1. Introduction

Differences in economic growth across countries have been varied throughout in history. Since 1950, the industrial countries have grown at a remarkably stable rate. A few developing countries have experienced rapid growth, while some other countries have grown at a stagnant rate. Over the last two hundred years the industrial leaders also have displayed accelerating economic growth: the United Kingdom grew around 1.2% per year from 1820 to 1890, while the United States had a 2% average annual growth rate throughout the twentieth century (data are from Maddison (2003)). But, what sustains growth over long periods of time? Which country will be the industrial leader in the twenty- rst century, and what will its trend growth rate be? In this paper, I extend the “Business Cycle Accounting” framework of Chari et al. (2007) to provide a platform for addressing these questions.[1]

Chari et al. (2007) explains that a neoclassical growth (NCG) model with taxes is a good perspective from which underlying causes of the observed gaps in growth can be analyzed. Wedges associated with a prototype economy's equilibrium conditions can be de ned as exogenous variables and interpreted as taxes, ef ciency shifters, and government consumption. Furthermore, speci c growth models that can theoretically explain the observed gaps also correspond to these wedges. Compared with the conventional growth accounting method, the whole set of equilibrium conditions, rather than only production functions, are used to decompose economic growth. And the decomposition results can be connected eters into each equilibrium condition of the prototype economy gives the wedge value associated with that equation. When the values of individual wedges are given, their relevance can be evaluated through the prototype economy and this

Klenow (2009), studied the misallocation of manufacturing activities with rm-level precision, which underlies the exogenous ef ciency shifters in my paper.

where y, l, x_h, k and h are per person output of nal goods, labor input, investment in human capital, physical capital stock and human capital stock respectively;[4] v and u represent the fractions of physical capital stock and labor devoted to the nal goods sector; represents the common capital share in both sectors,[5] and A and B are two productivity shifters within these two sectors. [6]

Firms face competitive output and factor markets. They take all prices as given when they make their output decisions. These prices include the relative price of human capital in terms of nal goods q, factor prices of physical capital and labor in the nal goods sector (r_k, w_k) and in the other sector (r_h, w_h). The costs of physical capital and labor in the nal goods sector are taxed with rates $_1$ and $_2$ and rms nd the capital-labor combinations to maximize their pro ts,

$$y(t) \quad (1 + \ _1)r_k(t)v(t)k(t) \quad (1 + \ _2)w_k(t)u(t)l(t);$$

$$q(t)x_h(t) \quad r_h(t)(1 \quad v(t))k(t) \quad w_h(t)(1 \quad u(t))l(t):$$

Let x_k denote per person physical capital investment, $_k$ the depreciation rate of physical capital. Then the law of motion for physical capital is,

$$(1 + n)k(t + 1) = (1 \quad _k)k(t) + x_k(t); \tag{3}$$

With a depreciation rate for human capital $_h$, the law of motion for human capital can be similarly de ned, [7]

$$(1 + n)h(t + 1) = (1 \quad _h)h(t) + x_h(t): \tag{4}$$

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[4]When there is no risk of confusion, I drop time arguments, but whenever there is the slightest risk of confusion, I will err on the side of caution and include relevant arguments.

[5]Capital shares need be sector-speci c both conceptually and empirically. However, the lack of reliable data for certain components of human capital makes calibrating the human capital production function considerably more dif cult.

[6]These production technologies are labor-augmented $Y = AK \ (hL)^{1}$, where uppercase

There is a representative household in the model. The physical capital and human capital investment made and the total labor income earned by the household are taxed with after-tax rates $(1+\tau_{xk})(1-\tau_1)$, $(1+\tau_{xh})(1-\tau_l)$ and $(1-\tau_l)$ respectively. The household also receives a lump-sum transfer, whose per person value, T, equals all tax revenues minus the government consumption g. Assume that $\tau_{xk}\tau_1=\tau_{xh}\tau_1=0$. Then

$$T=\tau_1 r_k k_k+\tau_2 w_k l_k+(\tau_{xk}-\tau_1)x_k+(\tau_{xh}-\tau_l)qx_h+\tau_l[w_k ul+w_h(1-u)l]-g.$$

The household has $N(t)$ members, which grows at a rate of n. It maximizes a discounted utility over flows of consumption $c(t)$ and leisure $1-l(t)$. Let $\beta\in(0,1)$ be its discount factor, and $\alpha\in(0,1)$ be the consumption share in the period utility function. The household's problem is,

$$\max\sum_{t=0}^{\infty}\beta^t[\alpha\ln c(t)+(1-\alpha)\ln(1-l(t))]N(t);$$

subject to (a) a budget constraint,

$$\begin{aligned}c(t)+(1+\tau_{xk})(1-\tau_1)x_k(t)+(1+\tau_{xh})(1-\tau_l)q(t)x_h(t)&=r_k(t)v(t)k(t)\\&+r_h(t)(1-v(t))k(t)+(1-\tau_l)[w_k(t)u(t)l(t)+w_h(t)(1-u(t))l(t)]+T(t);\end{aligned}$$

