Intangible Capital, Barriers to Technology Adoption and Cross-Country Income Differences

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Abstract

I add intangible capital to a variant of the neoclassical growth model and study the implications of this extension for cross-country income differences. I calibrate the parameters associated with intangible capital by using new estimates of investment in intangibles by Corrado et al. [2006]. I find that the addition of intangible capital significantly improves the model's ability to account for cross-country income differences. Specifically, when intangible capital is added to the model, the required TFP ratio to explain observed income differences falls from 4.05 to 2.97. I also study variants of the model with endogenous and exogenous barriers to accumulation of technology capital, which consists of intangible capital and a fraction of physical capital that embodies technology. The addition of endogenous barriers, for reasonable parameter values, has a very small positive effect on the ability of the model to account for income differences. The addition of exogenous barriers suggests that huge cross-country differences in such barriers are needed to generate the observed income differences.

Key words: Cross-country Income Differences; Intangible Capital; Technology Adoption
JEL Classification Codes: O33; O41; O47

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1 Introduction

Intangible capital is an important factor of production. It consists of productive and reproducible assets that are not 'tangible' and hence difficult to measure.[1] For this reason, most of the studies of cross-country income comparisons exclude intangible capital from their analysis. The neglect of intangible capital leads to a narrow definition of capital and has important implications for cross-country income differences. Some studies that incorporate intangible capital, examples include Parente and Prescott [1994] and Prescott [1998], derive interesting implications for cross-country income differences. However, due to unavailability of data, these authors speculate on the size of investment in intangible capital. For example, Parente and Prescott [1994] conclude that "there must be a large unmeasured investment in the business sector ... We find that for our model to be consistent with both the observed income disparity and development miracles, this investment must be about 40 percent of measured output." [p.318] According to Prescott [1998] "it is not reasonable to assume a share (of intangible capital in output) parameter much above 0.30 (which would imply investment in intangible capital of 32 percent of measured output)."[p.539]

In this paper, I use new estimates of investment in intangible capital, constructed by Corrado et al. [2006] (from here on, CHS), and study their implications for cross-country income differences. I find that inclusion of intangible capital significantly improves the ability of the one-sector neoclassical growth model to account for cross-country variation in output.[2] This is despite the fact that the estimates of investment in intangible capital by CHS are much smaller than those suggested by Parente and Prescott [1994] and Prescott [1998]. I also study the implications of the extended model for the effects of barriers to technology adoption on relative output. I find that huge differences in the barriers are needed to explain the observed cross-country variation in output. This result holds regardless of whether the barriers are endogenous or exogenous. This result is in contrast to findings in Parente and Prescott [1994] and Klenow and Rodriguez-Clare [2005] that a small difference in barriers to technology adoption can explain large cross country income differences.

In the traditional neoclassical model, and in its later extensions, there are two types of accumulable factors: physical capital and human capital. More recently, researchers, at both

[1] Some authors classify human capital as intangible capital. However, for reasons to be explained later, in this study I distinguish between intangible and human capital.

[2] The word 'significant' does not imply significance in a statistical sense. Instead, it is based on a subjective judgement that the difference between two quantities is large.

micro and macro levels, have found evidence that firms invest sizable resources for purposes other than the accumulation of physical and human capital.[3] These investments could be considered investments in intangible capital. But we need a more precise definition of intangible investments. In this regard I closely follow CHS. Their definition of investment is based on the idea that "any use of resources that reduces current consumption in order to increase it in the future qualifies as an investment". They distinguish between tangible and intangible investments. In the tangible category they include the usual investments in structures, tools and machinery. For the intangibles, they identify three main categories of investment. The first category is *computerized investment* and consists mainly of computer software. The second category is *innovative property*, which is divided into two subcategories. The first subcategory is *scientific R&D* and consists of National Science Foundation's industrial R&D series. The second subcategory is *non-scientific R&D*, which includes revenues of non-scientific commercial R&D industry, spending for new product development by financial services and insurance firms and cost of development of new product by the entertainment industry. The third category is *economic competencies*. This is also divided into two subcategories. The first subcategory is *brand equity* and consists of a fraction of the advertisement expenditure. The second subcategory is *firm specific resources* and includes a fraction of the cost of employer-provided worker training and management time devoted to enhancing the productivity of the firm.[4]

There can hardly be any disagreement on whether there is any investment in intangible capital. What is likely to be controversial is the size of such investment. One contribution of the present study is that it uses recent estimates of the size of this investment and examines their implications for cross-country income differences. In general, a higher investment in intangible capital would imply a greater share for it in the output. This in turn would imply that more of the cross-country variation in output is due to factor accumulation and less due to differences in total factor productivity (TFP) or the efficiency with which these factors are used.

This last observation relates this paper to what may be called the 'neoclassical revival debate'. In this debate, one group of economists, most prominent among them are Mankiw et al. [1992], argues that an extended version of the neoclassical growth model can explain most of the variation in cross-country output. Another influential group argues that although an

[3]For micro evidence, see Brynjolfsson et al. [2002] and references therein. For macro evidence see CHS and McGrattan and Prescott [2007a].

