An Accounting Method for Economic Growth

Hongchun Zhao*
PhD student at University of Southern California

April 2011 – Version 2.0
Preliminary and Incomplete

Abstract

As Chari et al. (2007) indicate, many growth theories explaining frictions in real economies are equivalent to a competitive economy with some exogenous taxes. Using this idea, I develop an accounting method for identifying fundamental causes of economic growth. I use a two-sector neoclassical growth model with taxes as a prototype economy and show that two detailed growth models correspond to two different wedges in the prototype economy, respectively. Furthermore, the importance of wedges in explaining the long-run growth rate, and other variables of interest, can be evaluated through the prototype economy, and promising models connect to the relevance of their corresponding wedges. Applying this method to Hong Kong, Korea, Singapore, and Taiwan reveals that two investment wedges account for their rapid growth, while applying to Argentina, Brazil, Chile, and Peru reveals that the labor wedge helps understand their stagnant growth.
1. Introduction

Differences in economic growth across countries have been substantial in history. Since 1950 the industrial countries have either grown at a remarkably stable rate or converged to the stable trend, a few developing countries have experienced rapid growth, yet some other countries grow at only a stagnant rate. Over the last two hundred years the industrial leaders also witness sustained economic growth: the United Kingdom grew around 1.2% per year from 1820 to 1890; and the United States has a 2% average annual growth rate throughout the twentieth century (use data from Maddison (2003)). What sustains growth over long periods of time? Which country will be the industrial leader in the twenty-first 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

The insight from Chari et al. (2007) is that a neoclassical growth (NCG) model with taxes is a good perspective with which underlying causes of the observed gaps in growth can be analyzed. Wedges associated with a prototype economy’s equilibrium conditions can be defined as exogenous variables, and interpreted as taxes, efficiency shifters, etc. Furthermore, specific growth models that can theoretically explain the observed gaps correspond to these wedges too. 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 to theoretical explanations more easily. I choose a two-sector NCG model as the prototype economy, in which the long run economic growth is endogenously driven by the accumulation of the broadly defined human capital. The prototype economy defines seven wedges, which resemble taxes, productivity shifters and government consumption.

The reason why many specific growth models can be connected to the prototype economy is because most theories in the growth literature capture certain

¹Kydland and Prescott (1982) unify business cycle and growth theory by arguing that business cycle models should be consistent with the empirical regularities of long-run growth. So growth theories can naturally take advantage of any methodology that proves to be useful in business cycle models.
frictions of real economies that could prevent production from achieving optimality in a neoclassical structure. For example, Lucas (1988) specifies that the accumulation of human capital is not subject to diminishing returns; Romer (1990) incorporates both monopolistic competition and knowledge externalities into a neoclassical framework; and Klenow and Rodriguez-Clare (2005) explicitly claim that their models incorporate externalities. Additionally, economic policies and competitive barriers, which are emphasized by McGrattan and Schmitz (1999) and Cole et al. (2005), are seen as explicit frictions in the production process.

As examples for the equivalence results that many growth theories are isomorphic to the prototype economy, I show that an international knowledge spillover model (adapted from Klenow and Rodriguez-Clare (2005)) and a monopolistic competition model (adapted from Romer (1990)) correspond to a human capital investment wedge and a labor wedge in the prototype economy respectively. The human capital investment wedge is the wedge associated with the Euler equation for the human capital, and the labor wedge is the wedge associated with the labor-leisure trade-off condition.

In addition, the wedges defined by equilibrium conditions of the prototype economy can be recovered, when values of endogenous variables and parameters are observable. Thus the relevance of potential theories in explaining economic growth is connected to the relevance of their corresponding wedges, which are recovered from actual data. This flexibility allows us to tackle the important question of identifying fundamental causes of the long-term economic growth.

I collect the relevant data for four East Asian countries, four Latin American countries, and the United States, measure various wedges for each country and evaluate the contributions of individual wedges. The main findings confirm and extend the results of Young (1995): country-specific features that facilitate the accumulation of labor-augmented technology drive the growth of Hong Kong, South Korea, and Taiwan, while the policies stimulating physical capital investment also drive the growth of Singapore and South Korea in a significant way; as

---

2Some endogenous growth theories are not isomorphic to the prototype economy. For example, endogenous growth models with multiple equilibria are not, because the equilibrium of the prototype economy is uniquely defined. Also two-sector models with a different partition of output are not equivalent to each other. For example, two-sector models with a agriculture/non-agriculture partition are not equivalent to those with a consumption/capital goods partition.
for Argentina, Brazil, Chile, and Peru, the frictions that restrict competition and impede the operation of normal market forces in product and labor markets delay these countries gaining ground on the United States. These results will help researchers develop quantitative models of economic growth.

This paper relates to a large literature that studies the determinants of the large gaps of economic performance. Some studies deal with proximate causes, such as physical and human capital, or technology changes and adoption (e.g., Lucas (1988), Romer (1990) and Klenow and Rodriguez-Clare (2005)). Others pay more attention to fundamental causes, such as differences in luck, raw materials, geography, preferences, and economic policies (e.g., McGrattan and Schmitz (1999), Cole et al. (2005), Acemoglu et al. (2001) and Rodrik et al. (2004)). My paper complements this literature by organizing promising stories under a unified framework. In this respect, my work provides a particular response to Lucas (1988), where the author recommended economists: (1) to develop quantitative theories that describe the observed differences across countries and over time, in both levels and growth rates of income per person; (2) to explore the implications of competing theories with respect to observable data; and (3) to test these implications against observation.

The rest of the paper is organized as follows. Section 2. describes the prototype economy and its steady-state equilibrium. Section 3. establishes equivalence results for two detailed models. Section 4. presents the raw data sources, the construction of the broadly defined human capital and its relative price in terms of final goods, and briefly explain the accounting procedure. Section 5. shows the experiment results, and compares them with previous level and growth accounting studies, both conceptually and numerically. Section 6. concludes.

---

3Solow (1957) is an early, but modern, attempt to account for different patterns of economic development, which becomes the cornerstone of the NCG model. Lucas (1988) emphasizes the effects of human capital accumulation; Romer (1990), among others, endogenizes technological change; Klenow and Rodriguez-Clare (2005) address the interaction between open economies. McGrattan and Schmitz (1999) focus on differences in economic policies and review estimates for a wide range of policy variables; Cole et al. (2005) argue that Latin America’s failure to replicate Western economic success is primarily due to TFP differences, and that barriers to competition are the cause of these differences.
2. The Prototype Economy

In this section, I specify the prototype economy as a two-sector model of endogenous growth with taxes, and describe its steady-state equilibrium.

The prototype economy is a variant of Rebelo’s two-sector model (see Rebelo (1991)). One sector produces final goods, which can be either consumed or invested in physical capital; the other sector produces human capital, which enhances labor productivity. Both sectors use Cobb-Douglas aggregate production functions,\(^4\)

\[
y(t) = A[v(t)k(t)]^\alpha[u(t)h(t)l(t)]^{1-\alpha}, \tag{1}
\]

\[
x_h(t) = B[(1 - v(t))k(t)]^\alpha[(1 - u(t))h(t)l(t)]^{1-\alpha}, \tag{2}
\]

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

Output and factor markets are competitive, and firms maximize their profits,

\[
y(t) - (1 + \tau_1)rk(t)v(t)k(t) - (1 + \tau_2)wk(t)u(t)l(t),
\]

\[
q(t)x_h(t) - rh(t)(1 - v(t))k(t) - wh(t)(1 - u(t))l(t),
\]

given the relative price of human capital in terms of final goods \(q\), and factor prices of physical capital and labor in the final goods sector \(r_k, w_k\) and in the other sector \(r_h, w_h\). Notice that factor incomes in the final goods sector are taxed with rates \(\tau_1\) and \(\tau_2\).