(b) factor prices derived from profit maximization problems,

$$(1+\tau_1)r_k(t)=\theta y(t)/[v(t)k(t)];$$

$$(1+\tau_2)w_k(t)=(1-\theta)y(t)/[u(t)l(t)];$$

$$r_h(t)=q(t)\gamma x_h(t)/[(1-v(t))k(t)];$$

$$w_h(t)=q(t)(1-\gamma)x_h(t)/[(1-u(t))l(t$$

satisfy the resources balance,

$$c(t) + x_k(t) + g(t) = y(t): \qquad (5)$$

The return to human capital investment is a higher labor income. Notice that the wage rate perceived by the household is $w = \frac{q(1\quad)x_h}{(1\quad u)hl}h$, which equals the human capital stock multiplied by a term given to the household in equilibrium. At this point the equilibrium conditions can be derived as follows,

hhtetur8]TJ/F50 11.2 0 5034.514(h)]TJ ET q 31TJ/F50 11.11.07n e0 m 36.5
(1 :tetu93]TJ/F50[(h1)]T80-6034-514(h)]T54(h(g(y)]TJ/F15(t)-214(tu8)]TJ/F5

The prototype economy also has a steady-state equilibrium, whose local properties are now well understood: a unique steady-state equilibrium exists, and it is saddle-path stable (e.g., Mulligan and Sala-i Martin (1993)). In the steady-state equilibrium the growth rate of every variable is constant. [9] More speci cally, v, u, l, and q are constants and all other endogenous variables grow at the same rate, . As a result, solutions to the steady-state equilibrium are only ratios or rates.

In later sections, only the steady-state equilibrium conditions have been used to derive country-speci c wedges. For clarity, the steady-state equilibrium conditions are collected in one place as follows,

$$(1 \quad _l)\frac{1 \quad l}{l}\frac{(1 \quad)qx_h}{(1 \quad u)h}\frac{h}{k} = \frac{1 \quad}{}\frac{c}{k}; \tag{11}$$

$$(1 + \quad _1)v\frac{qx_h}{h}\frac{h}{k} = (1 \quad v)\frac{y}{k}; \tag{12}$$

$$(1 + \quad _2)u\frac{qx_h}{h}\frac{h}{k} = (1 \quad u)\frac{y}{k}; \tag{13}$$

$$(1 + \quad)(1 + \quad _{xk}) = \quad [\frac{y}{vk} + (1 \quad _k)(1 + \quad _{xk})]; \tag{14}$$

$$(1 + \quad)(1 + \quad _{xh}) = \quad [\frac{(1 \quad)x_h}{(1 \quad u)h} + (1 \quad _h)(1 + \quad _{xh})]; \tag{15}$$

$$\frac{y}{k} = Av \; (ul\frac{h}{k})^{1} \quad ; \tag{16}$$

$$\frac{x_h}{h}\frac{h}{k} = B(1 \quad v) \; ((1 \quad u)l\frac{h}{k})^{1} \quad ; \tag{17}$$

$$\frac{x_h}{h} = \quad + n + \quad _h; \tag{18}$$

$$\frac{x_k}{k} = \quad + n + \quad _k; \tag{19}$$

Notice that $r_k = \frac{y}{(1+ \quad _1)vk}$. And the Maclaurin approximation suggests that $(1 + \quad _1)^{1} \quad 1 \quad _1$. Then we have the Euler equations (9) and (10).

[9] To avoid repetition, let $_a$ be the growth rate of an arbitrary variable a in steady state. Equations (7) and (8) imply that $_u = \quad _v = 0$, equation (6) implies $_l = 0$, equation (8) implies $_y = \quad _{xh} + \quad _q$, equation (5) implies $_c = \quad _{xk} = \quad _g = \quad _y$, the law of motion for h implies $_{xh} = \quad _h$, the law of motion for k implies $_{xk} = \quad _k$, production function (1) implies $_y = \quad _k + (1 \quad) \quad _h$, production function (2) implies $_{xh} = \quad _k + (1 \quad) \quad _h$. Combining all of these results implies that v, u, l, q are constant, and all the other variables grow at the same rate.

$$\frac{c}{k} + \frac{x_k}{k} + \frac{g}{k} = \frac{y}{k}: \tag{20}$$

There are ten equations that can be used to solve for the ten endogenous variables, v, u, l, q, , h=k, y=k, c=k, x_k=k, and x_h=h. Here $_l$ equals the labor wedge, $_1$ the capital input wedge, $_2$ the labor input wedge, $_{xk}$ the capital investment wedge, $_{xh}$ the human capital investment wedge, A the nal goods ef ciency wedge, B the human capital ef ciency wedge, and g=k the government consumption wedge.

