2.1	4.4	-	-
Thailand	-	-	-	-	20.9	17.9	49.2	40.3
Vietnam	-	-	-	-	8.1	11.1	-	-

Source: World Development Indicators 2010.

4. Methodology

We maintain the view, as propounded in the endogenous growth theory, that it is through the externality effects the education sector contributes to growth. As an extension to Solow neoclassical growth model, the endogenous growth theory as developed by Romer (1986) incorporates externalities related to the accumulation of knowledge. Later endogenous growth theorists introduce the production of human capital, where the education sector being human capital intensive, produces more human capital employed within firms. Therefore externalities are generated by the education sector in the form of education and knowledge in the society and this raises economy-wide labour productivity further.

Our analytical framework is a generalisation of Lau and Sin (1997a and 1997b) where a neoclassical and a special form of Romer (1986) type production function is used to assess the impact of externalities of public investment for a closed economy. The production function in Lau and Sin (1997a) is:

$$y_{jt} = Ak_{jt}^{\alpha}\left[(1+\gamma)^{t} l_{jt}\right]^{1-\alpha} \widetilde{K}_{t}^{\lambda} \widetilde{S}_{t}^{\theta} \varepsilon_{t}^{p} \tag{1}$$

where, $0 \leq \alpha, \lambda, \theta < 1$ and y_{jt}, k_{jt} and l_{jt} , are the output, physical capital and labour inputs of agent j at time t and K_t and S_t are congestion adjusted to be defined later private and public capital available to all agents in time t. The Harrod-neutral rate of technical progress is denoted by γ. This type of production function can accommodate both Neoclassical and endogenous growth models in one framework through the parameter γ. The production function represents constant returns to scale with respect to capital and labour inputs of a representative agent. In addition, the congestion adjusted private and public capital are external inputs in an agent's production function in such a way that they produce spillover effects. The parameters λ and θ represent these externality effects.

Ganegodage and Rambaldi (2011)-GR extends the above Lau and Sin (1997a and 1997b) framework by further decomposing the public capital component S_t into an aggregate human capital, an open economy and the institutional factor due to war to assess external effects of these variables on Sri Lankan economy.

In this paper we modify the GR framework in two ways: firstly, we disaggregate the human capital stock by gender based primary, secondary and tertiary levels of enrolment ratios and secondly, we elaborate the open economy assumption by taking into account of international capital flows by explicitly modelling remittances and foreign direct investment (FDI) into the model. The resource constraint of the open economy in GR is as follows:

$$Y_{it} = C_{it} + I_{it} + G_{it} + X_{it} - M_{it} \tag{2}$$

Adding net international transfer receipts (R) as a measure for remittances flows, to both sides of the resource constraint, we write (6) as follows:

$$Y_{it} + R_{it} = C_{it} + I_{it} + G_{it} + (X_{it} + R_{it} - M_{it}) \quad (3a)$$

Saving, that is gross income less domestic absorption, $S_{it} = Y_{it} + R_{it} - C_{it} - G_{it}$, we note:

$$S_{it} = I_{it} + (X_{it} + R_{it} - M_{it}) \quad (3b)$$

Eq. (3 b) shows that any imbalance in the domestic economy would result in an external imbalance which will be reflected in the capital account of the balance of payments. In most Asian economies where the current account is in deficit, the net capital outflows tend to be negative which is indicative of a net inflow of FDI. Eq. (3b) defines the resource constrain in our paper.

Modifying GR framework by disaggregating human capital by levels of education and gender, elaborating the openness assumption, and adding a financial sector, we integrates nine new variables to the model. The effects of these variables are considered external because only physical capital and labour are considered as inputs. Our modified framework is discussed below.

Given the discussion above we consider the following production function:

$$y_{jit} = Ak_{jit}^{\alpha}\left[(1+\gamma)^{t} l_{jit}\right]^{1-\alpha} \widetilde{K}_{it}^{\lambda} \widetilde{FP}_{it}^{\varphi} \widetilde{FS}_{it}^{\eta} \widetilde{FT}_{it}^{\omega} \widetilde{MP}_{it}^{\delta} \widetilde{MS}_{it}^{\nu} \widetilde{MT}_{it}^{\mu} \widetilde{V}_{it}^{\xi} \widetilde{N}_{it}^{\tau} \widetilde{R}_{it}^{\chi} \widetilde{D}_{it}^{\psi} \widetilde{G}_{it}^{\pi} \widetilde{M}_{it}^{\vartheta} \varepsilon_{it} \quad (4)$$

$$i = 1 \ldots N, t = 1 \ldots T, A > 0, 0 \leq \alpha \; and \; \lambda, \varphi, \eta, \omega, \delta, \nu, \mu, \xi, \tau, \chi, \psi, \pi, \vartheta < 1 \quad (4a)$$

where y_{jit}, k_{jit} *and* l_{jit} are the output, physical capital and labour inputs of agent *j* at time *t* in country *i* and ε_{it} is the error term. In Eq. (4), with respect to capital and labour inputs for a representative agent there is constant return to scale and a competitive equilibrium exists such that all private factors are paid according to their marginal products exhausting all output. The other variables – $\widetilde{K}$, $\widetilde{FP}$, $\widetilde{FS}$, $\widetilde{FT}$, $\widetilde{MP}$, $\widetilde{MS}$, $\widetilde{MT}$, $\widetilde{V}$, $\widetilde{N}$, $\widetilde{R}$, $\widetilde{D}$, $\widetilde{G}$, are congestion adjusted available physical capital (*K*), female enrolment ratio in primary schools (*FP*), female enrolment ratio in secondary schools (*FS*) female enrolment ratio in tertiary institutions (*FT*), male enrolment ratio in primary schools (*MP*), male enrolment ratio in secondary schools (*MS*) and male enrolment ratio in tertiary institutions (*MT*) and investment ratio (*V*), a measure of trade openness (*N*), ratio of migrant workers' remittances to home country (*R*) foreign direct investment (*D*), the ratio of government current expenditure (*G*) and a proxy for the development of financial sector (*M*). These variables are considered external inputs in an agent's production function in such a way that they produce spillover effects. The parameters $\lambda, \varphi, \eta, \omega, \delta, \nu, \mu, \xi, \tau, \chi, \psi$ and π represent these externality effects.

