Cognitive Skills, Openness, Education and Growth

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Abstract

A significant positive relationship exists between the trade share and educational spending to GDP implying that countries which are more open on the trade front also spend more on education. An open economy endogenous growth model with human capital is developed to understand this stylized fact. The model demonstrates that countries with greater cognitive skill spend more on education, and grow faster. These countries open up on the trade front to finance import of physical capital which becomes scarce due to the diversion of resources to education. The model highlights the importance of the productivity of human capital or cognitive skill as an important economic fundamental determining the comovement between trade share and education share.

JEL Classification: F41, O11, O33, O41
Keywords: Growth, Openness, Human capital, Cognitive Skill

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1 Introduction

While the relationships between trade openness and growth as well as growth and education have been well explored, little effort has been made to understand these variables in an integrated growth model. Do open countries invest more in human capital? The issue is relevant for both empirical and theoretical reasons. It is well known that human capital is a vehicle of growth and growing economies are more open.[1] However, it is not clear whether there are common fundamentals that link education, openness and growth. This paper is a quest for such fundamentals.

We propose that cognitive skills of a country's population are powerfully connected to growth, openness and education. Cognitive skills of pupils reflect the quality of schooling measured by international test scores in mathematics, science and reading. A recent paper by Hanushek and Woessman (2008) argues that differences in quality of schooling make cognitive skills differ even though the years of schooling are the same across countries. This results in cross-country differences in returns to schooling and growth rates.

The development facts that we present in the next section document that there is a significant cross country positive correlation between trade share, education share and cognitive skills. This motivates us to develop an open economy growth model to understand this linkage. In our stylized model, we assume that the prototype small open economy imports all physical

[1] Barro (1991) Mankiw, Romer and Weil (1992), Jogenson and Fraumeni (1992), Parente and Prescott (2002)) analyze closed economy endogenous growth models to study theoretically and empirically the link between growth and education leaving the trade issue aside. Grossman and Helpman (1990) as well as Manning (1982) show the relationship between trade, education and growth in an open economy. Cartiglia (1997) had shown how trade liberalization in skill scarce country leads to a higher investment in human capital and creates the pattern of comparative advantage on international trade. Basu and Guariglia (2007) point out that FDI can complement human capital and could be beneficial for growth at the expense of greater inequality. Galor and Mountford (2008) further show that gains from trade are directed towards investment in education and growth in per capita income in OECD countries but channelled towards higher fertility and population growth in developing countries.

capital and specializes in the export of human capital (skill) intensive goods. This assumption is motivated by the work of Thoenig and Verdier (2003) as well as Neary (2002) who demonstrate that trade integration among similar countries may give rise to a defensive skill based technical change. In our model, the principal driver of this skill based technical change is cognitive skill. A higher cognitive skill of the population could enhance the returns from schooling which provides the nation an incentive to divert raw labour from the goods to education sector. This gives rise to a relative scarcity of physical capital with respect to human capital. If the bulk of physical capital is imported from abroad, such a shortage makes it necessary for the economy to open up more on the trade front. Countries with higher cognitive skills thus invest more in education and also become more open on the trade front. We demonstrate this in terms of an open economy endogenous growth model in the tradition of Becker (1975) and Lucas (1988). The paper derives closed form solutions for the balanced growth, educational investment and openness showing how cognitive skills jointly determine all these three macroeconomic variables. To the best of our knowledge, our paper is the first in the literature which explores the role of cognitive skills in determining openness, education and growth within an endogenous growth model.

The rest of the paper is organized as follows. The following section documents some development facts. Section 3 lays out the endogenous growth model. Section 4 describes the long run properties of the model. Section 5 performs short run analysis in terms of impulse responses. Section 6 concludes.

2 Some Development Facts

To gain empirical motivation, in this section we present some cross-country development facts about education, openness, growth and cognitive skill.

Table 1 reports the summary statistics on these three relevant variables.[2] Data show enormous variation across countries. Among 186 countries range of openness measured by the ratio of exports to GDP was 217. Small and highly developed countries like Singapore export around 221 percent of GDP followed by Aruba, Hong Kong, Luxemburg and Macao which have openness more than 100 percent.[3] On the other extreme are countries such as Argentina, Brazil, USA and India with exports less than 10 percent of their GDP. Only 45 countries have export more than 50 percent of their GDP. Median export ratio is 29 percent. Similar variation is seen in the education spending among 175 countries. Countries like Guam, American Samoa and New Caledonia spend more than 10 percent of GNI in education while countries like Laos, Congo, Chad, Haiti, Myanmar, Bangladesh, Somalia and Indonesia have less than 1.5 percent of GNI in it. The range of cognitive skill in the sample of 77 countries is 2.249, with South Korea the highest cognitive skill of 5.338 and South Africa the lowest cognitive skill of 3.09. [4]

The trends of cross country averages of ratio of education spending to Gross National Income (GNI), growth rates of GDP and ratios of imports and exports to GDP are shown in Figure 1 for the last thirty five years. The secular rising trend in import and export ratios indicate the rapid pace of

[2]For each of these variables, the time average is first computed for each country over the period 1960-2007. Countries with missing data have a shorter sample period. Then a cross country mean, median, skewness (indicating the difference between mean and median) and the inter-quartile ranges are computed.

[3]For many of these emerging countries export shows up as more than their GDP in the balance of payments account. For example, Singapore buys textiles in China and sells them in Europe; It buys high tech equipments from the US and sells to China. In both cases goods were not produced in Singapore but these are counted as exports of Singapore. This explains why exports share in GDP can exceed unity in extremely open countries.

[4]Data for education ratio is not available for 11 countries: Aruba, Bosnia and Herzegovina,Macao, China,Micronesia, Fed. Sts., Montenegro, Palau, Serbia, Turkmenistan, United Arab Emirates,West Bank and Gaza,Yemen, Rep. Yemen, Rep. Countries such as Cayman Islands, Guam, Isle of Man,Marshall Islands, Mayotte,Monaco.Netherlands Antilles,San Marino,Timor-Leste are dropped from computations because of missing data in more than two variables.