There is a representative household in the model whose size \(N(t)\) grows at

\(^4\)Sturgill (2009) suggests that the inclusion of energy as a further input has a substantial impact on the estimated contribution of TFP on long-run growth. So this widely-used specification of production function deserves a further consideration.

\(^5\)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.

\(^6\)These production technologies are labor-augmented \(Y = AK^{\alpha}(hL)^{1-\alpha}\), where uppercase variables denote total amounts. The reason why I choose the labor-augmented technology is that any technology consistent with balanced growth can be represented by this form.
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 $\theta \in (0,1)$ be the consumption share in the period utility function. The household’s problem is,

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

subject to (a) a budget constraint,

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

(b) factor prices derived from profit maximization problems,

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

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

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

$$w_h(t) = q(t)(1 - \alpha)x_h(t)/[(1 - u(t))l(t)],$$

(c) the law of motion for physical capital and human capital,

$$(1 + n)k(t + 1) = (1 - \delta_k)k(t) + x_k(t), \quad (3)$$

$$(1 + n)h(t + 1) = (1 - \delta_h)h(t) + x_h(t), \quad (4)$$

with $x_k(t), x_h(t) \geq 0$. Here $\tau_{xk} - \tau_1, \tau_{xh} - \tau_1, \tau_l$ are tax rates on physical capital investment, human capital investment, and total labor income; $T$ is a per person lump-sum transfer, which equals total tax revenues minus government tax revenues. If the tax is on labor income, it equals the difference between total tax revenues and total labor income.

If the labor-augmented human capital includes a general technology level that can be “publicly” used, population growth would not dilute the human capital stock per person. Then the law of motion would be $h(t + 1) = (1 - \delta_h)h(t) + x_h(t)$. Both forms follow Ben-Porath (1967). A different approach is a log-linear law of motion. Chang et al. (2002) use the log-linear approach to analyze learning by doing, Hansen and Imrohoroglu (2009) extend it to study on-the-job training. Both approaches are approximately isomorphic to each other around steady state.
consumption $g$, 

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

And $\delta_h$ and $\delta_k$ denote the depreciation rates of human capital and physical capital respectively; $x_k$ is per person physical capital investment.

The competitive equilibrium of the prototype economy is a set of prices and allocations such that they are solutions to firms’ and consumers’ problems, and satisfy the resources balance,

$$c(t) + x_k(t) + g(t) = y(t).$$ (5)

The equilibrium conditions are

$$(1 - \tau_l) \frac{\theta}{c(t)} \frac{(1 - \alpha) q(t) x_h(t)}{(1 - u(t)) l(t)} = \frac{1 - \theta}{1 - l(t)}$$ (6)

$$(1 + \tau_1) q(t) x_h(t) v(t) = y(t) [1 - v(t)],$$ (7)

$$(1 + \tau_2) q(t) x_h(t) u(t) = y(t) [1 - u(t)],$$ (8)

$$\frac{c(t) + 1}{c(t)} (1 + \tau_{xk}) = \beta \left[ \frac{\alpha y(t + 1)}{v(t + 1) k(t + 1)} + (1 - \delta_k)(1 + \tau_{xk}) \right]$$ (9)

$$\frac{c(t) + 1}{c(t)} (1 + \tau_{xh}) = \beta \frac{q(t + 1)}{q(t)} \left[ \frac{(1 - \alpha) x_h(t + 1)}{(1 - u(t + 1)) h(t + 1)} + (1 - \delta_h)(1 + \tau_{xh}) \right],$$ (10)

together with production functions, laws of motion, and the resources balance. Given the transversality condition, $\lim (\beta(1 + n)) t c(0)^{-\theta} y(0) = 0$, and the initial stocks, $k(0), h(0)$, these equations characterize competitive equilibrium paths of the prototype economy.8

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), Bond et al. (1996)).

8Solving the following Bellman equation yields equilibrium conditions,

$$V(k, h) = \max \{ U(c, l) + \beta (1 + n) V(k', h') \}$$

where $c = r_k v k + r_h (1 - v) k + (1 - \tau_l) [w_k u l + w_h (1 - u) l] + T - (1 + \tau_{xk})(1 - \tau_1)[(1 + n) k' - (1 - \delta_k) k] - (1 + \tau_{xh})(1 - \tau_1) q'^{(1 + n) h'} - (1 - \delta_h) h$. Notice that equations (6), (7) and (8) are from first
In the steady-state equilibrium, the growth rate of every variable is constant. More specifically, \( v, u, l, \) and \( q \) are constants, and all other endogenous variables grow at the same rate, \( \gamma \). As a result, solutions to the steady-state equilibrium are only ratios or rates. There are ten equations that can be used to solve for the ten endogenous variables, \( v, u, l, q, \gamma, h/k, y/k, c/k, x_k/k, \) and \( x_h/h \).

For clarity, the steady-state equilibrium conditions are collected in one place as follows,

\[
(1 - \tau_l) \frac{1 - l}{l} (1 - \alpha) q x_h h \frac{h}{k} = \frac{1 - \theta c}{\theta k},
\]

(11)

\[
(1 + \tau_1) \frac{q x_h h}{h} \frac{h}{k} = (1 - v) \frac{y}{k},
\]

(12)

\[
(1 + \tau_2) \frac{q x_h h}{h} \frac{h}{k} = (1 - u) \frac{y}{k},
\]

(13)

\[
(1 + \gamma)(1 + \tau_{xx}) = \beta \left[ \frac{\alpha y}{v k} + (1 - \delta_k)(1 + \tau_{xx}) \right],
\]

(14)

\[
(1 + \gamma)(1 + \tau_{xh}) = \beta \left[ \frac{(1 - \alpha)x_h}{(1 - u)h} + (1 - \delta_h)(1 + \tau_{xh}) \right],
\]

(15)

\[
\frac{y}{k} = A v^\alpha \left( \frac{h}{k} \right)^{1-\alpha},
\]

(16)

\[
\frac{x_h h}{h} = B(1 - v)^\alpha \left( \frac{h}{k} \right)^{1-\alpha},
\]

(17)

order conditions with respect to \( l, v \) and \( u \),

\[
U_c(1 - \tau_l)(w_k u + w_h (1 - u)) + U_l = 0
\]

\[
r_k k - r_h k = 0
\]

\[
(1 - \tau_l)(w_k l + w_h l) = 0.
\]

Using canonical dynamic programming, we obtain,

\[
c'(1 + \tau_{xx})(1 - \tau_l) = c \beta [v' + (1 - \delta_k)(1 + \tau_{xx})(1 - \tau_l)]
\]

\[
c'(1 + \tau_{xh})(1 - \tau_l)q = c \beta [v' + (1 - \delta_k)(1 + \tau_{xh})(1 - \tau_l)].
\]

These are the Euler equations (9) and (10).

To avoid repetition, let \( \gamma_a \) be the growth rate of an arbitrary variable \( a \) in steady state. Equations (7) and (8) imply that \( \gamma_u = \gamma_v = 0 \), equation (6) implies \( \gamma_l = 0 \), equation (8) implies \( \gamma_y = \gamma_x + \gamma_y \), equation (5) implies \( \gamma_c = \gamma_{xx} = \gamma_y \), the law of motion for \( h \) implies \( \gamma_{xx} = \gamma_h \), the law of motion for \( k \) implies \( \gamma_{xx} = \gamma_k \), production function (1) implies \( \gamma_y = \alpha \gamma_k + (1 - \alpha) \gamma_h \), production function (2) implies \( \gamma_{xx} = \alpha \gamma_k + (1 - \alpha) \gamma_h \). Combining all of these results implies that \( v, u, l, q \) are constant, and all the other variables grow at the same rate.
\[ \frac{x_h}{h} = \gamma + n + \delta_h, \]  
\[ \frac{x_k}{k} = \gamma + n + \delta_k, \]  
\[ \frac{c}{k} + \frac{x_k}{k} + \frac{g}{k} = \frac{y}{k}. \]

Altogether there are eight wedges. However, to overcome data availability restrictions and make easy to compare with the literature, later I only experiment with the labor wedge \( \tau_L = \tau_{L1} + \tau_{L2} \), the physical capital investment wedge \( \tau_{xk} \), the human capital investment wedge \( \tau_{XH} = \tau_{xh} + \tau_B \), the final goods efficiency wedge \( \tau_A = 1 - \frac{A}{A_{US}} \) (in addition \( \tau_B \) is similarly defined), and the government consumption wedge \( g/k \).