The congestion effects are defined as follows. There are two notions congestion applied to public goods literature (Eicher and Turnovsky 2000): relative congestion and aggregate (absolute) congestion. The former specifies the level of services obtained by an individual from the provision of a public good in terms of the usage of his individual capital stock relative to the aggregate capital stock. For example, university level education. Unless an individual opts for a tertiary degree, he derives no service from a state university, and in general the services he derives depends upon his own efforts relative to that of others in the economy, as total usage contributes to congestion. Aggregate congestion indicates how aggregate usage of the service alone influences the services received by an individual. Compulsory primary education could be an example of this. In principle, everybody can take the benefit of this service independent of their own actions, though the amount of service they may actually derive varies inversely on the limited resources devoted to this public service.

For any variable, X_{it}, the congestion effect is modelled as follows:

$$\widetilde{X}_{it} = \frac{X_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}} \tag{5}$$

where $0 \leq \phi \leq 1$. For our model X_{it} represents the aggregate level of the variables external to the production function outlined above. For each of the congestion adjusted variables, substituting the relevant expression for (5) in (4), and assuming that $y_{jit} = y_{it}$ and $k_{jit} = k_{it}$ gives us the following growth equation in per capita terms to test for the externality effects[1]:

$$\begin{aligned} y_{it} = {} & A k_{it}^{(\alpha+\lambda-(\lambda+\varphi+\eta+\omega+\delta+\nu+\mu+\xi+\tau+\chi+\psi+\pi+\vartheta)\phi)} (1+\gamma)^{t(1-\alpha-(1-\phi)(\lambda+\varphi+\eta+\omega+\delta+\nu+\mu+\xi+\tau+\chi+\psi+\pi+\vartheta)} \\ & fp_{it}^{\varphi} fs_{it}^{\eta} ft_{it}^{\omega} mp_{it}^{\delta} ms_{it}^{\nu} mt_{it}^{\mu} v_{it}^{\xi} n_{it}^{\tau} r_{it}^{\chi} d_{it}^{\psi} g_{it}^{\pi} m_{it}^{\vartheta} \varepsilon_{it} \end{aligned} \tag{6}$$

The lower case variables are all in per capita term represented as female primary enrolment (*fp*), female secondary enrolment (*fs*) female tertiary enrolment (*ft*), male primary enrolment (*mp*), male secondary enrolment (*ms*) male tertiary enrolment (*mt*),and investment ratio (*v*), a measure of trade openness (*n*), workers' remittances (*r*), foreign direct investment (*d*), the ratio of government current expenditure (*g*) and a proxy for the development of financial sector (*m*).This model of growth allow us to estimate the externality effects of these variables of which we are mainly interested in the gender effects of primary, secondary and tertiary enrolments.

As a contrast to the growth models given in Eq. (4) and Eq. (6), we model the growth enhancing external variables in a rather simple framework based on Rao (2010a, 2010b) which is a heuristic extension to exogenous growth model of Solow (1956). In this

[1] A detailed derivation of Eq. (6) is provided in the appendix.

framework the contribution of the external variables are considered through their effects via TFP only. Consider the Cobb-Douglas production function with constant returns and Harrod neutral technical progress is as follows.

$$Y_t = K_t^{\alpha}\left(A_t L_t\right)^{1-\alpha} \tag{7}$$

where A is the stock of knowledge, Y is income , K is capital and L is employment. The solution for the steady state level of per worker income is:

$$y^* = \left(\frac{s}{d+g+n}\right)^{\frac{\alpha}{1-\alpha}} A \tag{8}$$

where $y = (Y / L)$. The steady state growth rate (*SSGR*), when the parameters in the brackets remain constant, is:

$$\Delta \ln y^* = \Delta \ln A = g \tag{9}$$

In the Solow model although the stock of knowledge (A) is assumed exogenous, in the empirical work it is common to assume that A grows at a constant rate of g, i.e.,

$$A_t = A_0 e^{gt} \tag{10}$$

where A_0 is the stock of knowledge in the initial period. It is reasonable to decompose the growth of knowledge by making the stock of knowledge to depend, besides time, on other variables, M_i, such as those in Eq.(4). In this way, it is assumed that g in Eq. (10) is a function of the M variables, so that:

$$A_t = A_0 e^{(g_0 + g_i M_{it})t} \qquad i = 1.....n \tag{11}$$

The advantage of this extension is that it is relatively easy to estimate the growth effects of M_i via TFP. In (8) *TFP* is: $g = g_0 + \sum g_i M_i \quad i = 1...n$, where g_0 captures the effects of the neglected but trended variables. Thus, the long run growth rate depends on the levels of the M_i variables, as in the endogenous models. The coefficients $g_i \quad i = 0...n$, should be significant if the M_i variables cause TFP to grow.

Writing Eq. (7) in per capita term and combining with Eq. (11), we arrive at the simple growth model as follows:

$$y_{it} = A_0 e^{(g_0 + g_1 fp_{it} + g_2 fs_{it} + g_3 f_{it} + g_4 mp_{it} + g_5 ms_{it} + g_6 mt_{it} + g_7 v_{it} + g_8 n_{it} + g_9 r_{it} + g_{10} d_{it} + g_{11} g_{it} + g_{12} m_{it})t} k_{it}^{\alpha} \qquad (12)$$

It is interesting to note the differences between the growth models in Eq. (6) and Eq. (12). The former imply that the twelve variables other than capital labour ratio, directly affect per capita income growth through the externality effects as well as through capital accumulation by interfering with the private return to capital as long as the congestion parameter $\phi > 0$. Similarly, the deterministic component of total factor productivity (TFP) given by $[(1+\gamma)]^{1-\alpha}$ (Lau and Sin 1997a and 1997b), may also be altered by these externality parameters. Compared to this, in Eq. (12) the growth enhancing variables only explains albeit partially, the rate of growth of technology. In fact it only decomposes the part of the TFP growth into some plausible growth enhancing factors. Therefore Eq. (12) does not capture any externality effect. We will estimate the growth models given by Eq.(6) and Eq.(12) and compare the results. Our empirical strategy is discussed in the next section.