Table 1: Summary Statistics: 1971-2007

Variable	N	Mean	StDev	Min	Q1	Median	Q3	Max
Education	175	4.08	1.667	0.823	2.776	4.045	5.09	11.583
Exports	186	36.96	25.26	3.38	20.2	29.48	48.01	221.15
Growth rate	186	3.88	2.322	-1.624	2.613	3.668	4.742	16.882
Imports	186	43.97	24.4	8.3	26.91	37.02	58.69	196.3
Exp+import	186	80.93	47.21	15.85	50.31	71.27	105.81	417.45
Cognitive skill	75	4.5298	0.5629	3.089	4.107	4.641	4.995	5.338

globalization in the last four decades. This rise is associated with an increase in the ratio of spending on education to GDP during this period.

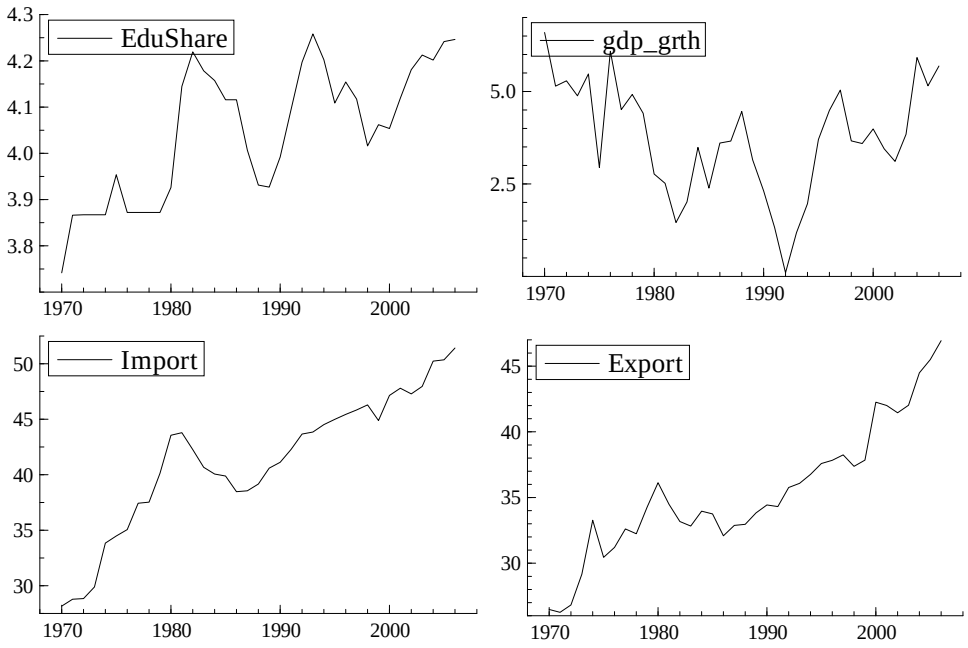

Figure 1: Trends of ratios education spending, growth, imports and exports

To get a broad picture of the relationship between trade openness and education, we compute the cross country correlations of the time averages of education share in GDP(edu_r) , export and import shares (exp_r and

imp_r)), growth rate (Growth) and the total trade share (Trade_r), i.e. the sum total export and import shares .[5]

Table 2: Correlation coefficients among ratios education spending, imports, exports and growth

	Edu_r	Export	Growth	Imp_r	Trade_r
Edu_r	1				
Exp_r	0.23	1			
Growth	-0.16	0.1687	1		
Import_r	0.23	0.81	0.14	1	
Trade_r	0.24	0.95	0.16	0.94	1

Correlations in Table 2 reveal a positive and significant relationship between export share and education share in GDP implying that countries with a higher spending on education relative to GDP have also a higher ratio of export and import to GDP.[6]

The positive correlations between trade openness and education share are reasonably robust with respect to finer partitions of countries. Tables 4 and 5 report the panel regression of export and import shares on education share for a wide range of countries grouped in 14 categories as per the World Development Indicators (2007).[7] The regression controls for country specific

[5] See http://www.esds.ac.uk/international/ and www.undp.org for detailed data source. All the series came from the World Bank's Development Indicator (WDI) database which covers 206 countries.

[6] Table 1 also reflects a negative correlation between growth rates and education spending. This reflects the fact that low income countries tend to grow faster than higher income countries which makes the education share to correlate negatively with growth. To verify this conjecture, we sort the data between low income and high income countries. For low income countries, the correlation is -0.17 while for high income countries it is .002. Also a panel regression of country growth rates on education shares after controlling for country specific effects provides a positive coefficient which is not statistically significant. Given that the cross country growth shows tremendous disparity, locating only education as a single explanatory variables may not be the way to determine education-growth relationship.

[7] These 14 groups include countries with low income, middle income, lower middle income, upper middle income, Asia and Pacific, Latin American, Middle East-

effects by adding country dummies. The coefficients of education share is statistically significant at the 5% level in both regressions. Panel augmented Dickey-Fuller (ADF) tests are reported in Table 3 to check for spurious correlations. ADF test statistics are significantly less than the critical value of -3.45 at 1 percent level of significance indicating stationarity of each series.[8]

Table 3: Test for Stationarity for Variables Included in Regressions

	Edu_r	Exp_r	Imp_r
ADF test	-3.669***	-6.237**	-5.715**
lag	0	1	1

Table 4: Panel and AR1 Regressions of Export Ratio on Education Spending Ratio

Dep Variable: Exp_r	Coefficient (Static Panel)	Coefficient (Dynamic Panel)
Constant	10.61**	1.88**
Edu_r	2.58**	0.31**
Exp_r(-1)	–	0.85**
R^2	.039	0.73
D-W	-	1.90
Sample size	N=14; T=36 (1971-2006)	$N \times T$ =503

Since the central hypothesis of our paper is to see the connection between cognitive skill, openness and growth, we use the latest data available from Hanushek and Woessman (2008).[9] The high cognitive skill of pupils could

ern, South Asian, South Africa, high income, high income OECD and highly indebted ones. Each country has 36 years of observation from 1971 to 2006. One degree of freedom is lost in the AR1 model. List of countries included in each of these 14 categories is given in Appendix C.