[4]For further details see CHS.

extended version can explain *more* variation in output than the traditional neoclassical model, it cannot explain *all* the variation and we need to look for other factors if we want to completely understand the causes of cross-country variation. Important papers that favor the latter point of view include Klenow and Rodriguez-Clare [1997], Hall and Jones [1999] and, more recently, Hulten and Isaksson [2007]. In this paper I take an intermediate position. On the one hand, I argue that the neoclassical model can explain a lot more variation in cross-country output than is possible without the intangible capital in the model. On the other hand, I acknowledge that even with intangible capital in the model, there is some variation in output that the model cannot explain and hence attributes to differences in TFP.

This paper is also related to a second strand of literature on barriers to technology adoption. This literature is large and growing. Some notable papers in this literature are: Acemoglu et al. [2006], Aghion et al. [2005], Caselli and Coleman [2001], Comin and Hobijn [2004], Eaton and Kortum [2001], Hall and Jones [1999], Klenow and Rodriguez-Clare [2005], Parente and Prescott [1994] and Parente and Prescott [1999]. The paper also makes contact with a recent literature that finds intangible capital to be important for our understanding of diverse phenomena like investment dynamics [McGrattan and Prescott [2007a]] and effects of openness on development [McGrattan and Prescott [2007b]]. The common theme is that intangible capital is important and has become more so over time.

The rest of the paper is organized as follows. In Section 2, I construct a variant of the neoclassical growth model with physical and human capital and calibrate its parameters such that the steady-state of the model matches some important features of the long term US data. In Section 3, I add intangible capital to the model and use the estimates of intangible investment in Corrado et al. [2006] to pin down the parameters related to intangible capital. The presence of human capital imposes some extra discipline on these parameters. In Section 4, I add barriers to accumulation of technology capital, which consists of intangible capital and a fraction of physical capital that embodies technology. I consider two types of barriers: endogenous and exogenous. My measure of endogenous barriers is the lack of human capital. For the exogenous barriers, I use the reciprocal of a composite index of the quality of institutions. In Section 5, I examine the sensitivity of my results to changes in various parameters and targets and Section 6 concludes.

2 The Baseline Model

Consider a one sector neoclassical growth model with two types of capital: physical (K) and human (H). Time is discrete. I focus on a social planner's problem. The aggregate production function is given by

$$Y_t = A_t K_t^{\theta_k} [(1 - u_{ht}) H_t]^{\theta_h} L_t^{1-\theta_k-\theta_h}, \tag{1}$$

where Y_t is output, A_t is total factor productivity (TFP), $1 - u_{ht}$ is the fraction of human capital used in production (the remaining fraction u_{ht} is used in accumulation of human capital) and L_t is raw labor. I assume that TFP grows exogenously at a rate γ and all per capita variables grow at a rate g which is defined as:

$$g = (1 + \gamma)^{\frac{1}{1-\theta_k-\theta_h}} - 1. \tag{2}$$

From this point on I shall focus on the quantities that are stationary in the steady state. Let $y_t \equiv Y_t/[(1 + g)(1 + n)]^t$, where n is the population growth rate. Let k_t and h_t be defined in the same manner. Let $a_t \equiv A_t/[1 + \gamma]^t$. With these new variables, the production function becomes

$$y_t = a_t k_t^{\theta_k} [(1 - u_{ht}) h_t]^{\theta_h}. \tag{3}$$

I next specify the laws of motion for the two state variables: k and h. The law of motion for the physical capital is standard and given by

$$(1 + g)(1 + n)k_{t+1} = (1 - \delta_k)k_t + x_{kt}, \tag{4}$$

where δ_k is the depreciation rate and x_k is investment in physical capital.

There are two popular approaches to model the accumulation of human capital. According to the first approach human capital accumulation requires financial investment (see, for example, Mankiw et al. [1992] [equation (9a), p.416] and Chari et al. [1996] [equation (3.3) p.11]). According to the second approach, human capital accumulation is time intensive and hence a fraction of human capital has to be taken out of production and devoted to accumulation of human capital. Examples of this approach include Lucas [1988] [equation (13), p.19] and

Prescott [1998] [p.541]. I combine the two approaches and assume that the accumulation of human capital requires both the financial investment as well as time.[5] Specifically, the law of motion for human capital is

$$(1+g)(1+n)h_{t+1} = (1-\delta_h)h_t + (u_{ht}h_t)^{\psi} x_{ht}^{\phi}, \tag{5}$$

where u_t is the fraction of human capital devoted to the production of human capital and x_{ht} is the financial investment in accumulation of human capital.