2.1. The mapping between a one-sector optimal growth model and the prototype economy

Chari Here

capita lump-sum transfers.

The production function is $y = Ak\ \ ((1+\ \ )^t l)^{1}$, where y is per capita output and the labor-augmenting technology progress $(1+\ \ )$ is assumed to be constant. Both the nal goods and factor markets are competitive and rms are pro t-maximizers. The equilibrium of this model is summarized by the following,

$$c(t) + x(t) + g(t) = y(t);$$

$$\frac{1}{\quad}\ \frac{c(t)}{1 \quad l(t)} = [1 \quad\ {}_{l}(t)](1 \quad\ )\frac{y(t)}{l(t)};$$

$$\frac{c(t+1)}{c(t)}[1 + \ {}_{x}(t)] = \quad [\ \frac{y(t+1)}{k(t+1)} + (1 \quad\ )[1 + \ {}_{x}(t)]];$$

and the production function.

Notice that in the one-sector model the labor-augmenting technology $1+$ is exogenous and not correlated with the four wedges, while in the two-sector model it is the long-run growth rate that is endogenously determined by exogenous wedges. Thus the underlying causes of growth can be analyzed in a two-sector model even though growth is typically constant throughout business cycle theories.

Suppose that the total consumption in Chari et al. (2007) contains both the nal goods consumption and the human capital investment in terms of nal goods. Then the consumption in Chari et al. (2007) equals

$$c^{CKM} = c + qx_h;$$

and the output in Chari et al. (2007) equals

$$y^{CKM} = y + qx_h:$$

Substituting the two aforementioned equations into the equilibrium conditions of the one-sector model and comparing them with the equilibrium conditions of the two-sector model in steady state, yields the mapping between these two prototype economies. Table 1 summarizes this relationship.

Through this simple illustration, we can see the correspondence between the

Wedges and Growth		Variables	
One-sector	Two-sector	One-sector	Two-sector
A^{CKM}	$[Av\ \ u^{1}\ \ + qB(1\ \ v)\ \ (1\ \ u)^{1}\ \ ]$	y^{CKM}	$y + qx_h$
$1\ \ {}_{l}^{CKM}$	$\frac{1\ \ l}{1+u\ 2}\frac{c+qx_h}{c}$	c^{CKM}	$c + qx_h$
$1 +\ \ {}_{x}^{CKM}$	$\frac{(1+v\ _1)(1+\ _{xk})}{1+\ _1}$	x^{CKM}	x
g^{CKM}	g	k^{CKM}	k
$(1 +\ \ ^{CKM})^{t}$	h	l^{CKM}	l

Table 1: Equivalence Result for Chari, Kehoe, and McGrattan (2007)

wedges in Chari et al. (2007) and the wedges embedded in Rebelo (1991). The ef- ciency wedge largely contains ef ciency shifters, the labor wedge is largely two labor related wedges, the investment wedge is quite close to the physical capital investment wedge, and the government consumption wedges in these two prototype economies are identical. In the one-sector growth model, wedges are not correlated with the growth , while in the two-sector model, wedges determine the growth. The following sections address the relative importance of each wedge in explaining growth and nd the human capital ef ciency and investment wedges are important.

3. Method and Data

The accounting method consists of computing wedge values and evaluating the t of individual wedges. Envisage a world consisting of $j = 1; \ldots; J$ countries. For any country j the economy experiences one event s_j which indexes the state for that country. This state determines country j's economic performance. Notice that endogenous variables in the prototype economy include aggregate variables that characterize a country's economic performance and that the wedges a$_j$nd -he -heowth m2 m2p2818(ototype)-240(e2)-omy i2t2m2p29nts state equilibrium conditions of the prototype economy gives the wedge values across countries.

Notice that despite resembling tax rates, ef ciency levels or government consumption in the prototype economy, wedges are clearly not formal tax rates, measures of technological ef ciency, or observed government consumption. Rather wedges are the results of policies and institutions that make economic activities more costly or reduce their associated returns. In particular, every wedge in the prototype economy is a measure of overall frictions in the particular market with which it is associated.

To evaluate the importance of wedges in explaining growth I change each wedge in the favorable direction by 0.1% of its observed values while keeping the rest wedges xed, and decompose the marginal change of growth and ef ciency into the effects of individual wedges.