[8]While running this panel regression, we controlled for country heterogeneity, and conditional convergence. This is done by adding dummies for groups of countries, and adding growth rate and level of GDP as regressors. Full details of these regressions are omitted for brevity but available from the authors upon request. ** means that the test statistic is significant at the 5% level while *** means significance at the 1% level.

[9]Hanoushek and Woesman (2008) dataset contains 75 countries. They compute the

Table 5: Panel and AR1 Regressions of Import Ratio on Education Spending Ratio

Dep variable: Imp_r	Coefficient (Static Panel)	Coefficient (Dynamic Panel)
Constant	12.42**	1.73**
Edu_r	2.41**	0.22*
Imp_r (-1)	-	0.88**
R^2	.039	0.77
D-W	-	1.84
Sample size	N =14; T=36 (1971-2006)	$N \times T$=503

result from a host of factors including better quality of schooling, as well as fiscal subsidy to education. Using their data set for cognitive skills we compute the cross-country correlation of cognitive skills with export, import and education share for 75 countries which is reported in Table 6**.** High-cognitive skill countries tend to spend more in education and also have higher trade share.

Table 6: Correlation coefficients among cognitive skill, imports, exports and education

	Exp_r	Imp_r	Edu_r
Cog Skill	.2558	.3299	.2708

These developmental facts can be summarized as follows. First, there is a significant cross-country positive correlation between trade openness and educational investment. Second, countries with a higher cognitive skill index tend to be more open on the trade front and invest more in education. In the rest of the paper we set up an endogenous growth model to understand the linkage between cognitive skill, openness and education.

cognitive skills average of each country based on student test scores. We thank them for providing us this data.

3 The Model

The model is a small open economy adaptation of the Lucas-Uzawa (Lucas, 1988) model. There are two sectors, goods and education. We view the problem from the perspective of a representative small open economy in a global environment. The home country imports physical capital and produces the output in the goods sector (y_t) with this imported physical capital (k_t) and home grown intangible or human capital (h_t).[10] Human capital is augmented only with the aid of human capital and this activity is called schooling. At any date t, a fraction l_{Gt} of human capital is allocated to the goods sector and remaining fraction l_{Ht} is allocated to schooling. The human capital evolves following the technology:

$$h_{t+1} = (1 - \delta_h)h_t + A_{Ht}l_{Ht}h_t \tag{1}$$

where the variable A_{Ht} is the crucial fundamental namely, cognitive skills of the home country's population. Given the current level of human capital (h_t) and the raw labour or efforts (l_{Ht}) put in schooling, the human capital achieved in the following period will be greater if the cognitive skills, A_{Ht} are higher. Quality of schooling and education subsidy could significantly account for this variable. The introduction of this cognitive skills variable is motivated by the recent work of Hanushek and Woessman (2008). Basu and Guariglia (2008) also use the same human capital investment technology to understand the effect of education on the pace of industrialization.

Final goods (y_t) are produced with the help of human and physical capital

[10] The assumption that the home country exports human capital intensive goods and imports all physical capital can be motivated by the persuasive argument of Thoenig and Verdier (2003) that in a globally integrated environment, countries which are identical in every respect may opt for a defensive skill biased technology. A more comprehensive trade model (which is beyond the scope of this paper) can analyze a two country general equilibrium model where the north is the home country which imports physical capital from the south and produces human capital based final goods.

via the Cobb-Douglas production technology:

$$y_t = A_{Gt} {k_t}^{\alpha} (l_{Gt} h_t)^{1-\alpha} \tag{2}$$

where A_{Gt} is the the date t total factor productivity (TFP) in the goods sector.

We assume the following stationary stochastic processes for these two TFP shocks around the steady state:

$$A_{Gt} - \bar{A}_G = \rho_G (A_{Gt-1} - \bar{A}_G) + \xi_t^G \tag{3}$$

$$A_{Ht} - \bar{A}_H = \rho_G (A_{Ht-1} - \bar{A}_H) + \xi_t^H \tag{4}$$

where $\bar{A}_G$ and $\bar{A}_H$ are the steady state TFP of the goods and education sectors. ρ_G and ρ_H are positive fractions and ξ_t^G and ξ_t^H are white noises.

Final goods are used for consumption (c_t) and export (x_t). The home country faces a fixed price p^k for investment goods (i_t^k) . It finances this physical investment by a combination of export and foreign borrowing (b_t) at a fixed world interest rate, r^*.

The resource constraint facing the home country is:

$$c_t + x_t = y_t \tag{5}$$

The current account equation is given by:

$$x_t + b_{t+1} = (1 + r^*) b_t + p^k i_t^k \tag{6}$$

where

$$i_t^k = k_{t+1} - (1 - \delta_k) k_t \tag{7}$$

The home country faces a borrowing constraint. The amount that it

can borrow in the international market is constrained by the current capital stock which means:

$$b_t \leq k_t \tag{8}$$

The timeline is as follows. At date t, the state of the economy is characterized by k_t, h_t and b_t. The home country after realizing the TFP shocks, ξ_t^G, ξ_t^H , makes decisions about goods production (y_t), schooling (l_{Ht}), exports (x_t), external borrowing (b_{t+1}) and consumption (c_t) which maximizes the following expected utility functional.

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t)$$

subject to (1) through (8).

4 Balanced Growth Properties

Hereafter we specialize to a logarithmic utility function, $U(c_t) = \ln c_t$, to analyze the long run and short run properties of the model. We also assume that the borrowing constraint (8) binds. In order to focus on the long run properties of the model, assume also that the two productivity variables, A_{Gt} and A_{Ht} are stationary at $\bar{A}_G$ and $\bar{A}_H$.

The balanced growth equations for the key macroeconomic variables are as follows. The Appendix A shows the details of the derivation.