### 3. Equivalence Results

In this section, I show that two detailed models are equivalent to the prototype economy with different wedges. In particular, international knowledge spillovers accord with a human capital investment wedge, while monopolistic competition in the intermediate inputs market corresponds to a labor wedge. Yet many other economic theories with policy implications can be connected to these two wedges, and some will be discussed in section 5\(^{10} \).

#### 3.1. The mapping between an international knowledge spillover model and the prototype economy

Klenow and Rodriguez-Clare (2005) present a growth model with international knowledge spillovers. In its simplest version, the production of knowledge of a certain country is affected by the country’s productivity relative to an exogenous world technology frontier and technology diffusion from abroad that does not depend on domestic research efforts. Here I show that this version is equivalent to the prototype economy with a human capital investment wedge.

\(^{10}\)For example, McGrattan and Prescott (2007) show the relationship between development and openness to foreign direct investment (FDI), which also corresponds to a human capital investment wedge, and Cole and Ohanian (1999, 2004), and Ohanian (2009) present theory that many types of cartel policies map into an optimal growth model featuring a labor wedge.
Suppose in a country, the output is produced with a Cobb-Douglas production function, \( Y = K^\alpha (AL)^{1-\alpha} \), where \( Y \) is total output, \( K \) is the capital stock, \( A \) is a technology index, and \( L \) is the total number of workers which are growing at the rate \( n \). Output can be used for consumption \( C \), investment \( I \), or research \( R \), thus \( Y = C + I + R \). Capital is accumulated according to \( K(t+1) = (1 - \delta)K(t) + I(t) \). The technology index \( A \) contains effects of research efforts, technology diffusion from abroad, and relative productivity to the world technology frontier. The growth rate of this frontier is exogenous. In particular, \( A \) evolves according to,

\[
A(t+1) = A(t) + \left[ \lambda R(t)/L(t) + \epsilon A(t) \right] [1 - A(t)/A^*(t)], \tag{21}
\]

where \( \lambda \) and \( \epsilon \) are positive parameters and \( A^* \) is the world technology frontier. The R&D investment rate is denoted by \( 1 - s = R/Y \). Let lowercase letters denote per person values of aggregate variables. Then the production function becomes \( y = k^\alpha A^{1-\alpha} \). Assuming that factor markets are competitive, the rental rate of capital becomes \( r = \alpha [k(t)]^{\alpha-1}[A(t)]^{1-\alpha} \), and the rate of return on \( A \), \( w = (1 - \alpha)k^\alpha A^{-\alpha} \).

This model can be written succinctly as the following maximization problem:

\[
\max \sum_{t=0}^{\infty} \beta^t \ln[c(t)]L(t),
\]

subject to

\[
c(t) + i(t) + R(t)/L(t) = r(t)k(t) + w(t)A(t), \quad (1 + n)k(t+1) = (1 - \delta)k(t) + i(t), \quad A(t+1) = [1 + \epsilon(1 - A(t)/A^*(t))]A(t) + \lambda[1 - A(t)/A^*(t)]R(t)/L(t),
\]

\[
r(t) = \alpha [k(t)]^{\alpha-1}[A(t)]^{1-\alpha}, \quad w(t) = (1 - \alpha)[k(t)]^\alpha[A(t)]^{-\alpha},
\]

and initial values, \( k(0) \) and \( A(0) \).

Let \( a(t) = A(t)/A^*(t) \). Klenow and Rodriguez-Clare (2005) show that \( a \) is constant in steady state. The following conditions characterize the steady-state
Table 1: Equivalence Result for Klenow and Rodriguez-Clare (2005)

<table>
<thead>
<tr>
<th>Wedges</th>
<th>Variables</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype (P)</td>
<td>KRC</td>
<td>P</td>
</tr>
<tr>
<td>( A^p )</td>
<td>1</td>
<td>( v^p )</td>
</tr>
<tr>
<td>( B^p )</td>
<td>1</td>
<td>( u^p )</td>
</tr>
<tr>
<td>( 1 - \tau_1^p )</td>
<td>1</td>
<td>( h^p )</td>
</tr>
<tr>
<td>( 1 + \tau_1^p )</td>
<td>1</td>
<td>( k^p )</td>
</tr>
<tr>
<td>( 1 + \tau_2^p )</td>
<td>1</td>
<td>( x_h^p )</td>
</tr>
<tr>
<td>( 1 + \tau_{xk}^p )</td>
<td>1</td>
<td>( x_k^p )</td>
</tr>
<tr>
<td>( 1 + \tau_{xh}^p )</td>
<td>( (n - \frac{s-a}{1-a})(1-a)\lambda + \frac{1-s}{1-\alpha} )</td>
<td>( y^p )</td>
</tr>
<tr>
<td>( g^p )</td>
<td>0</td>
<td>( p^p )</td>
</tr>
<tr>
<td>( q^p )</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

where \( \gamma \) be the growth rate in steady state.

The following claim shows that a prototype economy replicates the international knowledge spillover model detailed above:

**Proposition 1** (Human capital investment wedge and technology spillovers): Consider a prototype economy with a human capital investment wedge \( 1 + \tau_{xh}^p = ((n -
\[ \frac{s-\alpha}{1-\alpha}(1-a)\lambda + \frac{1-s}{1-\alpha} \] but no other wedges. Let the depreciation rate of human capital be \( \delta_h = \frac{\gamma - (1-a)\gamma}{(1-a)\lambda} - \gamma - n \). Then the equilibrium allocations of both the prototype economy and the international knowledge spillover model detailed above coincide.

**Proof of Proposition 1.**

To prove this and other equivalence results we compare steady-state equilibrium conditions of the detailed model to those of the prototype economy. To save words, all notations used in the prototype economy are with a superscript \( p \).

By the definition of final goods, the shares of production factors used in final goods production are \( u^p = v^p = s \), and the output of final goods is \( y^p = c+i = sy \). From the production function, capital shares in both sectors are \( \alpha \). Let investment in technology be \( x^p_h = R/L \). Then from the law of motion for technology \( A \) in steady state, we know that \( h^p = A \), and \( \delta^p_h = \frac{\gamma - (1-a)\gamma}{(1-a)\lambda} - \gamma - n \). Notice that the production functions for consumption plus investment and for the investment in technology in the detailed model are the same. Thus the final goods efficiency and human capital efficiency wedge are equal, \( A^p = B^p = 1 \). For the same reason, the relative price of technology is one, \( q^p = 1 \).

Comparing the law of motion for \( k \) in the detailed economy gives \( \delta^p_h = \delta \), \( k^p = k \) and \( x^p_k = i \). Bear this in mind, we know \( \tau^p_{xk} = 0 \) from the Euler equation (26). From the factor market clearing conditions, wedges \( \tau^p_1 \) and \( \tau^p_2 \) must be zero. Since the representative household does not value leisure and supplies its labor inelastically, the labor wedge \( \tau^p_l \) is zero.