For example, country j's long-run growth rate $_j$, a differentiable function of all wedges, can be decomposed as follows,

$$
\begin{aligned}
\hat{}_j \quad _j \quad & \frac{\partial}{\partial A}(\hat{A}_j \quad A_j) + \frac{\partial}{\partial B}(\hat{B}_j \quad B_j) \\
& + \frac{\partial}{\partial_l}(\hat{}_{lj} \quad _{lj}) + \frac{\partial}{\partial_1}(\hat{}_{1j} \quad _{1j}) + \frac{\partial}{\partial_2}(\hat{}_{2j} \quad _{2j}) \\
& + \frac{\partial}{\partial_{xk}}(\hat{}_{xk\,j} \quad _{xkj}) + \frac{\partial}{\partial_{xh}}(\hat{}_{xh\,j} \quad _{xhj}) + \frac{\partial}{\partial(g/k)}[(\hat{\frac{g}{k}})_j \quad (\frac{g}{k})_j]:
\end{aligned}
$$

Here each variable with a hat is the computed value of growth rate when all wedges are slightly different from their observed values, $_j$ is the growth rate observed from the data and $\frac{\partial}{\partial x}(\hat{x} \quad x)$ is the difference between the observed value and the computed value of the growth rate when only one wedge x is slightly different from its observed value, but all other wedges are kept at their observed values. It imitates the marginal effect of wedge x on growth rate . Thus the left-hand side of this expression is the comprehensive marginal effect on growth rate and the right-hand side is the sum of individual marginal effects. Dividing the

As shown in table 1

human capital stock is available.[10] Notice that the wage rate, by de nition, is equal to $(1 \quad)GDP{=}l$. Thus,

$$\ln w(t) = \ln(1 \quad)TFP + \quad \ln \frac{k}{hl} + \ln \; h(s) + \quad (t \quad s) + \quad (sch(t)):$$

The average wage rate depends on a constant term, a trend term, and schooling years. Labor economists estimate the following Mincerian regression (see Mincer (1974)), which is informative to construct (

Total GDP includes two parts: nal goods output and the human capital investment in terms of nal goods. The latter is the value added only in the education sector (ISIC:M),[12] and corresponds to qx_h in the prototype economy. The rest is the nal goods output y in the prototype. The partition between nal goods and human capital investment may be arbitrary. However, they are consistent with the concepts used in the prototype economy. [13]

When the human capital investment qx_h is known, with the law of motion of human capital in steady state, I construct the human capital stock in terms of nal goods as,

$$(qh)_j = \frac{(qx_h)_j}{\ _j + n_j + \ _h}:$$

Dividing this value by $e^{(s\ \ t)} e^{(sch(t))}$, we have

$$\frac{(qh)(t)_j}{e^{\ _j(t\ \ s)} e^{\ (sch_j(t))}} = \frac{q_j h_j(s) e^{\ _j(t\ \ s)}\ \ e^{\ (sch_j(t))}}{e^{\ _j(t\ \ s)} e^{\ (sch_j(t))}} = q_j h_j(s)$$

Notice that the human capital is broadly de ned and equal to the labor augmented technology in the litndists/F [9is as, freight trucks in Western Europe and North America, and importantly, the personal computer, the cellular phone, the internet, and the World Wide Web that have contributed to profound socio-political and economic transformations.

In addition, changes in production methods, the political developments in 1990s, economic policies towards deregulation, multilateral efforts to liberalize international trade, and to stabilize macroeconomic environment have helped all countries in the world access the most advanced available knowledge. So around 2000, the accessible broadly de ned human capital is roughly constant across countries.

I assume that $h_j(2000)$ is constant across countries and rescale the relative price of the broadly de ned human capital across countries by assuming that relative price is one in the US. So for any country j,

$$q_j = \frac{q_j h_j(2000)}{q_{US} h_{US}(2000)}$$

Consequently, the human capital stock for country j is

$$h_j(t) = (qh)_{US}(t) \quad e^{(\ _j \quad _{US})(t \quad 2000)} e^{\ (sch_j(t)) \quad (sch_{US}(t))}$$

3.2. Data and calibration

Data sources used in this analysis include the Groningen Growth and Develop-

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capital share

rate. The value of $_k$ is chosen to be consistent with the average ratio of depreciation to GDP observed in the data from 1980 to 2004. The initial stock of capital is chosen so that the initial capital-output ratio in 1959 should match the average capital-output ratio over the 1960-1970 period. Using this rule gives the estimate for the depreciation rate $_k$.

The depreciation rate of human capital $_h$ comes from the same procedure, except its value is chosen to be consistent with $\frac{x_h}{h} = \quad + n + \quad_h$. By comparison, Kendrick (1976)'s estimates imply the depreciation rates of capital, $_k = 0{:}0616$, of education, $_e = 0{:}0343$, of health care, $_{hc} = 0{:}0718$ and of R&D, $_{RD} = 0{:}0876$.