Growth Rate:

$$1 + g = \frac{h_{t+1}}{h_t} = \frac{k_{t+1}}{k_t} = \frac{c_{t+1}}{c_t} = \beta[1 + \bar{A}_H - \delta_h] \tag{9}$$

Raw Labour:

$$
\begin{aligned}
l_H &= \beta - (1-\delta_h)(1-\beta)/\bar{A}_H \qquad (10)\\
l_G &= 1 - l_H
\end{aligned}
$$

Physical to Human Capital Ratio:

$$
k_t/h_t = \left[\frac{\alpha\bar{A}_G}{(p^k-1)\left(\bar{A}_H - \delta_h\right) + p^k\delta_k + r^*}\right]^{1/(1-\alpha)} .(1-\beta+(1-\delta_h)(1-\beta)/\bar{A}_H) \qquad (11)
$$

Export Share

$$
\frac{x_t}{y_t} = \frac{\alpha\beta(1-\delta_h+\bar{A}_H)(p^k-1) + \alpha(1+r^*) - \alpha(1-\delta_k)p^k}{MPK} \qquad (12)
$$

Import Share

$$
\frac{m_t}{y_t} = \frac{\alpha p^k\{\beta(1+\bar{A}_H-\delta_h) - (1-\delta_k)\}}{MPK} \qquad (13)
$$

where MPK which denotes the marginal product of physical capital is given by:

$$
MPK = (p^k-1)\bar{A}_H + p^k(\delta_k - \delta_h) + \delta_h + r^* \qquad (14)
$$

4.1 Education Share in GDP

Few clarifications about the education share in GDP is in order. Since education is a distinct good in our two sector setting, the issue arises whether it counts towards GDP or not. In the present model, we assume that the households produce education with the nonmarket time. The education is a purely nontraded good which does not pass through any organized market.

We, therefore, do not count this as a part of final good. However, while computing the ratio of education spending to GDP, one has to be careful about the shadow price of education and GDP because of the two sector nature of the model. To this end, we use the lagrange multipliers associated with each good. The share of education in GDP based on (5) and (1) is thus given by:

$$Educ = \frac{\mu_t \bar{A}_H l_H h_t}{\lambda_t y_t} \tag{15}$$

where λ_t and μ_t are the lagrange multipliers associated with the flow resource constraint (5) and the human capital constraint (1).[11]

The Appendix A shows that the education share in (15) is given by:

$$Educ = \frac{(1-\alpha) l_H}{l_G} \tag{16}$$

4.2 Baseline Calibration and Comparative Statics

This model is defined in terms of eight parameters, $\bar{A}_G$, $\bar{A}_H$, p^k ,r^*, $\alpha, \beta, \delta_h, \delta_k$ which describe the preferences, technology and accumulation processes in the economy. Our primary query is: what could contribute to a positive cross country correlation between openness and education as seen in the data? An inspection of the education share (16) and the export and import share equations (12) and (13) reveals that the cognitive skill parameter, $\bar{A}_H$ links the education and openness. A higher $\bar{A}_H$ raises the allocation of human capital to the research sector (equation 1) and this drives up the education/GDP share (16).

How do these two parameters impact trade share? This is not analytically obvious. To find answer we resort to a numerical comparative dynamics based on our baseline calibrated model.

Parameters, α, β, δ_k are fixed at the conventional levels as in many studies

[11] Note that μ_t/λ_t is the Tobin'q of human capital.

including Prescott (1986). The world interest rate r^* is fixed at 3% consistent with the Bank of England estimate.[12]. The remaining four parameters are chosen to target a baseline median growth rate of around 4% for the 78 countries in our sample and a median trade share of about 70% of GDP for the sample. A 50:50 time allocation between goods production and schooling is assumed for this calibration which is consistent with other studies including Benk et al. (2009) and Basu et al. (2009).[13] Table 7 reports the baseline values of these parameters.

Table 7: Baseline Parameters

$\bar{A}_G$	$\bar{A}_H$	p^k	r^*	α	β	δ_h	δ_k
1.2	.088	1.5	0.03	0.36	0.96	0.015	0.1

Table 8: Comparative Dynamics with respect to A_H

Scenarios	$\bar{A}_H$	l_{Gt}	l_{Ht}	$(x_t + m_t)/y_t$	Educ	Growth	k_t/h_t
1	.088	.489	.510	0.653	0.668	3.29%	1.424
2	.089	.484	.516	0.655	0.682	3.39%	1.404
3	.090	.479	.521	0.657	0.695	3.48%	1.385
4	.091	.474	.526	0.659	0.709	3.58%	1.366
5	.092	.469	.530	0.660	0.723	3.68%	1.33
6	.093	.465	.539	0.664	0.736	3.78%	1.312
7	.094	.460	.544	0.665	0.750	3.87%	1.295
8	.095	.456	.548	0.667	0.763	3.97%	1.278
9	.096	.452	.552	0.668	0.777	4.06%	1.262
10	.097	.447	.557	0.670	0.790	4.16%	1.246

[12] see:http://www.bankofengland.co.uk/statistics/rates/baserate.pdf

[13] Both Benk et al. (2009) and Basu et al. (2009) have leisure in the utility function. For the US data after allowing for leisure time, both papers calibrate the time devoted to goods and education are about .24 and .20 respectively.

Table 8 reports the comparative dynamics of the steady state variables with respect to changes in $\bar{A}_H$. A higher $\bar{A}_H$ can be interpreted as an improvement in the quality of the human capital or cognitive skill as in Hanushek and Woessman (2008). The model predicts that a higher $\bar{A}_H$ induces agents to invest more time in education and less time in goods production because education has a higher marginal return vis-a-vis goods production. As agents transfer resources away from goods to education, the physical to human capital ratio falls (last column of the Table 8), and growth rate rises. As long as the relative price of capital ($p^k > 1$) such a scarcity of physical capital raises the marginal product of physical capital (due to diminishing returns to factor proportion) as seen in (14). Since the home country has the option to augment physical capital by financing it through current account, it will take advantage of it by raising its export and import shares. Thus the country becomes more open on the trade front. The bottomline is that as a consequence of higher $\bar{A}_H$, the home country invests more in education, its growth rises and its trade share also increases.[14]

The model fails to predict quantitatively an empirically plausible magnitude for the education share of GDP which is about median 4% for our sample of countries. There are two reasons for this discrepancy. First, the education expenditure data only refer to public spending on education. The cross country data for private expenditure on education is not available for a sizable number of countries. Second, the education expenditure in our model basically reflects the opportunity cost of schooling due to the lost wages at work.[15] It is difficult to find a data counterpart of this opportunity cost. A more general human capital technology where physical capital is also em-

[14] Sensitivity analysis has been carried out and we find that the directions of comparative statics results are invariant to alterations of parameter values around the baseline. The effect of a lower rate of depreciation in δ_h is analogous to a higher $\bar{A}_H$ which we do not report here for brevity.