Notice that the depreciation rate of technology can be rewritten as \( \delta^p_h = -(1 - \frac{1}{(1-a)\lambda})\gamma - \frac{1}{(1-a)\lambda}(1-a)\epsilon - n \). As a result, the Euler equation (27) can be rewritten as

\[
1 + \gamma = \beta [(1+n)(1-a)\lambda w + 1 + n + (1-a)\epsilon] \\
= \beta [(1+n)(1-a)\lambda w + 1 - \delta^p_h - (1 - \frac{1}{(1-a)\lambda})\gamma - (1-a)\epsilon)] \\
= \beta [(1+n)(1-a)\lambda w + 1 - \delta^p_h - ((1-a)\lambda - 1)\frac{R}{AL}] \\
= \beta [((n - s - \alpha)(1-a)\lambda + \frac{1-s}{1-\alpha})w + 1 - \delta^p_h].
\]

The second line is obtained by substituting \( \delta^p_h \) into the Euler equation, the third
line follows \( \frac{R}{AL} = \frac{\gamma-(1-a)\epsilon}{(1-a)\lambda} \), the fourth line uses \( \frac{R}{AL} = (1-s)k^\alpha A^{-\alpha} \), and \( w = (1-\alpha)k^\alpha A^{-\alpha} \), and collects like terms. Finally, the human capital investment wedge is
\[ 1 + \tau_{xh}^p = ((n - s - \alpha)(1 - a)\lambda + \frac{1-s}{1-\alpha})^{-1}. \text{ QED.} \]

The mapping between these two economies is shown in table 1, where the columns labeled “Prototype” or “P” contain notation used in the prototype economy, and the columns labeled “KRC” used in the detailed economy. Substituting the notation used in the detailed economy into the equilibrium conditions of the prototype economy replicates the equilibrium conditions of the detailed economy.

In this simple version of Klenow and Rodriguez-Clare (2005), the human capital investment wedge is always negative when there is a gap between the current technology and the world technology frontier. However, positive values of this wedge can also be microfounded. For example, in McGrattan and Prescott (2007), which also corresponds to the human capital investment wedge, the sign of this wedge depends on the sign of a country’s net factor payment.

3.2. The mapping between Romer’s model and the prototype economy

Romer (1990) wrote a seminal paper on endogenous growth. The importance of his paper stems from two important features: its emphasis on the non-rival nature of knowledge and ideas in order to generate sustained economic growth and its emphasis on potential non-competitive elements. The non-rivalry of knowledge microfounds endogenous growth and now becomes a widely-used specification. In particular, Romer attributes spillovers across firms to physical capital. Here I adapt his model and let the spillovers work through human capital. Monopolistic competition in the intermediate inputs sector is a distinguishing feature of this model, turning out to be a labor wedge.

In this model there are three sectors: a research sector, in which firms use educated workers and capital to produce new knowledge; a final goods sector, which uses educated workers and capital to produce final goods; and an education sector, educating workers by using available knowledge and labor.

Let \( K_1 \) and \( K_2 \) be the capital devoted to producing final goods and R&D re-
respectively, $A$ be the total number of skills currently in existence, and $x_{1i}$ and $x_{2i}$ be the quantities of the $i$th skill from educated workers in the final goods sector and research sectors, respectively. All producers are profit maximizers.

As usual, final goods can be either consumed or invested in capital. The production function of final goods is $Y = K_1^\alpha \int_0^A x_{1i}^{1-\alpha} di$. Let $r_1$ be the rental rate of $K_1$, and $p_1(x_{1i})$ be the price of the $i$th skill. Then $\forall i \in [0, A], p_1(x_{1i}) = (1-\alpha)K_1^\alpha x_{1i}^{\alpha}$ and $r_1 = \alpha K_1^{\alpha-1} \int_0^A x_{1i}^{1-\alpha} di$.

The production function of the research sector is $X = \delta K_2^\alpha \int_0^A x_{2i}^{1-\alpha} di$, where $\delta$ is a productivity shifter. Let $p_X$ denote the price of investment in R\&D in terms of final goods. Similarly, we have, $\forall i \in [0, A], p_2(x_{2i}) = p_X \delta (1-\alpha)K_2^\alpha x_{2i}^{\alpha}$ and $r_2 = p_X \delta \alpha K_2^{\alpha-1} \int_0^A x_{2i}^{1-\alpha} di$.

Assume that the technology available to educate workers is linear, $x_i = L_i$, where $L_i$ is a raw labor input. Different from producers in the other two sectors, producers in the intermediate input sector are monopolists. For the $i$th skill, the profit is, $\pi_i = \max\{p_1(x_{1i})x_{1i} + p_2(x_{2i})x_{2i} - wL_i\}$, where the total labor supplied equals $L_i = L_{1i} + L_{2i}$. Therefore, in equilibrium, the wage rate is $w = p_1'(L_{1i})L_{1i} + p_2'(L_{2i})L_{2i} = p_1'(L_{1i})L_{1i}^\alpha - p_2'(L_{2i})L_{2i}^\alpha$, and the profit is $\pi_i = -\delta K_1^\alpha L_{1i}^{1-\alpha}$. Using the demand functions for the intermediate inputs derived above, wage rates in the final goods sector and the research sector respectively are $w_1 = (1-\alpha)^2K_1^\alpha L_{1i}^{-\alpha}$ and $w_2 = p_X \delta (1-\alpha)^2 K_2^\alpha L_{2i}^{-\alpha}$, and the profit is $\alpha (1-\alpha)\left[ K_1^\alpha L_{1i}^{-\alpha} + K_2^\alpha L_{2i}^{-\alpha} \right]$.

Romer (1990) shows that in a symmetric equilibrium, the number of educated workers in the $i$th profession, $x_i$ and its raw labor supply $L_i$ are constant across professions. Without loss of generality, let the size of the representative household be unity. Put simply, given the initial values, $K(0)$ and $A(0)$, the representative household maximizes,

$$\max_{\{C(t), L(t), I(t), X(t)\}} \sum_{t=0}^\infty \beta^t \left[ \theta \ln C(t) + (1-\theta) \ln(1 - L(t)) \right],$$

subject to,

$$K(t + 1) = (1 - \delta_k)K(t) + I(t),$$

$$A(t + 1) = A(t) + X(t),$$

$$r_1(t) = \alpha K_1(t)^{\alpha-1} A(t) L_1(t)^{1-\alpha},$$
\[ r_2(t) = p_X \delta \alpha K_2(t)^{\alpha-1} A(t) L_2(t)^{1-\alpha}, \]
\[ w_1(t) = (1 - \alpha)^2 K_1(t)^{\alpha} L_1(t)^{-\alpha}, \]
\[ w_2(t) = p_X \delta (1 - \alpha)^2 K_2(t)^{\alpha} L_2(t)^{-\alpha}. \]

\[ C(t) + I(t) + p_X(t)X(t) + A(t)[p_1 x_1 + p_2 x_2] = r_1(t) K_1(t) \]
\[ + r_2(t) K_2(t) + A(t)[p_1 x_1 + p_2 x_2] + A(t)[w(t) L(t) + \pi(t)], \]

where \( K = K_1 + K_2 \) is the total capital stock, \( \delta_k \) is its depreciation rate, and the total labor supply is \( L = L_1 + L_2 \).

Let \( \gamma \) be the growth rate of endogenous variables in steady state. Then the steady-state equilibrium is characterized by the following conditions,

\[ \theta(1 - \alpha)^2 p_X X (1 - L) = (1 - \theta) C L_2 \]  
(28)

\[ Y = AK_1^\alpha L_1^{1-\alpha} \]  
(29)

\[ X = \delta AK_2^\alpha L_2^{1-\alpha} \]  
(30)

\[ I/K = \gamma + \delta_k \]  
(31)

\[ X/A = \gamma \]  
(32)

\[ YK_2 = p_X X K_1 \]  
(33)

\[ YL_2 = p_X X L_1 \]  
(34)

\[ 1 + \gamma = \beta(\alpha Y/K_1 + 1 - \delta_k) \]  
(35)

\[ 1 + \gamma = \beta[(1 - \alpha)X L/(A L_2) + 1] \]  
(36)

\[ C + I = Y. \]  
(37)

The following claim shows that a prototype economy with a labor wedge replicates Romer’s model detailed above:

**Proposition 2** (labor wedge and monopolistic competition in an education sector): Consider a prototype economy with a human capital efficiency wedge \( B^p = \delta \), and a labor wedge \( \tau^p_l = \alpha \). Let the depreciation rate of human capital be \( \delta_h^p = 0 \), and the pop-
ulation growth be \( n = 0 \). Then the equilibrium allocations of both the prototype economy and the adapted Romer model coincide.