For the remaining two parameters, standard calibration formulae are available (e.g., an online note for Kehoe and Prescott (2007

Sub-sample	Total	OECD	non-OECD	above median	below median
Obs	50	26	24	25	25
l	15.65%	14.20%	17.22%	12.91%	18.38%
2	16.52%	16.37%	16.68%	15.06%	17.98%
xk	5.98%	6.44%	5.48%	6.81%	5.15%
xh	21.93%	22.27%	21.56%	23.33%	20.52%
A	11.91%	12.22%	11.59%	12.66%	11.17%
B	23.83%	24.44%	23.17%	25.32%	22.35%
g=k	4.18%	4.06%	4.31%	3.92%	4.44%

Table 3: Average Importance of Wedges on Growth Rate

in physical capital, human capital, and technology than others. In this section,

Normalized values	$_l$	$_2$	$_{xk}$	$_{xh}$	A	B	g=k
Total	1	1	1	1	1	1	1
OECD	1.07	1.21	-0.53	0.69	1.15	0.50	0.63
Non-OECD	0.95	0.79	2.67	1.33	0.85	1.54	1.38
Fast	0.79	0.79	0.20	0.91	0.90	0.93	0.75
Slow	1.24	1.24	1.80	1.09	1.12	1.56	1.25

Table 5: Wedges' Values

The aforementioned patterns for the full sample do not change much across sub-samples of countries in and out of the OECD; below and above the median values of respective endogenous variables. This may be due to that most countries in the sample are rich or middle-income countries, whereas extremely poor countries may have different patterns. Another possibility is that these patterns depend more on the NCG structure than the magnitude of the country-speci c wedges.

Table 5 presents the values of individual wedges for the total sample and sub-samples, and sheds some light on the above robustness. These values are normalized relative to the sample average. Although wedges differ across sub-samples, they have the same magnitude. Differences of $_{xk}$, $_{xh}$, and B between OECD and non-OECD countries are larger than those between fast and slow growers. But, except for $_{xk}$, all cross-sample normalized values are not far away from one.

What can be learned from these results? First, even if the human capital sector is small in the economy, a biased allocation of the broadly de ned human capital over time would change the long run growth very much. Second, frictions that distort the nal goods ef ciency wedge are less important in changing the long-run growth than those affecting the human capital ef ciency wedge. Third, compared with the other wedges, the two ef ciency wedges can hardly be microfounded. These wedges seem to re ect everything except for the mechanism suggested by a detailed model. If this is true, then, even after decomposing the ef ciency into the effects of seven wedges, it is still mostly a black box, because the final goods efficiency wedge alone takes up nearly 90% of it. As Prescott (1998) points out, a theory of TFP differences is still needed.

5. Conclusion

This paper presents a method to account for long-run economic growth across countries. It also sheds light on underlying mechanisms of economic growth. The main findings suggest that endogenous growth theories that are equivalent to the prototype economy with a human capital investment wedge and/or a labor wedge are more consistent with the observed patterns of developing countries.

As Klenow and Rodriguez-Clare (1997a) said, more work should be done to empirically distinguish between theories of endogenous growth; to accomplish this, a quantitative approach avoids misspecification in empirical work and fully exploits the quantitative implications of candidate models. Banerjee and Duflo (2005), moreover, show that even a series of convincing micro-empirical studies is not enough to give an overall explanation for aggregate growth, and that a promising alternative is to build macroeconomic models.

Numerous studies show that the neoclassical growth model with wedges is a useful workhorse in accounting for various macroeconomic events (Cole and Ohanian (2004), McGrattan and Ohanian (2006) and Chen et al. (2007)). These findings suggest that the “Business Cycle Accounting” idea, together with neoclassical models, is a good way to organize the increasingly available data on various dimensions and aspects of economic growth.

Endogenous Variable	Raw Data Used	Data Source
long-run growth rate	per capital GDP series	Maddison-GGDC
employment-pop ratio	employment, population	TED-GGDC
capital allocation	value added by industry,	UNSD
	public spending on education	WDI
labor allocation	employment by industry	ILO
investment-capital ratios	population growth	TED-GGDC
output-capital ratio	investment share in GDP	PWT 6.3
consumption-capital ratio	consumption share in GDP	PWT 6.3
relative price	education expenditure	UNSD
capital-human capital ratio	educational attainments	Barro-Lee 2001

Table 6: Data Sources for Endogenous Variables

A Appendix: variables in the cross-country dataset

This appendix explains how to create relevant variables for the cross-country dataset used in the paper.

The long-run growth rates come from the per capita GDP estimates by Maddison (2003). I compute the annual growth rates for each country year by year from 1951 to 2008, and assume the long-run growth rate equals the average of those annual growth rates. Fifty-eight years are long enough for a country to converge. The long-run population growth rates are from the midyear population estimates of the Total Economy Database. Similarly, I compute the annual growth rates from 1951 to 2008 and take the average. The Total Economy Database also has estimates for employment in the same period. I divide employment by midyear population and take their average as the average employment-population ratios.