[15] To see this, recall that this opportunity cost is the ratio of the multipliers, μ_t/λ_t which is the simply the ratio of marginal products of labour in the goods to education sectors. See (A.4) in the Appendix A.

ployed in the production of education is likely to reduce this opportunity cost of human capital.

4.3 Role of TFP in the Goods Sector

The central point of this paper is that the cognitive skill measured in terms of the human capital productivity is the major fundamental driving the cross country correlation between trade openness and education. What is the role of the goods sector productivity, $\bar{A_G}$, in determining the same correlation? It is straightforward to verify from (9), (10), (12) and (13) that the TFP in the goods sector has no effects on the balanced growth, the education share and the trade shares. This basically means that a rise in $\bar{A_G}$ is offset by a rise in (k/h) to keep the MPK constant (see (11)). Thus the long run cross country correlation between openness and education is driven by cognitive skill alone.

5 Short Run Dynamics

Until now we only analyzed the long run properties of the model. Such a long run analysis can be motivated by cross-country comparison of various long run averages such as average growth, trade share, education share. The underlying assumption here is that each country is in different long run steady states and the research question is what drives this cross-country dispersion. There are two productivity fundamentals, A_G and A_H in goods and education sectors among which we identify the latter as the crucial fundamental determining the cross country dispersion of growth, education share and trade share. However, such a long run analysis cannot reflect how a country can respond to shocks to its fundamentals, A_G and A_H. Shocks to these fundamentals can arise due to changes in tax policy. For example, an education subsidy in the form of hiring high quality teachers can have an impact upon

the cognitive skill, A_H. On the other hand, institution of a capital income tax could hurt the goods sector productivity, A_G. Analysis of this kind of *within-country* response to shocks necessitates a short run analysis to which we turn now.

5.1 Impulse Responses

Appendix B summarizes the relevant short run equations. There are eight endogenous variables namely, c_t/h_t, l_{Gt}, x_t/y_t, m_t/y_t, $Educ_t$, ca_t/y_t, k_t/h_t, y_{t+1}/y_t and two exogenous variables, A_{Gt} and A_{Ht}. Among these endogenous variables, only k_t/h_t is predetermined. The impulse response analysis is based on loglinearlized deviations of these variables from the steady state. Since this is a model of endogenous growth, the loglinearization is done around the balanced growth path described earlier. Figures 2 and 3 represent the impulse responses of various endogenous variables with respect to shocks to TFP in each sector, namely ξ_t^G and ξ_t^H based on (3) and (4) given the baseline parameters in Table 7.[16] In response to a positive shock to ξ_t^G, more time is devoted to goods production and this makes educational investment fall. Growth rate of output rises momentarily as more goods are produced but then it quickly turns negative due to paucity of investment of human capital. On the current account front, the home country responds to this shock by importing a lot of physical capital. This makes the current account (cay) decline in the short run.[17]

In response to a cognitive skill shock, ξ_t^H, the impulse responses behave differently. Agents devote more time to schooling less time to production of final goods. Growth rate of output picks up as more schooling increases the human capital base. Both export and import shares fall although the latter falls more than the former making the current account rise. At a later stage,

[16] A variant of the algorithm of Blanchard and Kahn (1980) is used to plot the impulse responses. All the calculations are done using DYNARE developed by Julliard (1996).

[17] In the impulse response chart, $ck = c_t/k_t$, $kh = k_t/h_t, xy = x_t/y_t$, $my = m_t/y_t$, $cay = ca_t/y_t$.

the nation starts allocating more resources to the goods sector which makes import and export share rise.

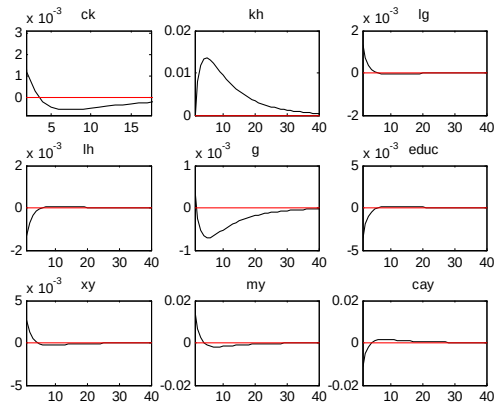

Figure 2: Impulse Response to A_G Shock

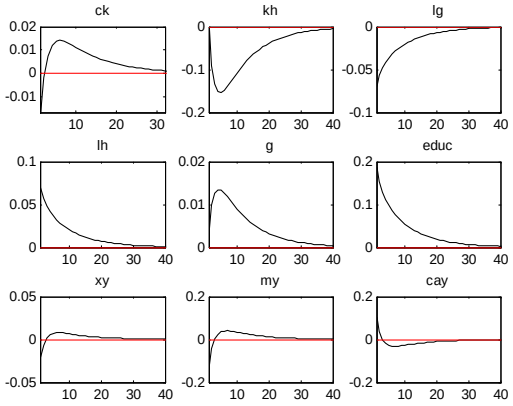

Figure 3: Impulse Response to A_H Shock

The analysis of the transitional dynamics vividly illustrates that the short run effects of these two types of productivity shocks have different implications for growth and current account. A positive TFP shock to the goods

sector diverts resources from education to the production of import intensive final goods at the expense of growth and current account deficit. In contrast, a cognitive skill shock raises growth rates with greater import substitution and thus causes less current account instability.[18] Thus a human capital oriented growth policy such as an education subsidy could lead to a more sustainable path of economic growth in the economy with import substitution compared to an investment tax credit which directly impacts the goods sector TFP.