5. Econometric Specification and Results

What are some important and potentially growth improving variables for inclusion into the growth models? Durlauf, Johnson and Temple (2005) found that the number of such potential growth improving variables in empirical work is as many as 145. There is no endogenous growth model in which the specification to estimate growth effects use more than one or two growth enhancing and control variables. Additional explanatory variables are often included in empirical work on an heuristic rather than theoretical basis if they are supposed to have some potential externalities. Using growth regressions and pure cross section methods, Levine and Renelt (1992) have used the extreme bounds analysis of Leamer (1985) and found that many fiscal and monetary policy variables have no effects or doubtful effects in the cross-country growth regressions. In contrast, using a less stringent criteria, Sala-i-Martin (1997) found that out of 62 explanatory variables used in various empirical studies, 25 variables have robust growth effects of which three are MUST use variables. These are initial income, life expectancy and years of primary schooling and they should be included in all growth regressions.[2] However, it is not clear how many variables will be robust if the growth equations are estimated with panel data methods. For pragmatic reasons, it seems necessary to follow some methodological norms in growth empirics.[3] In this paper to estimate the growth effects of enrolment ratios and select other control variables we shall use EBA with alternative assumptions. This would help understand the sensitivity of the effects of

[2] Levine and Renelt have also used four MUST use variables which are investment ratio, initial per capita income, secondary school enrolment ratio and the rate of growth of population. For the list of the 22 significant variables in Sala-i-Martin (1997) see Table 1 in his paper.

[3] By methodological norms we mean that there are no right or wrong answers.

enrolment ratios to alternative model specifications, which we expect will reduce model uncertainty.

Estimation of cross country growth regressions is often problematic due to the presence of outliers in the data, parameter heterogeneity and model uncertainty. Therefore, Temple (1998 and 2001) and Sturm and de Haan (2005) suggest estimating cross country growth equations with some robust methods such as the Least Mean Squares (LMS), Least Trimmed Squares (LTS) or EBA. LMS and LTS use OLS and are more suitable to identify outliers. Therefore, they can be used to estimate pure cross section growth regressions. Applications with LMS and LTS to estimate time series models or with panel data methods are yet to be developed.

Levine and Renelt (1992) and Sala-i-Martin (1997) use EBA to estimate pure cross country growth equations but use two different criteria to identify robust growth enhancing variables. Following some suggestions in Temple (2000), Sturm and de Haan (2005) have combined EBA and LTS to estimate only pure cross section growth equations with *OLS*. To the best of our knowledge, panel data routines to use LMS, LTS and a combination of them with EBA are not yet available to the applied researchers. Therefore, in this paper we shall use a panel data based EBA routine following Rao and Vadlamannati (2011), to examine in this paper if enrolment ratios and other proxies for education have any robust growth effects. This is the only tractable option available to us for using EBA to reduce model uncertainty with panel data methods.

The central idea of EBA is that out of a range of possible models it enables to examine how sensitive parameter estimates are to different specifications.[4] As noted by Sala-i-Martin, 'The problem faced by empirical growth economists is that growth theories are not explicit enough about what variables belong in the 'true' regression.' Therefore, he has used EBA to identify a good number of robust growth determinants. EBA can be briefly explained as follows. The general form of the regression, which is usually estimated in *EBA* is:

$$\Lambda = \mathbf{a}_j + b_{yj}\mathbf{y} + b_{zj}\mathbf{z} + b_{xj}\mathbf{x} + \mathbf{u}_j \tag{13}$$

where $\mathbf{y}$ is a vector of fixed variables that always appear in the regressions (for example, Sala-i-Martin's three MUST variables), $\mathbf{z}$ denotes the variable of interest (for example, one or all of the six enrolment ratios in our case) and $\mathbf{x}$ is a vector of three variables selected from the pool $\mathbf{X}$ of additional plausible control variables. In growth equations as many as 140

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4 Both LMS and LTA are useful to identify outliers in the data and estimate *OLS* regressions without these outliers. Bayesian methods have been also developed as an alternative to EBA to reduce model uncertainty. However, application of the Bayesian methods need balanced panel data. In contrast EBA can be applied to unbalanced data.

plausible control variables can be used. However, Levine and Renelt (1992) suggest that a few crucial control variables may be adequate, which in their EBA exercise were eight. Cross section and time subscripts are ignored in equation (13) for convenience. According to Levine and Renelt (1992) this design tries to reduce multi-collinearity problems by restricting the total number of explanatory variables to eight or fewer, choosing a small pool of variables from the $\mathbf{x}$ vector and excluding variables that might measure the same phenomenon. This specification design minimizes the risk of underspecified models while also minimizing the computer power needed to estimate the models.

Adapted to our purpose for testing the robustness of the components of enrolment ratios, the only variable we shall include in vector $\mathbf{y}$ is the log of per worker capital stock $(\ln(K/L) = \ln k)$, where K = real capital stock and $L =$ employment. Alternative sets of variables can be selected for inclusion in the vectors $\mathbf{z}$ and $\mathbf{x}$. First, we shall include all other potential growth affecting variables, which in our case are 13 (including ln*k*), in the $\mathbf{z}$ vector. Therefore, the set of three explanatory variables in $\mathbf{x}$, which change in each regression, are also selected from $\mathbf{z}$. In other words the vectors $\mathbf{x}$ and $\mathbf{z}$ have the same variables. These variables are a time trend (*t*), female primary enrolment (*fp*), female secondary enrolment (*fs*) female tertiary enrolment (*ft*), male primary enrolment (*mp*), male secondary enrolment (*ms*) male tertiary enrolment (*mt*),and investment ratio (*v*), a measure of trade openness (*n*), workers' remittances (*r*), foreign direct investment (*d*), the ratio of government current expenditure (*g*) and a proxy for the development of financial sector (*m*).

We perform three EBA exercises with alternative assumptions. Firstly, we include only the log of per worker capital stock in the $\mathbf{y}$ vector since we are estimating a production function. We include all other variables in the $\mathbf{z}$ and $\mathbf{x}$ vectors to get an idea of which variables have robust growth effects. Next, we repeat the first exercise by including time trend as an additional MUST variable in the $\mathbf{y}$ vector. Time trend is likely to capture the growth effects of trended and excluded variables from the production function. This would help to know if enrolment ratios have any independent permanent growth effects.

We first estimate and test the growth model in Eq. (6) using EBA. Note that the growth model in (6) can be expressed in log form as follows[5]:

$$\begin{aligned}\ln(y_{it}) = \beta_1 + \beta_2 \ln k_{it} + \beta_3 \ln fp_{it} + \beta_4 \ln fs_{it} + \beta_5 \ln ft_{it} + \beta_6 \ln mp_{it} + \beta_7 \ln ms_{it} + \\ \beta_8 \ln mt_{it} + \beta_9 \ln v_{it} + \beta_{10} \ln n_{it} + \beta_{11} \ln r_{it} + \beta_{12} \ln d_{it} + \\ \beta_{13} \ln g_{it} + \beta_{14} \ln m_{it} + \beta_{15} t + \ln \varepsilon_{it}\end{aligned} \tag{14}$$

where,

$\beta_2 = (\alpha + \lambda - (\lambda + \varphi + \eta + \omega + \delta + \nu + \mu + \xi + \tau + \chi + \psi + \pi + \vartheta)\phi)$,

[5] We assume, γ is small such that (1+γ) is approximated by γ (see Lau and Sin 1997b).