As for the shares of employment in the education sector, I divide employment in education by total employment obtained from the ILO, and then take the average. The length of these employment series varies across countries, yet the longest one comes from 1985 to 2008. To compute the shares of education output, I use value added of education and value added of the total economy in constant prices obtained from the National Accounts Of cial Country Data (Table 2.2) by the United Nations Statistics Division, and the public spending on education as a percentage of GDP is obtained from the World Development Indicators (WDI). I divide value added of education by value added of the total economy, take the average of them, and add it to the average percentage of public spending on education. The longest value added series comes from 1966 to 2008, and the longest public spending share series is from 1970 to 2008.

To construct investment-capital ratios for physical capital, I use the approach in Caselli (2005) $\frac{x_k}{k} = n + \quad + \quad _k$, together with estimates of growth rates and population growth rates, and calibrated values of depreciation rates. Similarly, $\frac{x_h}{h} = n + \quad + \quad _h$ can be constructed.

The nal goods output-capital ratios are computed by the following formula,

$$\frac{y}{k} = (1 \quad \frac{Edu\ VA}{VA})\frac{x_k}{k} = \frac{x_k}{GDP};$$

where x_k=GDP is the share of investment in GDP, which is obtained from the Penn World Table 6.3 (CI), Edu VA =VA is the share of education output in the total economy, and (x_k=k) is the investment-capital ratio for capital. The last two variables are both known from previous calculations. Similarly, the nal goods consumption-capital ratios can be calculated from the following formula,

$$\frac{c}{k} = \frac{y}{k}[\frac{CC}{GDP} \quad \frac{Edu\ VA}{VA}]=[1 \quad \frac{Edu\ VA}{VA}];$$

where (CC)/(GDP) is the share of consumption (CC) in GDP from the Penn World Table 6.3.

The method of estimating human capital and its relative price in terms of nal goods is detailed in the text. The data on schooling years are from Barro and Lee (2001). In particular, I use the average schooling years in the total population over age 25.

The physical capital-human capital ratio is derived using the following fomula,

$$\frac{k}{h} = \frac{x_k}{(1 \quad v)GDP} \frac{x_h}{h} \frac{k}{x_k} \quad q$$

B Appendix: robustness checks

This section is about the robustness of the ndings reported in the text. I change the value of each parameter, holding the remaining parameters xed to their calibrated values, and see whether the pseudo goodness-of- t of various wedges changes very much.

B1. Capital share

The capital share in the US has been rather stable. When it comes to cross-country comparisons, a traditional measure of the capital income is the residual after employee compensation has been taken out from national income. These estimates are generally higher in poor countries than in rich countries. After adjusting the labor income in self-employed and small rms, and some other differences, Gollin (2002) has convincingly shown that for most countries the capital share is in the range of 0.20 to 0.35.

Figure 1 plots the explanatory power of the various wedges on growth as the capital share moves from 0.20 to 0.35. Clearly, the contribution of the human capital investment wedge $_{xh}$ is quite stable with respect to alternative values of in this range. The government spending wedge g/k is not important, and also stable.