**Proof of Proposition 2.** Similar to the previous proof, I compare the equilibrium conditions of Romer’s model to those of the prototype economy.

Comparing production functions of \( Y \) and \( X \) in the adapted Romer model to those of \( y^p \) and \( x^p_h \) in the prototype economy implies \( v^p = K_1/K \), \( w^p = l_1/l \), \( A^p = 1 \), \( B^p = \delta \). It is easy to verify that \( y^p = Y \), \( k^p = K \), \( x^p_k = I \).

Let \( h^p = A \), and \( x^p_h = X \). Comparing the laws of motion for \( K \) and \( A \) implies \( \delta_k^p = \delta_k \), \( \delta_h^p = 0 \). The marginal product of capital in the final goods sector equals that in the research sector, and so does the wage rate. Thus \( \tau_1 = 0 \), and \( \tau_2 = 0 \).

The Euler equation of capital implies that the associated investment wedge is zero, or \( \tau^p_{xk} = 0 \). Notice that the wage rate is \( 1 - \alpha \) times of the marginal product of labor due to the monopoly in the education sector. This implies a labor wedge, \( \tau_l = \alpha \). Although there is a labor wedge, which plays the role as the human capital investment wedge, the fact that the sum of labor income and
profits equals the marginal benefit of technology $A$ makes sure that the human capital investment wedge is also zero, or $\tau_{sh}^p = 0$. QED.

The mapping between these two economies is shown in table 2, where the columns labeled “Prototype” contain notation used in the prototype economy, and the columns labeled “Romer” used in the detailed economy. Substituting the notation used in the detailed model into the equilibrium conditions of the prototype economy will replicate the equilibrium conditions of the detailed model.

Many policies that distort incentives and reduce competition in product and labor markets, including the monopolistic competition in the adapted Romer (1990) model, map into a labor wedge, which is between the marginal rate of substitution between consumption and leisure and the marginal product of labor. Other policies, like government nominal wage and price fixing, increasing worker bargaining power, work in a similar way.

4. Method and Data

The accounting method consists of computing wedge values and evaluating the fit of the model. 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. Assume that endogenous variables in the prototype economy include aggregate variables that characterize a country’s economic performance, and that the wedges and population growth in the prototype economy uniquely uncover the event $s_j$. Substituting country-specific values of endogenous variables into the steady-state equilibrium conditions of the prototype economy gives the wedge values across countries.

To evaluate the importance of wedges in explaining growth, I change each wedge in the favorable direction by 50% of its observed values while keeping the rest wedges fixed; and compare the values before and after each change.

Two points are worth noticing when preparing the dataset: How to divide GDP into final goods and the broadly defined human capital investment and how to measure the relative prices of human capital in terms of final goods. I first consider a comprehensive definition of human capital: all expenditures on
financial intermediation and community, social, and personal service activities (ISIC:J-P) are regarded as investment in human capital. Later a narrow definition only counts education as the proxy for human capital, but neglect other components including experience, health, R&D, and any other factors that may change the production efficiency. The expenditures on these components, if accounted, are in the final goods output. As for the relative prices of the broadly defined human capital, they are not estimated or observed directly, but derived by a few parametric assumptions.

4.1. Estimating human capital and its relative price in terms of final goods

Consider the following expression for human capital stock at time $t$,

$$h(t) = h(s) \cdot e^{\gamma(t-s)} \cdot e^{\phi(sch(t))}.$$ 

It depends on the initial stock $h(s)$, the education stock $e^{\phi(sch(t))}$ and a trend term. If the initial stock of education, steady state growth rate, schooling years and the function form of $\phi(\cdot)$ are known, then an estimate for the broadly defined human capital stock is available.$^{11}$ Notice that the wage rate, by definition, is equal to $(1 - \alpha)\text{GDP}/l$. Thus,

$$\ln w(t) = \ln(1 - \alpha)\text{TFP} + \alpha \ln \frac{k}{l} + \ln h(s) + \gamma(t - s) + \phi(sch(t))$$

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 $\phi(\cdot)$,

$$\ln w = \text{constant} + \phi \cdot \text{sch}$$

$^{11}$One concern is the impact of quality of years of schooling on growth. Hanushek and Kimko (2000) support the quality of schooling is a major factor for an explanation of long-run growth by using growth regressions. From different perspectives, McGrattan and Schmitz (1999) and Durlauf et al. (2005) both pointed out the potential flaws of growth regressions in establishing causalities. After adjusting the quality of schooling, Caselli (2005) finds that the quality of schooling is not important for explaining cross-country income gaps. Pritchett (2006) summarizes some empirical results of measuring human capital stocks.
Hall and Jones (1999) assume that \( \phi(\cdot) \) is a continuous, piecewise linear function constructed to match the rates of return on education reported in Psacharopoulos (1993). For schooling years between 0 and 4, the return to schooling \( \phi'(\cdot) \) is assumed to be 13.4 percent which is an average for sub-Saharan Africa. For schooling years between 4 and 8, the return to schooling is assumed to be 10.1 percent, which is the world average. With 8 or more years, the return is assumed to be 6.8 percent, which is the average for the OECD countries.\footnote{McGrattan and Schmitz (1999) summarize popular approaches of measuring human capital stock, including the alternative Mincerian formula used by Klenow and Rodriguez-Clare (1997b),}

\[
h_{HJj} = e^{\phi(sch_j)}.
\]

Then they construct human capital stocks using \( h_{HJj} = e^{\phi(sch_j)} \). I use the Hall and Jones (1999) specification to construct \( e^{\phi(sch_j)} \), with the growth rate in steady state and a guess of education stock in a base year, to construct the human capital stock.

Total GDP includes two parts: final goods output and the human capital investment in terms of final goods. The latter is the value added in all the sectors identified in ISIC J-P or only the education sector (ISIC:M) alternatively,\footnote{Kendrick (1976) discussed a broad class of capital stocks, including tangible and intangible, human and non-human capital. He categorized physical capital as “tangible non-human capital”, child rearing costs as investments in “tangible human capital”, research and development (R&D) expenditures as investments in “intangible non-human capital”, and outlays of education, training, health, safety, and mobility as investments in “intangible human capital”. Ideally human capital should contain all tangible and intangible human capital.}

and corresponds to \( qx_h \) in the prototype economy. The rest is the final goods output \( y \) in the prototype. The partition between final goods and human capital investment may be arbitrary. However, they are consistent with the concepts used in the prototype economy.\footnote{One concern about the definition of human capital investment is that GDP do not include the value of students’ time, an important component of education investment. This slippage between model and data affects estimates for \( x_h \) and \( h \). However, it will not change \( x_h/h \) in steady-state. Kendrick (1976) found about half of schooling investment consists of education expenditures which are included in GDP.}
When the human capital investment $q x_h$ is known, with the law of motion of human capital in steady state, I construct the human capital stock in terms of final goods as,

$$(qh)_j = \frac{(qx_h)_j}{\gamma_j + n_j + \delta_h}.$$  

Dividing this value by $e^{\gamma_j(t-s)}e^{\phi(sch_j(t))}$, we have

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

Notice that the human capital is broadly defined and equal to the labor augmented technology in the literature. Parente and Prescott (2006) argue that “most of the stock of productive knowledge is public information, and even proprietary information can be accessed by a country through licensing agreements or foreign direct investment”.