$\beta_3 = \varphi$, $\beta_4 = \eta$, $\beta_5 = \omega, \beta_6 = \delta, \beta_7 = \nu, \beta_8 = \mu, \beta_9 = \xi, \beta_{10} = \tau, \beta_{11} = \chi,$
$\beta_{12} = \psi, \beta_{13} = \pi, \beta_{14} = \vartheta,$ and

$$\beta_{15} = \gamma(1-\alpha) - [(1-\phi)(\lambda + \varphi + \eta + \omega + \delta + \nu + \mu + \xi + \tau + \chi + \psi + \pi + \vartheta)] \quad (15)$$

The theoretical specification in Eq. (6) and its econometric specification in (14) will help us identify the externality effects of education on growth. Specifically, the six gender based enrolment ratios are included because they are the variables of interest to us. Many previous studies used the secondary school enrolment ratio as a proxy to measure the growth effects of education or human capital. Therefore, our findings with six gender-based enrolment ratios will be of considerable use to policy makers. Moreover using EBA we will be able see how robust these gender disaggregated enrolment ratios are in the growth models.

In an EBA analysis, for each model *j* one estimate of b_{zj} and the corresponding standard deviation σ_{zj} are made. The lower extreme bound for this parameter is defined as the lowest value of $b_{zj} - 2\sigma_{zj}$ and the upper extreme bound is the largest value of $b_{zj} + 2\sigma_{zj}$. If the lower extreme bound is negative and the upper extreme bound is positive, according to Leamer and Levine and Renelt, the effect of the variable is fragile. This criterion of Leamer (1983, 1985) was criticized by McAleer *et al.* (1985) and Sala-i-Martin (1996, 1997) as too stringent. Sala-i-Martin proposed an alternative criterion based on the cumulative distribution function (*CDF*) of the estimated coefficients. He selected 0.95 as the critical value for the CDF, which implies that 95% of all the estimates of a coefficient are within the plus and minus two standard errors of this coefficient. If the CDF for a coefficient is equal to or more than 0.95, then the effects of the variable is considered to be robust, whereas in Leamer's criterion if the estimated coefficient changes sign once, it is considered to be a fragile variable.

The results of the EBA exercises of Eq. (14) are in Tables 2 to 3. Data for 18 Asian countries from 1970 to 2009 is divided into eight panels of five years. Countries included range from the newly industrialised ones such as South Korea to the rapidly growing countries such as China and India. In addition, we include the relatively neglected small countries including Bhutan and Nepal. The countries in our sample are listed in the appendix.

Our results in Table 2 are different to those of Levine and Renelt (1992) and Sala-i-Martin (1997). In both studies there have been significant differences between the selected robust variables. However, in our EBA the Levine and Renelt criteria in column (3) and the Sala-i-Martin criteria in column (4) we select the same set of robust variables. Furthermore, the t-ratios in column (2) can also be used for this purpose. The variables that are significant at the 95% level are also robust according to the criteria in columns (3) and (4). The selected robust variables are log capital per worker ln(*k*), log female secondary, log female tertiary, log male primary, log male secondary, log male tertiary. Note that although log female primary is not robust according to Levine and Renelt (LR) criteria, it is robust according to

Sala-i-Martin criteria. Hence all the six education enrolment variables are robust according to our EBA analysis. Other robust variables are log trade, log financial sector, log foreign direct investment, and log remittances. In contrast, log investment and log government expenditure are fragile in our analysis.

Table 2: Extreme Bounds Analysis-1

$$\ln(y_{it}) = \beta_1 + \beta_2 \ln k_{it} + \beta_3 \ln fp_{it} + \beta_4 \ln fs_{it} + \beta_5 \ln ft_{it} + \beta_6 \ln mp_{it} + \beta_7 \ln ms_{it} + \beta_8 \ln mt_{it} + \beta_9 \ln v_{it} + \beta_{10} \ln n_{it} + \beta_{11} \ln r_{it} + \beta_{12} \ln d_{it} + \beta_{13} \ln g_{it} + \beta_{14} \ln m_{it} + \beta_{15} t + \ln \varepsilon_{it}$$

Variables	(1) Average Coefficient	(2) Average t-ratio	(3) LR Score	(4) CDF	(5) Lower Bound	(6) Upper Bound
t	0.0044	7.21	1	1	0	0.0055
ln(*k*)	0.3727	16.93	1	1	0	0.4167
ln(*Female Primary*)	0.0800	1.67	0	0.9514	-0.0160	0.1761
ln(*Female Secondary*)	0.2384	6.53	1	1	0	0.3113
ln(*Female Tertiary*)	0.1493	4.93	1	1	0	0.2098
ln(*Male Primary*)	0.2230	2.89	1	0.9978	0	0.3775
ln(*Male Secondary*)	0.5793	9.77	1	1	0	0.6979
ln(*Male Tertiary*)	0.1934	4.09	1	0.9999	0	0.2880
ln(*Investment*)	0.0390	0.67	0	0.7470	-0.0781	0.1561
ln(*Trade*)	0.0998	3.82	1	0.9999	0	0.1519
ln(*Financial Sector*)	0.2501	7.49	1	1	0	0.3169
ln(*Government Exp.*)	-0.0272	-0.31	0	0.6221	-0.2017	0.1474
ln(*Remittances*)	0.0426	2.07	1	0.9803	0	0.0837
ln(*FDI*)	0.0414	4.24	1	0.9999	0	0.0609

Notes: Only $\ln k$ is included in the y vector. All the 14 explanatory variables (including capital per worker) are included in the z and x vectors.

How large are the growth effects of these robust variables and in particular the school enrolment ratios? In order to answer this question we have to compare average coefficients obtained in our EBA analysis with the regression estimates in studies that have used level-specific growth effects of education. As mentioned in the introduction there are only few such studies. To the best our knowledge no studies have combined the level and gender specific dimension of education in growth models, therefore our results may not be strictly comparable but can be used as a guide. McMahon (1998) applies the endogenous growth framework to estimate the growth effects of primary, secondary and higher education enrolment ratios in Asian countries. In spirit this is closer to what we are doing in this paper. Because McMahon (1998) used various econometric models, adding and dropping many control variables, it is not possible to report the range of these results. His central finding was that primary and secondary enrolments taken separately or together in all his models, always have a positive and almost always have a highly significant relationship to growth. He also notes 'In East Asia secondary education can be regarded as a foundation for the successful export-oriented growth strategy common to these nations...'. In his final model which included all control variables the estimated coefficients on primary and secondary enrolment were 0.0266 and 0.3094. In the same model the estimated coefficient for higher education was negative (-0.7253) and insignificant like in the rest of the models.