wedges r labor to

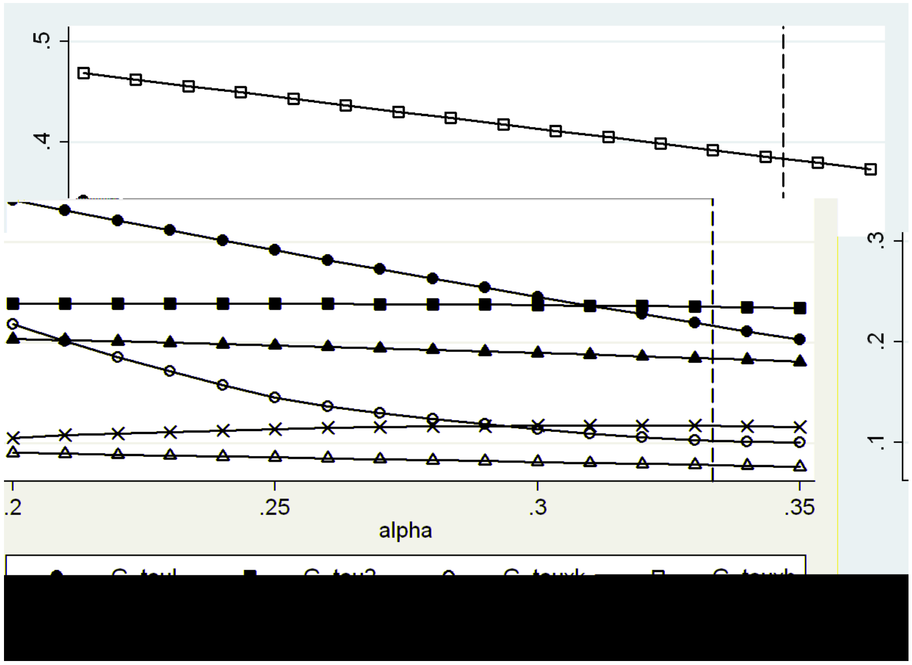


Figure 1: Robustness check with on growth

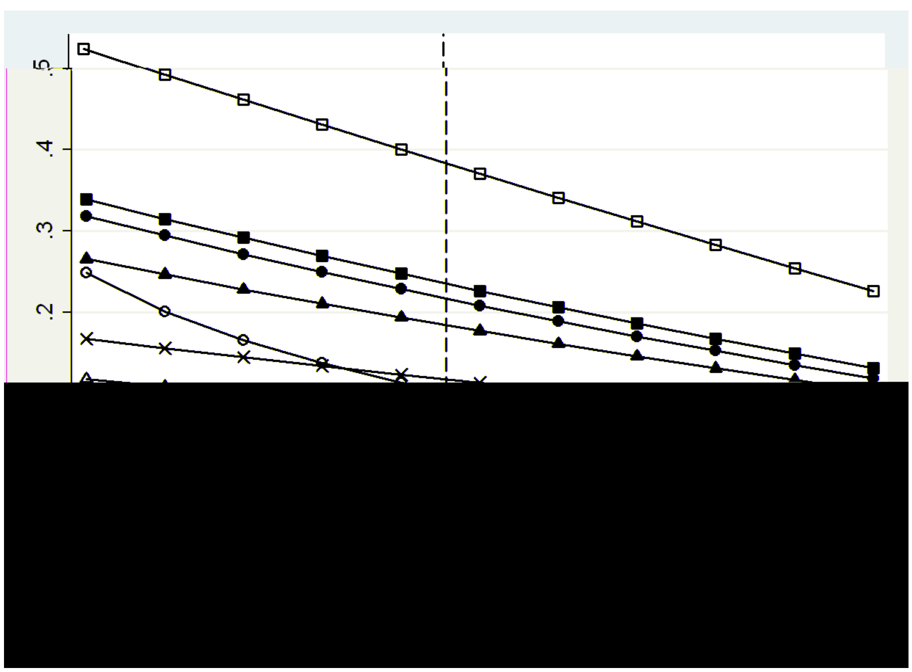
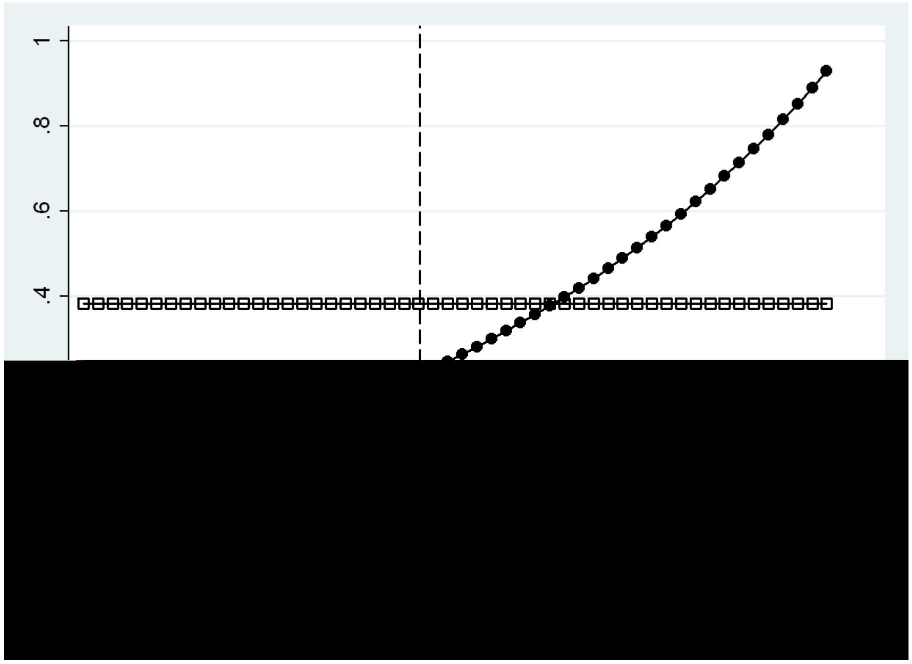


Figure 2: Robustness check with on growth



[redacted]

Figure 3: Robustness check with on growth

bound could be 0.67, and the lower bound could be 0.16. Figure 3 plots the contributions of various wedges in explaining growth in this range. Since only affects the labor wedge $_l$, except for the labor wedge, the contributions of all other wedges does not change. The labor wedge, however, is quite sensitive to changes in . When is around 0.23, the labor wedge reaches its bottom, and could be the least important factor in accounting for growth. But its explanatory power increases sharply, and it becomes the most important factor when is equal or higher than 0.47. The high sensitivity of $_l$ around the benchmark value of implies that our results about the labor wedge may change non-trivially with more precise measures of the consumption share.