6 Conclusion

A plethora of literature exists about the relationship between openness and growth. There is also a voluminous literature on education and growth. However, less is known about the fundamentals driving openness, education and growth. The motivation for this study comes from cross-country evidence that trade openness and educational spending positively covary. We construct an open economy endogenous growth model in the tradition of Lucas (1988). The time allocation between goods production and schooling is an essential ingredient of human capital growth. Our model identifies cognitive skill represented by the productivity of human capital as a crucial fundamental causing this comovement between education and trade openness. In terms of our endogenous growth model, we demonstrate that the cross-country differences in cognitive skill play a central role in determining the cross-country correlation between trade share and education share. This corroborates the developmental facts outlined in the paper that countries with a higher cognitive skill are more open and spend more on education. The short run impulse

[18]The short run correlation between trade share and education is negative while cross country data suggest that it is positive. As mentioned earlier, the cross country correlations refers to the long run comparison of countries which differ in terms of long run average TFP. This basically means between-country variation in trade shares and education shares. The short run analysis can be interpreted as within-country response of a transitory shock to productivity.

response analysis suggests that a growth policy which has a positive effect on cognitive skill has a more sustainable effects on growth with minimal instability to the external current account compared to a growth policy which subsidises import intensive physical investment.

Our model is the first in the literature in showing explicitly the connection between cognitive skill, growth and trade openness. A useful extension of our work will be to bring skill differences in the technology along the line suggested by the recent paper of Epifani and Gancia (2008) and explore the implications for skill premium in the context of endogenous growth.

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A Appendix

A.1 First order conditions

Let $\lambda_t, \mu_t, \omega_t$ be the lagrange multipliers associated with the flow budget constraint (5), human capital technology, (1) and the borrowing constraint (8).

First order conditions are:

$$c_t : \beta^t U'(c_t) = \lambda_t \tag{A.1}$$

$$k_{t+1} : \lambda_t p^k + E_t\omega_{t+1} = E_t\lambda_{t+1}\{A_{Gt+1}\alpha k_{t+1}^{\alpha-1}(l_{Gt+1}h_{t+1}\}^{1-\alpha} + (1-\delta_k)p^k\} \tag{A.2}$$

$$\begin{aligned} h_{t+1} \quad : \quad & \mu_t = E_t\mu_{t+1}\{1-\delta_h + A_{Ht+1}(1-l_{Gt+1})\} \\ & + E_t\lambda_{t+1}\{A_{Gt+1}(1-\alpha)k_{t+1}^{\alpha}h_{t+1}^{-\alpha}l_{Gt+1}^{1-\alpha} \end{aligned} \tag{A.3}$$

$$l_{Gt} : \lambda_t(1-\alpha)A_{Gt}l_{Gt}^{-\alpha}k_t^{\alpha}{h_t}^{1-\alpha} - \mu_t A_H h_t = 0 \tag{A.4}$$

$$b_{t+1} : \lambda_t = E_t(1+r^*)\lambda_{t+1} - E_t\omega_{t+1} \tag{A.5}$$

A.2 Derivation of the Balanced Growth Equations

Along the balanced growth path, we assume that $A_{Gt} = \bar{A}_G, A_{Ht} = \bar{A}_{H.}$ We also exploit the fact that the raw labour allocation variables l_{Gt} and l_{Ht} are stationary along the balanced growth path.

Use (A.4) to rewrite (A.3) as:

$$\frac{\lambda_t}{\lambda_{t+1}} = [1 + \bar{A}_H - \delta_h] \tag{A.6}$$

Using (A.1), we get the following balanced growth rate (g) as follows:

$$=> 1 + g = \frac{h_{t+1}}{h_t} = \frac{k_{t+1}}{k_t} = \frac{c_{t+1}}{c_t} = \beta[1 + \bar{A}_H - \delta_h] \tag{A.7}$$

From (A.2) one gets:

$$\frac{\lambda_t}{\lambda_{t+1}} = [\alpha(\bar{A}_G/p^k)l_G^{1-\alpha}(k/h)^{\alpha-1} + 1 - \delta_k] + \frac{\omega_{t+1}}{p^k\lambda_{t+1}} \tag{A.8}$$

Using (A.7) and (A.8), one gets:

$$\left[\frac{k/h}{l_G}\right]^{1-\alpha} = \frac{\alpha\bar{A}_G}{p^k(\bar{A}_H + \delta_k - \delta_h) + \frac{\omega_{t+1}}{\lambda_{t+1}}} \tag{A.9}$$

Next use (A.5) to obtain:

$$\frac{\omega_{t+1}}{\lambda_{t+1}} = 1 + r^* - \frac{\lambda_t}{\lambda_{t+1}} \tag{A.10}$$

Now use (A.2) to obtain

$$\frac{\omega_{t+1}}{\lambda_{t+1}} = \frac{\lambda_t}{\lambda_{t+1}}p^K - [\bar{A}_G\alpha(k/h)^{\alpha-1}l_G^{1-\alpha} + (1-\delta_k)p^k] \tag{A.11}$$

Equating (A.10) and (A.11), one gets:

$$k_t/h_t = \left[\frac{\alpha\bar{A}_G}{(p^k-1)(A_H - \delta_h) + p^k\delta_k + r^*}\right]^{1/(1-\alpha)} l_G \tag{A.12}$$

Next use (1) and (A.7) to solve for l_G and l_H in (10). Plugging (10) into (A.12) uniquely solves k/h as in (11).

To get the export share equation (12) use (6), (7) and (8) which gives:

$$x_t + k_{t+1} = (1 + r^*)k_t + p^k(k_{t+1} - (1 - \delta_k)k_t)$$

Divide through by y_t and use the fact that along a balanced growth path k_t/y_t is a constant and for the Cobb-Douglas production function (2) $MPK = \alpha y_t/k_t$.