Compared with McMahon (1998), our results agree in one aspect – the growth effect education in Asia is still strongest at the secondary level. This can be seen from the female and male school enrolment effects in column (1) of Table 2. The average coefficients for female primary, secondary and tertiary are 0.0800, 0.2384 and 0.1493 respectively. The similar numbers for male are 0.2230, 0.5793 and 0.1934. These coefficients represent elasticities. Because the enrolment variables are all in per worker terms, these elasticities are to be interpreted, for example, as follows: for a one percent increase in the female secondary enrolment of per worker, output will increase by 0.24 percent and likewise, for a one percent increase in the male secondary enrolment of per worker, output will increase by 0.58 percent. This finding is comparable to Tallman and Wang (1994) who found a value of around 0.5 percent for Taiwan indicating a crucial role for aggregate human capital in promoting economic growth. One can easily observe that the output elasticity of secondary enrolment for both sexes are higher than that of tertiary enrolment. A possible reason for this could be found in the labour literature which shows that in Asia there is a falling rate of social return to investment in education at the tertiary level compared to that of secondary (Psacharopoulos and Patrinos 2004). Despite this, our major finding in contrast to earlier research which detects no significant relationship between higher education and income growth (Barro 1999; McMohan , 1998 and Pritchett, 2001), is that the externality effects of tertiary education are positive and significant for both male and female and in addition, these effects are robust within the EBA exercise. McMahon (1998) has used five year panels from 1965 to 1990, our data is a five year panel from 1970 to 2009 for 18 Asian countries.

Having twenty years of additional data has led us to the finding that the elasticity of tertiary education to economic growth is comparatively smaller than that at the secondary level; it is nonetheless positive and significant for both male and female. However, the main question to be answered is why McMahon (1998) found a negative coefficient for tertiary enrolment as opposed to our findings. Our answer to this would lie in the demographic transition in Asia. The Asian economies experienced a major population boom starting between 1960 and 2000. The demographic transition had produced a ‘youth bulge’ defined as a phenomenon when the percentage of adolescent and youth aged between 15 and 24 in total population exceeded20 percent. For example, while in 1960 the Asian ‘youth bulge’ was 17.28 percent of the total population, the figure was 20.26 percent in 1990 (Hugo, 2008). Although there are interregional differences in the age structure in the Asian continent, the absolute and relative size of the population will overall remain high in Asia and by 2030 the region will represent 55 percent of the total global population in the 15-to-34 age group (Hugo, 2008). Two decades back, when the Asian miracle economies were growing at a very fast rate, those with secondary qualifications could enter the job market and through on-the-job training could maximise earnings rendering university education not so attractive. Therefore the opportunity cost of obtaining higher education in terms of forgone income was high. However, with the demographic transition and the ‘youth bulge’, relaxed the supply constraint in the labour market and the wage level was depressed. Thus attending university was relatively more attractive for this growing youth population. On the demand side, as these Asian economies were gradually shifting from light manufacturing towards industrialisation and high technology, it required workers with more skills and higher education. We believe both these reasons – lower opportunity cost of university education in terms of forgone income and greater demand from employers of graduates with higher education, encouraged a higher fraction of the ‘youth bulge’ to invest in tertiary qualifications and thus spurred the spillover effects causing the positive externalities which can be seen from the positive elasticities in the tertiary enrolment coefficients for both males and females in our model in Table 2.

In a panel of African countries, Gyimah-Brempong, Paddison and Mitiku (2006) have found for the period 1960 – 2000 the contribution to economic growth by primary, secondary and higher education is 0.08, 0.06 and 0.09, respectively. These estimates are relatively low compared to ours. One reason is that our focus is Asia which has had a much faster growth rate than Africa, along with a faster rate of human capital accumulation. Secondly, it is not clear how education externalities are modelled in their paper and therefore these results, in a strict sense, are not directly comparable with those in our model. At the country level, Pereira and Aubynb (2009) and Leoning (2005) have used disaggregated levels of education to examine the effect on growth. Pereira and Aubynb (2009) find that the long run effect on Portuguese economic growth of the labour force with primary (level 3) and secondary schooling are 0.546 and 0.208 respectively and the effect of tertiary schooling negative. On other hand, Leoning (2005) identifies the need to use level-specific education variables in macro studies and applies it to identify the contribution of primary, secondary and tertiary level education in his growth regressions for Guatemala for the period 1950-2002. His estimates were 0.163, 0.075 and 0.056 for the primary, secondary and tertiary level respectively. Compared to those of our findings, these are relatively low.

The second prominent feature of the results based on the six enrolment ratios in Table 2 is the discrepancy between the elasticity of output between male and female enrolments. At each level of enrolment, one can observe that the externality effect of male education is higher than that of female. For example, the highest elasticity of output with respect to enrolment ratio comes from male secondary which is 0.579. The elasticity of output with respect to female secondary enrolment is only half of this. The gap closes a bit at the tertiary level. The elasticity of output with respect to male tertiary enrolment is 0.193 and the same effect for female enrolment is roughly equal to three quarter of this. The lowest figure comes from primary enrolments where the female growth effect is only one third that of male. Given that there is a labour literature related to the cross-country gender wage gap (Blau and Kahn, 2003), we are not surprised by our findings. Since we are estimating a production function where all the inputs are in per worker terms, the elasticity of the human capital variables with respect to output, although considered external producing spillover effects, can be interpreted as the marginal productivity for that particular input. As such the systematic gap found in our EBA results between the elasticity of output with respect male and female enrolment variables per worker, can be interpreted as their respective productivity differentials.

The third feature of our results in Table 2 relates to the other variables included in the production function. It can be seen that remittances, trade, foreign direct investment and financial sectors are all robust according to the criteria in columns (3) and (4) and their average coefficients are found to be positive which is expected from the literature. Although there is a relative controversy over the growth effects of remittances, we would like to stress the fact that our model captures the externalities effect of remittances. It is well documented that remittances lead to better schooling and health for the children in the recipient households creating such externality effects which is captured by our empirical growth model in Eq. 14

Our second EBA exercise shows how sensitive the results in Table 2 are, given the inclusion of the variable time trend along with log capital per worker in the $\mathbf{y}$ vector. The results are reported in Table 3. It can be seen there not much difference and only small changes have occurred in the estimates of average coefficients. The criteria that we followed to decide the robust variables have identified the same set of variables as robust except for female secondary enrolment which has now become fragile according to both the LR and Sala-i-Martin criteria.