This statement is, in particular, true by the end of the 20th century. Technological innovations have improved the speed of transportation and communications and lowered their costs. These included jet airplanes and their universal use in transporting people and goods, the containers used in international shipping, the improved road infrastructure that enabled a large share of trade to be carried by 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 defined 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 defined 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

$$h_j(t) = (qh)_{US}(t) \cdot e^{(\gamma_j - \gamma_{US})(t-2000)} e^{\phi(sch_j(t)) - \phi(sch_{US}(t))}$$

### 4.2. Data and calibration

Data sources used in this analysis include the Groningen Growth and Development Center (GGDC), the United Nations Statistics Division (UNSD), the International Labor Organization (ILO), the World Bank, the Penn World Table 6.3 and the Barro and Lee (2001) educational attainment dataset.\(^\text{15}\)

Some variables are directly observable from data sources, such as the average growth rate for per capita GDP and population, employment-population ratio, the share of workers in the education sector, physical capital investment-GDP ratio, consumption-GDP ratio, and schooling years. Other variables are derived from these observable variables under certain assumptions. Appendix A presents the data sources and data construction in detail.

Since no much information of capital used in education across countries is available, I assume that the share of education expenditure in GDP is equal to the share of capital used in the education. Notice that this assumption is equivalent to that the capital input wedge $\tau_1$ is always equal to zero in the prototype economy (see equation (7)).

There are five parameters in the prototype economy: the capital share, $\alpha$, the depreciation rates, $\delta_k$ and $\delta_h$, the discount factor, $\beta$, and the consumption share, $\theta$. Each is assumed to be constant across countries. Online appendix presents the data used in calibration. Table 3 reports their calibrated values. One concern is the heterogeneity of parameters across countries. Gollin (2002) convincingly show that the capital share $\alpha$ is a number between 0.20 to 0.35 for most countries. Appendix B checks the robustness of the findings by changing parameter values

---

\(^{15}\)The preliminary tests consider Hong Kong, Singapore, South Korea, Taiwan, Argentina, Brazil, Chile, Peru, and the United States. Later the sample extends to Argentina, Australia, Austria, Belgium, Bangladesh, Bulgaria, Bahrain, Brazil, Canada, Switzerland, Chile, China, Costa Rica, Germany, Denmark, Dominican Republic, Ecuador, Egypt, Spain, Ethiopia, Finland, France, United Kingdom, Greece, Guatemala, Hungary, Ireland, Iran, Iraq, Israel, Italy, Japan, Republic of Korea, Mexico, Malaysia, the Netherlands, Norway, New Zealand, Peru, the Philippines, Poland, Portugal, Romania, Sweden, Thailand, Turkey, Uganda, Uruguay, United States, and Vietnam.
HONGCHUN ZHAO

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>capital share</td>
<td>$\alpha$ 0.3333</td>
</tr>
<tr>
<td>depreciation rate of physical capital</td>
<td>$\delta_k$ 0.0665</td>
</tr>
<tr>
<td>depreciation rate of human capital</td>
<td>$\delta_h$ 0.0518</td>
</tr>
<tr>
<td>consumption share</td>
<td>$\theta$ 0.3908</td>
</tr>
<tr>
<td>discount factor</td>
<td>$\beta$ 0.9457</td>
</tr>
</tbody>
</table>

Table 3: Calibrated Values of Parameters

in reasonable ranges for the full sample.

Following the literature, I assume that the capital share is 0.3333. For other parameters, I use the national accounts data for the US to calibrate them, by assuming that wedges are zero in the US economy during the 1960-2000 period.

The depreciation rate $\delta_k$ is estimated from the perpetual inventory method (see, for example, Kehoe and Prescott (2007), for a detailed description),

$$K(t + 1) = I(t) + (1 - \delta)K(t),$$

together with a few restrictions on the initial capital stock and the depreciation rate. The value of $\delta_k$ 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 $\delta_k$.

The depreciation rate of human capital $\delta_h$ comes from the same procedure, except its value is chosen to be consistent with $\frac{\delta_k}{\delta_h} = \gamma + n + \delta_h$. By comparison, Kendrick (1976)’s estimates imply the depreciation rates of capital, $\delta_k = 0.0616$, of education, $\delta_e = 0.0343$, of health care, $\delta_{hc} = 0.0718$ and of R&D, $\delta_{RD} = 0.0876$.

For the remaining two parameters, standard calibration formulae are available. The discount factor $\beta$ stems from the following equation,

$$1 + \text{average growth rate} = \beta \left[ \frac{\alpha \times \text{output-capital ratio}}{\text{share of education in GDP}} + 1 - \delta_k \right].$$
The consumption share $\theta$ is from,

$$\theta = \frac{\text{share of consumption in GDP} \times \text{empl. rate}}{\text{share of consumption in GDP} \times \text{empl. rate} + (1 - \alpha) \times (1 - \text{empl. rate})}.$$  

### 4.3. Descriptive Statistics

Table 4 presents the average growth rates, physical capital-GDP ratios, human capital-physical capital ratios, employment rates and various wedge values for four East Asian and four Latin American countries. Apparently, four East Asian countries experienced rapid growth after WWII, while four Latin American countries are stagnant during the same period. Look at capital-GDP ratios and human capital-physical capital ratios, Singapore accumulated much capital, which is consistent with Young (1995) and Hsieh (2002); and physical capital accumulation in Latin American countries are moderate relative to East Asian countries. Although the employment rates are roughly the same across East Asian countries or across Latin American countries, they are typically higher in East Asia than in Latin America.

Not surprisingly, the labor wedges in Latin American countries are high, given their employment rates are low. In terms of the physical capital investment wedge, Hong Kong, Singapore, and South Korea run negative values, while Taiwan has a quite big positive value. However, in Latin America, values of the physical capital investment wedges are either negligible, or large and positive. When it comes to the human capital investment wedge, Hong Kong and Singapore have negligible values, while South Korea, Taiwan and Latin American countries have large negative values. In addition, Latin American countries have worse final goods efficiency wedges relative to East Asian countries. Government consumption wedges are roughly moderate in East Asia, but in general higher in Latin America.

### 5. Findings

A large number of papers study the cross-country economic performance using either growth accounting or level accounting that connects economic perfor-
### Table 4: Comparison between East Asian and Latin American Countries

<table>
<thead>
<tr>
<th></th>
<th>Hong Kong</th>
<th>Singapore</th>
<th>South Korea</th>
<th>Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>4.76%</td>
<td>4.56%</td>
<td>5.67%</td>
<td>5.59%</td>
</tr>
<tr>
<td>Capital/GDP</td>
<td>2.17</td>
<td>3.29</td>
<td>2.28</td>
<td>1.30</td>
</tr>
<tr>
<td>Human Capital/Capital</td>
<td>2.01</td>
<td>1.36</td>
<td>3.63</td>
<td>5.59</td>
</tr>
<tr>
<td>Employment Rate</td>
<td>0.42</td>
<td>0.44</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>Labor Wedge</td>
<td>0.65</td>
<td>0.72</td>
<td>0.45</td>
<td>0.51</td>
</tr>
<tr>
<td>Phys. cap. inv. wedge</td>
<td>-0.12</td>
<td>-0.41</td>
<td>-0.21</td>
<td>0.40</td>
</tr>
<tr>
<td>Human cap. inv. wedge</td>
<td>-0.06</td>
<td>0.03</td>
<td>-0.41</td>
<td>-0.41</td>
</tr>
<tr>
<td>Efficiency wedge</td>
<td>0.44</td>
<td>0.41</td>
<td>0.35</td>
<td>0.42</td>
</tr>
<tr>
<td>Government wedge</td>
<td>0.04</td>
<td>0.02</td>
<td>0.05</td>
<td>0.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Argentina</th>
<th>Brazil</th>
<th>Chile</th>
<th>Peru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>1.51%</td>
<td>2.40%</td>
<td>2.36%</td>
<td>1.60%</td>
</tr>
<tr>
<td>Capital/GDP</td>
<td>1.90</td>
<td>1.45</td>
<td>2.21</td>
<td>2.36</td>
</tr>
<tr>
<td>Human Capital/Capital</td>
<td>5.70</td>
<td>7.94</td>
<td>4.86</td>
<td>7.35</td>
</tr>
<tr>
<td>Employment Rate</td>
<td>0.37</td>
<td>0.42</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>Labor Wedge</td>
<td>0.70</td>
<td>0.54</td>
<td>0.76</td>
<td>0.61</td>
</tr>
<tr>
<td>Phys. cap. inv. wedge</td>
<td>0.26</td>
<td>0.54</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Human cap. inv. wedge</td>
<td>-0.37</td>
<td>-0.35</td>
<td>-0.37</td>
<td>-0.44</td>
</tr>
<tr>
<td>Efficiency wedge</td>
<td>0.35</td>
<td>0.29</td>
<td>0.32</td>
<td>0.24</td>
</tr>
<tr>
<td>Government wedge</td>
<td>0.12</td>
<td>0.14</td>
<td>0.09</td>
<td>0.05</td>
</tr>
</tbody>
</table>
mance to inputs and the efficiency with which inputs are used.\textsuperscript{16} Despite the large volume of work, results from many studies on a given issue frequently reach opposite conclusions. Moreover, a serious criticism by Acemoglu (2007) says that “at some level to say that a country is poor because it lacks physical capital, human capital and technology is like saying that a person is poor because he does not have money”. To satisfactorily understand economic growth requires, not only the contribution of inputs and efficiency to the cross-country income variance, but also an analysis of the reasons making some countries more abundant in physical capital, human capital, and technology than others.