To get the import share equation, notice first that the share of import in

GDP is given by:

$$\begin{aligned} \frac{m_t}{y_t} &= \frac{p^k(k_{t+1}-(1-\delta_k)k_t)}{y_t} \\ &= p^k\left\{\frac{k_{t+1}}{y_{t+1}}(1+g)-(1-\delta_k)\frac{k_t}{y_t}\right\} \\ &= \frac{\alpha p^k\{(1+g)-(1-\delta_k)}{MPK} \end{aligned} \tag{A.13}$$

Plugging (9) one obtains (13). Plug (A.9) into $MPK = \alpha y/k$ one gets (14). Finally, using (A.4) we get:

$$Educ = \frac{(1-\alpha)l_H}{l_G} \tag{A.14}$$

A.3 Summary of Short-run Equations

The short run system is given by equations (A.15) to (A.22) are:

$$\frac{k_{t+1}}{h_{t+1}} = \frac{p^k\left(1-\delta_k\right)\frac{k_t}{h_t} + A_{Gt}(\frac{k_t}{h_t})^{\alpha} l_{Gt}^{1-\alpha} - \frac{c_t}{h_t} - (1+r^*)\frac{k_t}{h_t}}{\left(p^k-1\right)\left\{1-\delta_h + A_{Ht}(1-l_{Gt})\right\}} \tag{A.15}$$

$$1 = m_{t+1}.\frac{\alpha A_{Gt+1}\left(\frac{k_{t+1}}{h_{t+1}}\right)^{\alpha-1} l_{Gt+1}^{1-\alpha} + (1-\delta_k)p^k - 1 - r^*}{p^k-1} \tag{A.16}$$

$$\frac{A_{Gt}}{A_{ht}}.l_{Gt}^{-\alpha}.(\frac{k_t}{h_t})^{\alpha} =$$

$$m_{t+1}\left[\frac{A_{Gt+1}}{A_{ht+1}}.l_{Gt+1}^{-\alpha}.(\frac{k_{t+1}}{h_{t+1}})^{\alpha}\left\{1-\delta_h + A_{Ht+1}(1-l_{Gt+1})\right\} + A_{Gt+1}\left\{\frac{k_{t+1}}{h_{t+1}}\right\}^{\alpha} l_{Gt+1}^{1-\alpha}\right] \tag{A.17}$$

where m_{t+1} is the discount factor given by

$$m_{t+1} = \frac{\beta(c_t/h_t)}{(c_{t+1}/h_{t+1})} \frac{1}{(A_{Ht+1}(1-l_{Gt+1})+1-\delta_h)} \tag{A.18}$$

Export and import share equations are given by:

$$\begin{aligned} \frac{x_t}{y_t} &= [1+r^*-p^k(1-\delta_k)](k_t/y_t) \\ &+(p^k-1)(k_{t+1}/y_{t+1})(A_{Gt+1}/A_{Gt})\left(\frac{k_{t+1}/h_{t+1}}{k_t/h_t}\right)^{\alpha}\{1-\delta_h+A_{Ht}l_{ht}\}.\left\{\frac{l_{Gt+1}}{l_{Gt}}\right\}^{1-\alpha} \end{aligned} \tag{A.19}$$

$$\frac{m_t}{y_t} = p^k\left[\frac{k_{t+1}}{y_{t+1}}.\frac{A_{Gt+1}}{A_{Gt}}.\left(\frac{k_{t+1}/h_{t+1}}{k_t/h_t}\right)^{\alpha}\left\{\frac{l_{Gt+1}}{l_{Gt}}\right\}^{1-\alpha}\{1-\delta_h+A_{Ht}l_{ht}\}-(1-\delta_k).\frac{k_t}{y_t}\right] \tag{A.20}$$

The ratio of current account to GDP is defined as:

$$\frac{ca_t}{y_t} = \frac{x_t}{y_t} - \frac{m_t}{y_t} \tag{A.21}$$

The physical capital:output ratio is given by the production function (2) as:

$$\frac{k_t}{y_t} = A_{Gt}^{-1}(k_t/h_t)^{1-\alpha}l_{Gt}^{\alpha-1} \tag{A.22}$$

The education share equation is given by:

$$Educ_t = \frac{(1-\alpha)l_{Ht}}{l_{Gt}} \tag{A.23}$$

Finally the growth rate of output is given by:

$$\frac{y_{t+1}}{y_t} = \frac{A_{Gt+1}}{A_{Gt}}.\left[\frac{A_{Gt+1}}{A_{Gt}}\right]\left[\frac{k_{t+1}/h_{t+1}}{k_t/h_t}\right]^{\alpha}\{A_{Ht}l_{Ht}+1-\delta_h\}.\left[\frac{l_{Gt+1}}{l_{Gt}}\right]^{1-\alpha} \quad \text{(A.24)}$$

B Outline of the Derivation of the Short run equations

Use (5), (6), (7), (8) with equality to get:

$$k_{t+1} = \frac{p^k(1-\delta_k)k_t + A_{Gt}k_t^{\alpha}(l_{Gt}h_t)^{1-\alpha} - c_t - (1+r^*)k_t}{p^k - 1} \quad \text{(B.1)}$$

Dividing (B.1) by (1), one gets (A.15). (A.16) can be obtained by combining (A.1),(A.2) and (A.5).

Use (A.3) and (A.4) to obtain (A.17).

The discount factor (A.18) is basically $\beta c_t/c_{t+1}$. This can be rewritten as $\beta\{(c_t/h_t)/(c_{t+1}/h_{t+1})\}(h_{t+1}/h_t)^{-1}$. After using (1), one gets the expression for (A.18).

To obtain the export share equation (A.19) , use (6) and (8) to obtain:

$$x_t = (1+r^*)k_t + (p^k-1)k_{t+1} - p^k(1-\delta_k)k_t \quad \text{(B.2)}$$

Divide through by y_t to obtain

$$\frac{x_t}{y_t} = (1+r^*-p^k(1-\delta_k))\frac{k_t}{y_t} + (p^k-1)(\frac{k_{t+1}}{y_{t+1}})(\frac{y_{t+1}}{y_t}) \quad \text{(B.3)}$$

Next use the production function (2) and the human capital equation (1) to obtain (A.19).