Table 3: Extreme Bounds Analysis-2

$$\ln(y_{it}) = \beta_1 + \beta_2 \ln k_{it} + \beta_3 \ln fp_{it} + \beta_4 \ln fs_{it} + \beta_5 \ln ft_{it} + \beta_6 \ln mp_{it} + \beta_7 \ln ms_{it} + \beta_8 \ln mt_{it} + \beta_9 \ln v_{it} + \beta_{10} \ln n_{it} + \beta_{11} \ln r_{it} + \beta_{12} \ln d_{it} + \beta_{13} \ln g_{it} + \beta_{14} \ln m_{it} + \beta_{15} t + \ln \varepsilon_{it}$$

Variables	(1) Average Coefficient	(2) Average t-ratio	(3) LR Score	(4) CDF	(5) Lower Bound	(6) Upper Bound
ln(*k*)	0.4559	21.88	1	1	0	0.4975
ln(*Female Primary*)	0.0726	1.42	0	0.9211	-0.0298	0.1751
ln(*Female Secondary*)	0.2551	6.79	1	1	0	0.3302
ln(*Female Tertiary*)	0.1629	4.92	1	0.9999	0	0.2291
ln(*Male Primary*)	0.1834	2.21	1	0.9861	0	0.3489
ln(*Male Secondary*)	0.6157	10.17	1	1	0	0.7367
ln(*Male Tertiary*)	0.1973	3.96	1	0.9999	0	0.2969
ln(*Investment*)	0.0658	1.04	0	0.8515	-0.0602	0.1919
ln(*Trade*)	0.1231	4.43	1	0.9999	0	0.1786
ln(*Financial Sector*)	0.2783	8.12	1	1	0	0.3468
ln(*Government Exp.*)	-0.0174	-0.19	0	0.5750	-0.2010	0.1662
ln(*Remittances*)	0.0565	2.56	1	0.9945	0	0.1004
ln(*FDI*)	0.0481	4.62	1	0.9999	0	0.0689

Notes: Only $\ln k$ is included in the y vector. All the 13 explanatory variables (including capital per worker) are included in the z and x vectors.

Our next target is to report two more EBA exercises based on the simple growth model given in Eq. 12. By taking logs we get the following econometric specification:

$$\ln(y_{it}) = \ln(A_0) + \alpha \ln k_{it} + g_1 t + (g_2 fp_{it} + g_3 fs_{it} + g_4 ft_{it} + g_5 mp_{it} + g_6 ms_{it} + g_7 mt_{it} + g_8 v_{it} + g_9 n_{it} + g_{10} r_{it} + g_{11} d_{it} + g_{12} g_{it} + g_{13} m_{it}) \times t + \varepsilon_{it} \quad (15)$$

Note the difference between the econometric specifications in growth equations in (14) and (15). In the latter, growth is modelled to take place via two sources: capital accumulation and TFP and the part of the growth due to TFP is further decomposed into some plausible growth enhancing factors which do not have any direct effect on growth other than those through TFP. Therefore the critical difference between Eq. (14) and Eq. (15) is that the latter does not capture any externality effect. We will now present the EBA exercise of Eq. (15) in Table 4 and compare the results with Table 2.

Table 4: Extreme Bounds Analysis-3

$$\ln y_{it} = \ln A_0 + \alpha \ln k_{it} + g_1 T + (g_2 IRAT_{it} + g_3 TRAT_{it} + g_4 M2RAT_{it} + g_5 GRAT_{it} + g_6 REMRAT_{it} + g_7 FDIRAT_{it} + g_8 FPRI_{it} + g_9 FSEC_{it} + g_{10} FTER_{it} + g_{11} MPRI_{it} + g_{12} MSEC_{it} + g_{13} MTER_{it})T + \varepsilon_{it}$$

Variables	(1) Average Coefficient	(2) Average t-ratio	(3) LR Score	(4) CDF	(5) Lower Bound	(6) Upper Bound
t	0.0015	1.00	0	0.84	-0.0015	0.0045
ln(*k*)	0.3967	11.53	1	1	0	0.4656
(*Female Primary*) ×*t*	0.0064	2.68	1	1	0	0.0112
(*Female Secondary*) ×*t*	0.0107	2.86	1	1	0	0.0181
(*Female Tertiary*) ×*t*	0.0033	0.41	0	0.66	-0.0128	0.0195
(*Male Primary*) ×*t*	0.0064	2.79	1	1	0	0.0110
(*Male Secondary*) ×*t*	0.0110	2.80	1	1	0	0.0184
(*Male Tertiary*) ×*t*	$2.1E^{-5}$	0.00	0	0.50	-0.0134	0.0134
(*Investment*)×*t*	0.0312	3.30	1	0.99	0	0.0501
(*Trade*) ×*t*	0.0111	4.48	1	1	0	0.0161
(*Financial Sector*) ×*t*	0.0103	3.11	1	0.99	0	0.0170
(*Government Exp.*) ×*t*	0.0593	2.61	1	1	0	0.1047
(*Remittances*) ×*t*	0.0283	1.41	0	0.92	-0.0119	0.0685
(*FDI*) ×*t*	0.0869	2.37	1	0.99	0	0.1601

Notes: Only $\ln k$ is included in the y vector. All the 14 explanatory variables (including capital per worker) are included in the z and x vectors.

In Table 4, the coefficients of the female and male secondary enrolment ratios are similar at about 0.006, implying that a 1 point increase in both secondary enrolment ratios will increase the growth rate by 0.012 percent. This is very small compared to the estimated coefficients on the female and male secondary enrolment ratios in our previous model in

Table 2 where a 1 percent increase secondary enrolment ratio per worker leads to a 0.80 percent increase in growth rate. Likewise in Table 4 the coefficients of female and male primary enrolment ratios are similar but have smaller growth effects compared to the secondary school enrolment ratios and compared to the same in Table 2. In Table 4 the growth effects of the secondary enrolment are about 1.6 times larger than primary school enrolment. The same ratio based on the estimates found in Table 2 is 3 times as larger. This may be due to the fact that the former's effects are partly captured by the latter because those in secondary schools have already completed primary education. Furthermore, it is also likely that a large number of primary schools are located in rural and remote areas and inadequately staffed and resourced. The coefficients of the two tertiary enrolments are insignificant which makes them fragile variables unlike the results obtained in Table 2.