In this section, I first explore the relationship between cross-country policy differences and observed wedges, then evaluate the importance of each wedge in explaining growth in the above eight countries, and extend the discussion to fifty countries. As a robustness check, I replicate two previous studies using the data I collect, and compare the concept and the consequent numerical results derived from my method with theirs.

5.1. Wedges and their relationship with actual policies

We now discuss how the estimated wedges from the prototype economy relate to actual policies in the eight countries.

South Korea and Taiwan. The remarkable growth of South Korea and Taiwan is often portrayed as an example of what export-led growth can achieve in countries that chose to open themselves to international trade. Yet, Rodrik (1994) documents that both governments also gave investment a big push. In 1960 the Nineteen-Point Reform Program was instituted in Taiwan. This plan contains a wide range of tax subsidies for investment and signaled a major shift in government attitudes toward investment. However, by contrast, in Korea the major form of investment subsidy was the extension of credit to large business groups at negative real interest rates. In addition to providing subsidies, the Korean and Taiwanese governments also played a much more direct role by organizing private entrepreneurs into investments that they may not have otherwise made. By the early 1960s, economic growth had become a top priority for the authority

\textsuperscript{16}Bosworth et al. (2003) is a comprehensive study on growth empirics, including growth accounting. Caselli (2005) is a state-of-the-art study using level accounting.
of the two countries. And these observations coincide with a big positive government wedge in Taiwan, and a negative physical capital investment wedge in South Korea.

**Singapore.** The Singapore government also strongly committed to economic growth, greatly subsidized private investment, in particular, the foreign direct investment (FDI). Yet Singapore also introduced strict labor measures. In 1972 the National Wages Council was established, and it determined annual wage adjustments in both public and private sectors until 1985. Thereafter, quantitative restrictions were replaced by a qualitative wage restraint, which is still effective. These policies are consistent with the large positive labor wedge and negative physical capital investment wedge, but negligible human capital investment wedge.

**Hong Kong.** Hong Kong is the laissez-faire economy where government interventions are small, leading financial intermediaries, and openness to FDI. These all witness light labor and investment wedges.

**Latin American countries.** Cole et al. (2005) document a number of competitive barriers implemented by Latin American countries, including tariffs, quotas, multiple exchange rate systems, and regulatory barriers to foreign and domestic producers, inefficient financial systems, and large, subsidized state-owned enterprises. All these distortions witness large positive labor wedges, physical capital investment wedges, and negative human capital investment wedges.

### 5.2. Contributions of individual wedges

Table 5 shows the difference between the growth rates when the absolute value of an individual wedge decreases one half and the observed ones. These results confirm that Singapore is mainly driven by the accumulation of physical capital, since the growth rate would drop very much once incentives to accumulating capital disappear. Rapid growth in Hong Kong is mainly caused by the absence of government intervention, while human capital accumulation drives the growth in South Korea and Taiwan. Compared with East Asian countries, the patterns across Latin American countries are quite similar. The various policies that impede the normal market forces are the culprit.
One interesting observation is that the effects of the labor wedge depend on the magnitude of the human capital investment wedge. When the human capital investment wedges are large and negative, labor wedges impact growth significantly; otherwise, the effects are negligible. For four slow growers in Latin America, the particular combination of big positive labor wedges and big negative human capital investment wedges are detrimental to growth. Another interesting outcome is that two investment wedges seem to be substitutive, and either one can sustain growth. Four East Asian countries verify different successful stories.

Next I extend this accounting method to fifty countries with a different definition of the broadly defined human capital. Now only investments in education are counted as human capital. Table 6 summarizes the percentage change of growth, TFP, capital intensity, and employment from their actual values for the total sample, when a wedge changes 10% in the favorable direction. Clearly the effects of wedges on growth scatter more evenly than those on TFP across
The human capital investment wedge is the primary factor in explaining growth on average: its change can move wedges are detrimental to growth. The labor and labor input wedges are also important, and move growth 22% and 24% respectively. As for accounting for TFP, the final goods efficiency wedge is the dominant factor, and its change accounts for 13% of TFP while other wedges explain almost nothing.

The equivalence results reported in section 3. show that specific theories can microfound the human capital investment wedge and the labor wedge. However, more efforts are on the human capital investment wedge, as many endogenous growth theories that focus on the role of education or R&D are actually exploiting this wedge. The role of the labor and labor input wedge, and their associated policy implications, on growth are not fully explored and worthy of more attention.\(^\text{17}\)

The pattern of explaining capital intensity is similar to that of explaining growth, but with smaller magnitude. This confirms the previous observation that growth is highly correlated with investment in physical capital. As for the employment rate, not surprisingly, the labor and labor input wedges are two important factors. But in steady state, how efficiently a country produces goods would not change the incentives to work much, as illustrated by the small influences of efficiency shifters \(A\) and \(B\).

---

\(^{17}\)By comparing France and the United States, Prescott (2002) gives an example showing that the labor wedge is responsible for the gap in terms of relative income level between these two countries.
5.3. Do previous studies contradict this analysis?

Previous quantitative studies on cross-country income variance find that efficiency 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 use contradict previous studies? By using Hall and Jones (1999) and Bosworth et al. (2003) as the baseline research for level accounting and growth accounting, I redo these exercises. In the growth accounting case, I use my data set; in the level accounting case, I further impose a constant growth rate by steady state equilibrium. Decomposition results suggest that the alternative method is quite close to previous studies.

Before beginning with the detailed comparison, I would point out the different definitions of human capital and the residual in the growth accounts used by Klenow and Rodriguez-Clare (1997b), Hall and Jones (1999), and me. A general form by Parente and Prescott (2006) can cover these differences,

\[ y(t) = k(t)^\alpha [h(0)e^{\gamma t} \cdot edu(t) \cdot A(t)l(t)]^{1-\alpha}. \]

Notice that in Klenow and Rodriguez-Clare (1997b), the production function takes the form,

\[ y = k^{\alpha_1} h^{\alpha_2}_{KRC} (A_{KRC})^{1-\alpha_1-\alpha_2}, \]

and in Hall and Jones (1999) it takes the form,

\[ y = k^\alpha (A_{HJ} h_{HJ}l)^{1-\alpha}. \]

Notice that \( A \) is always a residual in any case. My specification follows Hall and Jones (1999), but has a slightly different measure for human capital. Table 7 illustrates definitions of human capital \( h \) and the residual \( A \) in these three cases in terms of the notations in Parente and Prescott (2006).