To get (A.20), use

$$\frac{m_t}{y_t} = \frac{p^k(k_{t+1}-(1-\delta_k)k_t)}{y_t} \quad \text{(B.4)}$$

which can be rewritten as:

$$\frac{m_t}{y_t} = p^k(\frac{k_{t+1}}{y_{t+1}}.\frac{y_{t+1}}{y_t} - (1-\delta_k)\frac{k_t}{y_t}) \tag{B.5}$$

which after using the production function (2) and the human capital equation (1) yields the expression (A.20).

The expression for (A.22) directly follows from the production function (2). The expression for (A.23) is the same as the steady state expression (1).

The expression for the growth rate in (A.24) follows from the use of the production function (2) and the human capital equation (9).

C Classification of Countries for the Panel Regression Model

Fourteen groups of countries used in panel regression are based on the World Development Indicators (2007). The official data (available using Athens login from the www.esds.ac.uk/international/WDI) define these categories (with our own notation for each category in parentheses) as follows:

1. World aggregate is average of all countries of the world (Wrld).

2. Low-income economies (Linc) are those in which 2007 GNI per capita was $935 or less including Afghanistan, Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Côte d'Ivoire, Eritrea, Ethiopia, Gambia, The, Ghana, Guinea, Guinea-Bissau, Haiti, Kenya, Korea, Dem. Rep., Kyrgyz Republic, Lao PDR, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Nigeria, Pakistan, Papua New Guinea, Rwanda, São Tomé and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, Tajikistan, Tanzania, Togo, Uganda, Uzbekistan, Vietnam, Yemen, Rep., Zambia, Zimbabwe.

3. Middle-income economies (Minc) are those in which 2007 GNI per capita was between $936 and $11,455 including countries in: Lower middle income and Upper middle income groups.

4. Lower-middle-income (Lminc) economies are those in which 2007 GNI per capita was between $936 and $3,705 and include: Albania, Algeria, Angola, Armenia, Azerbaijan, Bhutan, Bolivia, Bosnia and Herzegovina, Cameroon, Cape Verde, China, Colombia, Congo, Rep., Djibouti, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Georgia, Guatemala, Guyana, Honduras, India, Indonesia, Iran, Islamic Rep., Iraq, Jordan, Kiribati, Lesotho, Macedonia, FYR, Maldives, Marshall Islands, Micronesia, Fed. Sts., Moldova, Mongolia, Morocco, Namibia, Nicaragua, Paraguay, Peru, Philippines, Samoa, Sri Lanka, Sudan, Swaziland, Syrian Arab Republic, Thailand, Timor-Leste, Tonga, Tunisia, Turkmenistan, Ukraine, Vanuatu, West Bank and Gaza.

5. Upper-middle-income economies (Upminc) are those in which 2007 GNI per capita was between $3,706 and $11,455 including: American Samoa, Argentina, Belarus, Belize, Botswana, Brazil, Bulgaria, Chile, Costa Rica, Croatia, Cuba, Dominica, Fiji, Gabon, Grenada, Jamaica, Kazakhstan, Latvia, Lebanon, Libya, Lithuania, Malaysia, Mauritius, Mayotte, Mexico, Montenegro, Palau, Panama, Poland, Romania, Russian Federation, Serbia, Seychelles, South Africa, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Turkey, Uruguay, Venezuela, RB.

6. Low- and middle-income economies (lmdinc) are those in which 2007 GNI per capita was $11,455 or less and include the following country groups: East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, South Asia and Sub-Saharan Africa.

7. East Asia and Pacific regional aggregate (ASPC) includes: American Samoa, Cambodia, China, Fiji, Indonesia, Kiribati, Korea, Dem. Rep., Lao PDR, Malaysia, Marshall Islands, Micronesia, Fed. Sts., Mongolia, Myanmar, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands,

Thailand, Timor-Leste, Tonga, Vanuatu, Vietnam.

8. Latin America and Caribbean regional aggregate (LTACA) includes Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Uruguay, Venezuela, RB.

9. Middle East and North Africa regional aggregate (MDEAST) includes: Algeria, Djibouti, Egypt, Arab Rep., Iran, Islamic Rep., Iraq, Jordan, Lebanon, Libya, Morocco, Syrian Arab Republic, Tunisia, West Bank and Gaza, Yemen, Rep.

10. South Asia (SAsia) economies include: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka.

11. Sub-Saharan Africa (SSAFR) includes: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Côte d'Ivoire, Eritrea, Ethiopia, Gabon, Gambia, The, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Namibia, Niger, Nigeria, Rwanda, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

12. High-income economies (Hiinc) are those in which 2007 GNI per capita was $11,456 or more and include: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Rep., Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, United States.

13. High income non-OECD economies (HinOECD) are those in which 2007 GNI per capita was $11,456 or more and include: Andorra, Antigua and Barbuda, Aruba, Bahamas, The, Bahrain, Barbados, Bermuda, Brunei

Darussalam, Cayman Islands, Channel Islands, Cyprus, Equatorial Guinea, Estonia, Faeroe Islands, French Polynesia, Greenland, Guam, Hong Kong, China, Isle of Man, Israel, Kuwait, Liechtenstein, Macao, China, Malta, Monaco, Netherlands Antilles, New Caledonia, Northern Mariana Islands, Oman, Puerto Rico, Qatar, San Marino, Saudi Arabia, Singapore, Slovenia, Trinidad and Tobago, United Arab Emirates, Virgin Islands (U.S.).

14. Heavily indebted poor countries (HIPC) include: Afghanistan, Benin, Bolivia, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Côte d'Ivoire, Eritrea, Ethiopia, Gambia, The, Ghana, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Kyrgyz Republic, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nepal, Nicaragua, Niger, Rwanda, São Tomé and Principe, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Uganda, Zambia.