C Do previous studies contradict this analysis?

Previous quantitative studies on cross-country income variance nd that ef - ciency is at least as important as inputs in explaining both growth and relative income differences. Does the data I collect or the alternative accounting method I

Hall and Jones (1999)	Income	Capital	Education	Residual
Average (45)	0.481	0.957	0.695	0.678
Standard Deviation	0.283	0.194	0.165	0.278
Corrlation w/ $Y=L$ (logs)	1.000	0.658	0.700	0.812
Corrlation w/ A (logs)	0.812	0.156	0.225	1.000

Bosworth et al. (2003)	Income	Capital	Education		Residual
Industrial Countries (22)	2.2%	0.9%	0.3%		1.0%
China (1)	4.8%	1.7%	0.4%		2.6%
East Asia less China (7)	3.9%	2.3%	0.5%		1.0%
Latin America (22)	1.1%	0.6%	0.4%		0.2%
This Work	**Income**	**Capital**	**Education**	**Labor**	**Residual**
Industrial Countries (20)	2.1%	0.9%	0.4%	0.2%	0.6%
China (1)	4.3%	2.4%	0.7%	0.4%	0.9%
East Asia less China (4)	3.5%	1.9%	0.8%	0.4%	0.4%
Latin America (9)	1.8%	1.1%	0.5%	0.3%	-0.1%

Table 9: Growth Accounting Comparison

is smoothed using the perpetual inventory method. However, in my study it is not smoothed, but comes from the investment-output ratio with a linear transformation.

The education stock in the baseline study and the human capital stock in this work are related, but not identical concepts. Remember that I choose 2000 as the base year, and use the average growth rate to infer human capital stock. If all countries would share the same average growth rates, then the relative human capital would be identical to the education stock in the baseline study. And if a country grows faster than the US, its derived relative human capital would be smaller than its relative education stock. The observation that the average human capital stock is slightly smaller than the education stock con rms that countries in the sample grow slightly faster than the US, on average. It seems that the steady-state equilibrium is not too restrictive to examine cross-country differences in economic performance, at least for countries in this sample.

The labor participation says that, on average, other countries in this sample work less than the US. The residual in the alternative study, not surprisingly, looks similar to the baseline study; given that the human capital stock differs little from the education stock.

In the case of growth accounting, Klenow and Rodriguez-Clare (1997b) use the following formula to decompose growth

$$\ln \frac{Y}{L} = \ln A + \frac{1}{1 \quad 1 \quad 2} \ln \frac{K}{Y} + \frac{2}{1 \quad 1 \quad 2} \ln \frac{H}{Y}$$

where the sum of inputs' contribution can be expressed as $\ln X$. They also use covariances to measure the contribution of each term to growth,

$$\frac{Cov(\ln \frac{Y}{L}; \ln A)}{Var(\ln \frac{Y}{L})} + \frac{Cov(\ln \frac{Y}{L}; \ln X)}{Var(\ln \frac{Y}{L})} = 1:$$

Bosworth et al. (2003) use a production function and a de nition of human capital that is similar to Hall and Jones (1999), and a more conventional decomposition,

$$\ln \frac{Y}{L} = \ln A + \ln \frac{K}{L} + (1 \quad) \ln h_{HJ}$$

with averages to measure the contribution of each term, [17]

$$Ave(\frac{\ln A}{\ln \frac{Y}{L}}) + Ave(\frac{\ln(K=L)}{\ln \frac{Y}{L}}) + (1 \quad)Ave(\frac{\ln h_{HJ}}{\ln \frac{Y}{L}}) = 1:$$

Note that if the steady-state equilibrium were imposed, Klenow and Rodriguez-Clare (1997b) would wholly attribute growth to technology progress and not at all to capital accumulation; and Bosworth et al. (2003) would attribute of growth to capital accumulation. Growth accounting would not be interesting. So I use Bosworth et al. (2003) as

Notice that mostly, there are fewer countries in my sample. For example, twenty-two Latin American countries are in the baseline, but only nine are in my sample. Another point worth noticing is that the effect of labor participation is excluded from the residual in my calculation, while not in the baseline study.

Bosworth et al. (2003) con rms widely accepted observations across regions: in general, TFP contributes as much as physical capital accumulation and the increase of education explains a relatively small part; East Asia less China accumulates physical capital more rapidly during its miraculous growth in the past than others; and TFP grows slowly in Latin America. My calculations also con- rm the baseline. It veri es that the data I have collected is as good (or bad) as the data used by previous studies.

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