Overall our conclusion is that the difference between the results in Table 2 and Table 4 is that of externality effects. When we use the specification in Eq. (14), the growth effects of level-specific male and female enrolment ratios per worker are much higher capturing the externality effects of education on growth. In contrast, the specification in Eq. (15) only decomposes the part of the TFP growth due to these enrolment variables and others and do not capture any externality effects. Because TFP growth in Asia has been negligible, it is no surprise that the coefficients in Table 4 are rather small.

Finally, we present our fourth EBA exercise to show how sensitive the results in Table 4 are to changes to the variables in the vector $\mathbf{y}$, which consists of variables that should always be included in all regressions. Although time trend is found not to be a robust variable in Table 3, TFP is generally assumed to follow a deterministic trend pattern. EBA results with both capital and trend in the $\mathbf{y}$ vector are shown in Table 5. It can be seen that these results are similar to those in Table 4 with very small changes in the estimates of the average coefficients. The three criteria in columns (2), (3) and (4) indicate that the same ten variables are robust.

Table 5: Extreme Bounds Analysis-4

$$\ln y_{it} = \ln A_0 + \alpha \ln k_{it} + g_1 T + (g_2 IRAT_{it} + g_3 TRAT_{it} + g_4 M2RAT_{it}$$
$$+ g_5 GRAT_{it} + g_6 REMRAT_{it} + g_7 FDIRAT_{it} + g_8 FPRI_{it} + g_9 FSEC_{it}$$
$$+ g_{10} FTER_{it} + g_{11} MPRI_{it} + g_{12} MSEC_{it} + g_{13} MTER_{it}) T + \varepsilon_{it}$$

Variables	(1) Average Coefficient	(2) Average t-ratio	(3) LR Score	(4) CDF	(5) Lower Bound	(6) Upper Bound
ln(*k*)	0.3863	11.14	1	1	0	0.4557
(*Female Primary*) ×*t*	0.0065	2.59	1	0.9965	0	0.0182
(*Female Secondary*) ×*t*	0.0106	2.76	1	0.9974	0	0.0181
(*Female Tertiary*) ×*t*	0.0048	0.61	0	0.7279	-0.0110	0.0207
(*Male Primary*) ×*t*	0.0065	2.69	1	0.9959	0	0.0113
(*Male Secondary*) ×*t*	0.0106	2.69	1	0.9958	0	0.0185
(*Male Tertiary*) ×*t*	0.0014	0.23	0	0.5857	-0.0118	0.0147
(*Investment*)×*t*	0.0354	3.19	1	0.9993	0	0.0503
(*Trade*) ×*t*	0.0118	4.51	1	0.9999	0	0.0170
(*Financial Sector*) ×*t*	0.0108	3.04	1	0.9988	0	0.0179
(*Government Exp.*) ×*t*	0.0595	2.54	1	0.9938	0	0.1063
(*Remittances*) ×*t*	0.0310	1.48	0	0.9190	-0.0108	0.0727
(*FDI*) ×*t*	0.0848	2.28	1	0.9877	0	0.1594

Notes: Only $\ln k$ and T are included in the y vector. All other explanatory variables (including capital per worker) are included in the z and x vectors.

6. Summary and Conclusions

This study employed the Extreme Bounds Analysis to investigate the robust growth effects of male and female education disaggregated at the primary, secondary and tertiary levels by gender for a panel of Asian countries. Both the stringent criteria of Levine and Renelt (1992) and Sala-i-Martin's (1997) criteria based on the cumulative distribution of the estimates of the coefficients indicated that male and female primary, secondary and tertiary enrolment ratios have robust and relatively high growth effects when these are considered in a model where externalities are explicitly modelled within. In such model, a gender effect is also observed wherein the growth effects of male enrolment per worker are consistently estimated to be higher than that of their female counter part. We believe this could be an important finding for those researchers studying the gender wage gap in the cross-country labour market. When these effects are studied in an alternative model without externalities, female and male primary and secondary school enrolment ratios have robust but small growth effects while the growth effects of tertiary enrolment ratios are insignificant for both sexes.

In addition to enrolment ratios, some of the variables used as control variables, are also found to have robust growth effects. Of these control variables financial sector development has the largest growth effect and is more than twice the growth effect of domestic investment. Trade openness, remittances and foreign direct investment have similar robust growth effects. In our alternative growth model, remittances was found to have fragile growth effects, although according to the Levine and Renelt (1992) criteria, has a CDF of 0.93 and can be said to have growth effects in some countries but not in all countries.

We hope that our paper will encourage additional empirical work on estimating the growth effects of education via other growth models and TFP. In particular, it would be interesting to disaggregate current government expenditure into various components and estimate their growth effects. However, our conclusions should be interpreted with caution due to some limitations. Our panel is not balanced because data for some years are not available for all countries on crucial variables such as GDP, employment, investment and for some enrolment ratios. Therefore, our findings need further analysis by other investigators employing a larger sample of countries.

Appendix
Derivation of Eq. (6)

We start with Eq. (4) which is repeated for convenience below:

$$y_{jit} = Ak_{jit}^{\alpha}\left[(1+\gamma)^{t} l_{jit}\right]^{1-\alpha} \widetilde{K}_{it}^{\lambda} \widetilde{FP}_{it}^{\varphi} \widetilde{FS}_{it}^{\eta} \widetilde{FT}_{it}^{\omega} \widetilde{MP}_{it}^{\delta} \widetilde{MS}_{it}^{\nu} \widetilde{MT}_{it}^{\mu} \widetilde{V}_{it}^{\xi} \widetilde{N}_{it}^{\tau} \widetilde{R}_{it}^{\chi} \widetilde{D}_{it}^{\psi} \widetilde{G}_{it}^{\pi} \widetilde{M}_{it}^{\vartheta} \varepsilon_{it}$$

The congestion effects are modelled as follows:

$$\widetilde{K}_{it} = \frac{K_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{FP}_{it} = \frac{FP_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{FS}_{it} = \frac{FS_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{FT}_{it} = \frac{FT_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}},$$
$$\widetilde{MP}_{it} = \frac{MP_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{MS}_{it} = \frac{MS_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{MT}_{it} = \frac{MT_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{V}_{it} = \frac{V_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}},$$
$$\widetilde{N}_{it} = \frac{N_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{R}_{it} = \frac{R_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{D}_{it} = \frac{D_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}, \widetilde{G}_{it} = \frac{G_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}},$$
$$\widetilde{M}_{it} = \frac{M_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}} \qquad \text{A.1}$$