Hall and Jones (1999) decompose output per capita of 127 countries in 1988 into three multiplicative terms: capital intensity \( K/Y \), education stock \( e^{\phi(sch)} \), and productivity, a residual term. All terms are expressed as ratios to US values. Forty-five countries in their sample overlap the sample I collect. As Hall and Jones (1999) do, table 8 reports each term’s comparable averages, standard
deviations, and correlations with other terms for the overlapped forty-five countries, from their work and this analysis. Bear in mind that the human capital in my level accounting includes a growth trend imposed by the steady state equilibrium, plus the education stock which is the same as the “human capital” in the baseline study. As a result, the residual in their exercise is different from mine. I also exclude the effect of relative labor participation from the residual term, since this information is available in my dataset.

The comparable characteristics for relative income and capital intensity are quite close to each other, as shown in the second and third column. The capital intensity in my accounting is more correlated with both per capita output and the residual than the baseline study. This is because, in the baseline study, capital 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 confirms 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.

<table>
<thead>
<tr>
<th></th>
<th>Human Capital</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Work</td>
<td>$edu \cdot h(0)e^{\gamma t}$</td>
<td>$A$</td>
</tr>
<tr>
<td>Hall and Jones (1999)</td>
<td>$edu$</td>
<td>$h(0)e^{\gamma t}A$</td>
</tr>
<tr>
<td>Klenow and Rodriguez-Clare (1997b)</td>
<td>$edu\frac{1-\alpha}{\alpha} \cdot h(0) e^{\gamma t} \cdot A$</td>
<td>$h(0)e^{\gamma t}A$</td>
</tr>
</tbody>
</table>

Table 7: Different Definitions in Growth Accounts
<table>
<thead>
<tr>
<th></th>
<th>Income</th>
<th>Capital</th>
<th>Education</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall and Jones (1999)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (45)</td>
<td>0.481</td>
<td>0.957</td>
<td>0.695</td>
<td>0.678</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.283</td>
<td>0.194</td>
<td>0.165</td>
<td>0.278</td>
</tr>
<tr>
<td>Correlation w/ Y/L (logs)</td>
<td>1.000</td>
<td>0.658</td>
<td>0.700</td>
<td>0.812</td>
</tr>
<tr>
<td>Correlation w/ A (logs)</td>
<td>0.812</td>
<td>0.156</td>
<td>0.225</td>
<td>1.000</td>
</tr>
<tr>
<td>This Work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (45)</td>
<td>0.437</td>
<td>1.001</td>
<td>0.665</td>
<td>0.895</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.284</td>
<td>0.205</td>
<td>0.179</td>
<td>0.179</td>
</tr>
<tr>
<td>Correlation w/ Y/L (logs)</td>
<td>1.000</td>
<td>0.788</td>
<td>0.771</td>
<td>0.394</td>
</tr>
<tr>
<td>Correlation w/ A (logs)</td>
<td>0.785</td>
<td>0.433</td>
<td>0.388</td>
<td>-0.162</td>
</tr>
</tbody>
</table>

Table 8: Level Accounting Comparison

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

Table 9: Growth Accounting Comparison
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

$$\Delta \ln \frac{Y}{L} = \Delta \ln A + \frac{\alpha_1}{1 - \alpha_1 - \alpha_2} \Delta \ln \frac{K}{Y} + \frac{\alpha_2}{1 - \alpha_1 - \alpha_2} \Delta \ln \frac{H}{Y}$$

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

$$\frac{\text{Cov}(\Delta \ln \frac{Y}{L}, \Delta \ln A)}{\text{Var}(\Delta \ln \frac{Y}{L})} + \frac{\text{Cov}(\Delta \ln \frac{Y}{L}, \Delta \ln X)}{\text{Var}(\Delta \ln \frac{Y}{L})} = 1.$$

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

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

with averages to measure the contribution of each term,$^{18}$

$$\text{Ave}(\frac{\Delta \ln A}{\Delta \ln \frac{Y}{L}}) + \alpha \text{Ave}(\frac{\Delta \ln (K/L)}{\Delta \ln \frac{Y}{L}}) + (1 - \alpha) \text{Ave}(\frac{\Delta \ln h_{HJ}}{\Delta \ln \frac{Y}{L}}) = 1.$$

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 $\alpha$ of growth to capital accumulation. Growth accounting would not be interesting. So I use Bosworth et al. (2003) as the baseline to account for growth without imposing further restrictions.$^{19}$

$^{18}$Covariances are actually weighted averages, with higher weights for larger deviations from the average.

$^{19}$Actually, Klenow and Rodriguez-Clare (1997b) find that at least 85% of economic growth is due to technology growth under different specifications, which verifies that most countries in their sample are close to their steady states.
Table 9 presents the results from the baseline study in the upper panel and from my calculations in the lower panel. Decompositions are made for four regions: industrial countries, China, East Asia less China, and Latin America. 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) confirms 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 confirm the baseline. It verifies that the data I have collected is as good (or bad) as the data used by previous studies.

6. Conclusion

This paper presents a method to account for long-run economic growth across countries. It also links many endogenous growth theories to a two-sector neoclassical growth model, and sheds light on underlying mechanisms of economic growth. The main findings suggest that and 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 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 neo-classical models, is a good way to organize the increasingly available data on various dimensions and aspects of economic growth.
Table 10: Data Sources for Endogenous Variables

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

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
HONGCHUN ZHAO

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 Official 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) $x_k = n + \gamma + \delta_k$, together with estimates of growth rates and population growth rates, and calibrated values of depreciation rates. Similarly, $x_h = n + \gamma + \delta_h$ can be constructed.

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

$$\frac{y}{k} = (1 - \frac{\text{Edu VA}}{\text{VA}}) \frac{x_k}{k} / \frac{x_k}{GDP},$$

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 final goods consumption-capital ratios can be calculated from the following formula,

$$\frac{c}{k} = \frac{y}{k} \left[ \frac{\text{CC}}{GDP} - \frac{\text{Edu VA}}{\text{VA}} \right] / [1 - \frac{\text{Edu VA}}{\text{VA}}],$$

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 final 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 fo-
mula,

\[ \frac{k}{h} = \frac{x_k}{(1-v)GDP} \frac{x_h}{h} \frac{k}{x_k} \cdot q \]

\[k \]

\[h \]

\[x_k \]

\[x_h \]

\[x_k \]

\[\cdot \]

\[q \]

\[\cdot \]

\[q \]

\[B \quad \text{Appendix: robustness checks} \]

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

\[B1. \quad \text{Capital share} \]

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 firms, 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 \( \alpha \) moves from 0.20 to 0.35. Clearly, the contribution of the human capital investment wedge \( \tau_{xh} \) is quite stable with respect to alternative values of \( \alpha \) in this range. The government spending wedge \( g/k \) is not important, and also stable. The two labor related wedges \( \tau_l \) and \( \tau_2 \) are always more important than the capital investment wedge \( \tau_{xk} \) and two efficiency wedges \( A \) and \( B \).

\[B2. \quad \text{Preferences parameters} \]

Figure 2 shows the contributions of various wedges when changing \( \beta \) between 0.90 and 1. The order of various wedges does not change much in this range of \( \beta \). Thus the qualitative results in the text do not change at all.

When it comes to the values of the consumption share \( \theta \), different studies report different values. McGrattan and Schmitz (1999) reports that the upper
Figure 1: Robustness check with $\alpha$ on growth

Figure 2: Robustness check with $\beta$ 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 $\theta$ only affects the labor wedge $\tau_l$, except for the labor wedge, the contributions of all other wedges do not change. The labor wedge, however, is quite sensitive to changes in $\theta$. When $\theta$ 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 $\theta$ is equal or higher than 0.47. The high sensitivity of $\tau_l$ around the benchmark value of $\theta$ implies that our results about the labor wedge may change non-trivially with more precise measures of the consumption share.

Figure 3: Robustness check with $\theta$ on growth
References