Substitute congestion effects equations A.1 in Eq. (4):

$$y_{jit} = Ak_{jit}^{\alpha}\left[(1+\gamma)^{t} l_{jit}\right]^{1-\alpha} \times \left(\frac{K_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\lambda} \times \left(\frac{FP_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\varphi} \times \left(\frac{FS_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\eta}$$
$$\times \left(\frac{FT_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\omega} \times \left(\frac{MP_{it}}{K_{it}^{\phi}[(1+\gamma L_{it})]^{1-\phi}}\right)^{\delta} \times \left(\frac{MS_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\nu} \times \left(\frac{MT_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\mu}$$
$$\times \left(\frac{V_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\xi} \times \left(\frac{N_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\tau} \times \left(\frac{R_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\chi} \times \left(\frac{D_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\psi}$$
$$\times \left(\frac{G_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\pi} \times \left(\frac{M_{it}}{K_{it}^{\phi}[(1+\gamma)L_{it}]^{1-\phi}}\right)^{\vartheta} \qquad \text{A.2}$$

We rearrange equations in A.1 to express the aggregate variables in per capita:

$$k_{it} = \frac{K_{it}}{L_{it}}, fp_{it} = \frac{FP_{it}}{L_{it}}, fs_{it} = \frac{FS_{it}}{L_{it}}, ft_{it} = \frac{FT_{it}}{L_{it}}, mp_{it} = \frac{MP_{it}}{L_{it}}, ms_{it} = \frac{MS_{it}}{L_{it}}, mt_{it} = \frac{MT_{it}}{L_{it}},$$

$$v_{it} = \frac{V_{it}}{L_{it}}, n_{it} = \frac{N_{it}}{L_{it}}, r_{it} = \frac{R_{it}}{L_{it}}, d_{it} = \frac{D_{it}}{L_{it}}, g_{it} = \frac{G_{it}}{L_{it}}, m_{it} = \frac{M_{it}}{L_{it}} \qquad \text{A.3}$$

Substitute these equations and express Eq. A.2 in per capita terms and noting $y_{jit} = y_{it}$

$$y_{jit} = Ak_{jit}^{\alpha}\left[(1+\gamma)^{t}\right]^{1-\alpha} \times \left(\frac{k_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\lambda} \times \left(\frac{fp_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\varphi} \times \left(\frac{fs_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\eta}$$
$$\times \left(\frac{ft_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\omega} \times \left(\frac{mp_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\delta} \times \left(\frac{ms_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\nu} \times \left(\frac{mt_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\mu}$$
$$\times \left(\frac{v_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\xi} \times \left(\frac{n_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\tau} \times \left(\frac{r_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\chi} \times \left(\frac{d_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\psi}$$
$$\times \left(\frac{g_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\pi} \times \left(\frac{m_{it}}{k_{it}^{\phi}[(1+\gamma)L_{it}/L_{it}]^{1-\phi}}\right)^{\vartheta} \varepsilon_{\text{it}} \qquad \text{A.4}$$

Which gives us the following:

$$y_{jit} = A\left[(1+\gamma)^{t}\right]^{1-\alpha} k_{jit}^{\alpha} \times \left(\frac{k_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\lambda} \times \left(\frac{fp_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\varphi} \times \left(\frac{fs_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\eta}$$
$$\times \left(\frac{ft_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\omega} \times \left(\frac{mp_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\delta} \times \left(\frac{ms_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\nu} \times \left(\frac{mt_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\mu}$$
$$\times \left(\frac{v_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\xi} \times \left(\frac{n_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\tau} \times \left(\frac{r_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\chi} \times \left(\frac{d_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\psi}$$
$$\times \left(\frac{g_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\pi} \times \left(\frac{m_{it}}{k_{it}^{\phi}[(1+\gamma)]^{1-\phi}}\right)^{\vartheta} \varepsilon_{\text{it}} \qquad \text{A.5}$$

At equilibrium for a panel of countries, we assume $k_{it} = k_{jit}$, which is analogous to Lau and Sin (1997b) who assumes $k_t = k_{jt}$ for a single country and in the same spirit we also assume $y_{jit} = y_{it}$ to derive Eq. (6) in per capita term.

$$y_{it} = Ak_{it}^{(\alpha+\lambda-(\lambda+\varphi+\eta+\omega+\delta+\nu+\mu+\xi+\tau+\chi+\psi+\pi+\vartheta)\phi)}(1+\gamma)^{t(1-\alpha-(1-\phi)(\lambda+\varphi+\eta+\omega+\delta+\nu+\mu+\xi+\tau+\chi+\psi+\pi+\vartheta)}$$
$$fp_{it}^{\varphi} fs_{it}^{\eta} ft_{it}^{\omega} mp_{it}^{\delta} ms_{it}^{\nu} mt_{it}^{\mu} v_{it}^{\xi} n_{it}^{\tau} r_{it}^{\chi} d_{it}^{\psi} g_{it}^{\pi} m_{it}^{\vartheta} \varepsilon_{it} \qquad \text{A.6}$$

Table of Data Sources

Variable	Source
Per capita income (constant 2000 US$)	World Development Indicators 2010
Investment to GDP (V)	World Development Indicators 2010
Trade to GDP (N)	World Development Indicators 2010
M2 to GDP (M)	World Development Indicators 2010
Government final consumption expenditure to GDP (G)	World Development Indicators 2010
Remittances to GDP (R)	World Development Indicators 2010
Foreign Direct Investment to GDP (D)	World Development Indicators 2010
School enrolment primary female, total % gross (FP)	World Development Indicators 2010
School enrolment primary male, total % gross (MP)	World Development Indicators 2010
School enrolment secondary female, total % gross (FS)	World Development Indicators 2010
School enrolment secondary male, total % gross (MS)	World Development Indicators 2010
School enrolment tertiary female, total % gross (FT)	World Development Indicators 2010
School enrolment tertiary male, total % gross (MT)	World Development Indicators 2010

Countries Used in the Study

Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Korea, Lao, Malaysia, Maldives, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam. For Bhutan and Myanmar, data for the capital stock were not available and for Lao and Vietnam data were available only for part of the period. For the Maldives and Myanmar enrolment ratios are not available for the full period and for Singapore enrolment ratios were not available.

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