Final output can be used for either consumption or investment in physical or human capital. Hence the aggregate resource constraint of this economy is

$$c_t = y_t - x_{kt} - x_{ht}. \tag{6}$$

The social planner chooses the sequence $\{c_t, k_{t+1}, h_{t+1}, u_{ht}\}_{t=0}^{\infty}$, given k_0 and h_0, to maximize the present discounted value of the utility $u(c_t)$. More specifically the planner's problem is

$$\max_{\{(c_t, k_{t+1}, h_{t+1}, u_t)\}_{t=0}^{\infty}} \beta^t u(c_t), \tag{7}$$

subject to (3), (4), (5) and (6). I assume CRRA preferences and define the utility function as

$$u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}, \tag{8}$$

where σ is the inter-temporal elasticity of substitution.

The steady state equilibrium is a set of allocations $\{c, k, h, u\}$ such that c is at its maximum level and the steady state variants of (3), (4), (5) and (6) are satisfied. It is straight forward to show that the steady state level of output is

$$y = b_y a^{\xi}, \tag{9}$$

where b_y is a constant and

$$\xi = \frac{1-\psi}{(1-\phi)(1-\theta_k) - \phi\theta_h}. \tag{10}$$

[5] This human capital technology is due to Erosa et al. [2007].

The constant b_y depends on the parameters of the model. I assume that technology and preferences are the same across countries and the only thing that differs is the TFP. Hence b_y will be the same across countries and the output of country i relative to that of country j can be written as

$$\frac{y_i}{y_j} = \left(\frac{a_i}{a_j}\right)^{\xi}. \tag{11}$$

In cross-country income comparisons, ξ is the key parameter. For example, if $\xi = 2$, TFP in country i should be 6.3 times higher than that in country j to explain a forty-fold difference in their incomes ($40^{1/2} = 6.3$).[6] However, if $\xi = 3$, a TFP ratio of 3.4 : 1 can generate the same income differences [$40^{1/3} = 3.4$]. In the next subsection I calibrate the parameters of the model to get some idea about the value of ξ.

2.1 Calibration

I calibrate the parameters of the model such that the steady state of the model is consistent with certain long run features (targets) of the US economy. I report the targets and calibrated parameters in Table 1 and provide details of the calibration strategy in Appendix A. According to Heston et al. [2006] the average population growth rate in the US for 1950-2004 period has been 1.17% and per capita consumption growth rate has been 2.34% during the same period. Hence I set $n = 0.0117$ and $g = 0.0234$. I choose β such that the implicit real rate of interest is 5%. I choose σ to be equal to 2. This is on the lower side of the range of values used in the literature.[7] I assume 8% annual depreciation for physical capital. There is no satisfactory way to pin down δ_h so I follow Mankiw et al. [1992] and Chari et al. [1996] and assume that δ_h is equal to δ_k.

I choose θ_k such that the steady state ratio of investment in physical capital to output is 0.2. I pick θ_h such that the ratio of the combined share of labor and human capital (i.e. $1-\theta_k$) to the share of labor (i.e. $1 - \theta_h - \theta_k$) is equal to the skill premium observed in the data. The target value of skill premium is a moot point. What makes it even harder is the fact that it has been rising over time [Krusell et al. [2000]]. However, the choice of the value of skill premium

[6] According to Heston et al. [2006] in the year 2000 the ratio of real GDP of richest 10% countries to that of poorest 10% countries was 41.5. In this paper, I round this ratio to nearest tens and study how big are the TFP differences needed to explain a forty fold difference in real output. Throughout the paper, I shall use the words 'TFP ratio' to refer to the TFP ratio between the rich and poor countries required to generate fortyfold difference in outputs.

[7] See Ljungqvist and Sargent [2004], p.426 for a discussion on the value of σ.

is not important for the value of ξ (see below).

The value of ψ depends on the steady state value of u_h i.e. the fraction of time spent accumulating human capital. I assume this fraction to be equal to the ratio of average years of schooling to average life expectancy. The average years of schooling in the US in 2000 were 12.25 [Barro and Lee [2000]] and the life expectancy at birth was 79. This gives $u_h = 0.155$.

To pin down ϕ, my target is to match the expenditure on education as a fraction of GDP (ι_h). According to Haveman and Wolfe [1995] this fraction is 12.7%.[8] Hence I set $\iota_h = 0.127$.

2.2 Cross-Country Income Differences

Given the above parameter values the value of ξ in (11) is 2.636. This implies that in order to explain a fortyfold difference in output between the rich and poor countries, TFP in the former must be 4.05 times greater than that in the latter. In other words, the base line model can magnify a TFP ratio of 4.05 to an output ratio of 40.

3 The Extended Model

I now add intangible capital to the baseline model. The modified production function is

$$y_t = a_t k_t^{\theta_k} z_t^{\theta_z} [(1 - u_{ht}) h_t]^{\theta_h}, \tag{12}$$

where z represents intangible capital. It is important to note that after the addition of intangible capital, y is no longer the measured output as given in the National Income and Product Accounts (NIPA). Instead, it also includes investment in intangible capital. In other words,

$$y = y_m + x_z, \tag{13}$$

where y_m is the measured output (as in NIPA) and x_z is the investment in intangible capital. This distinction between y and y_m will play an important role when we calibrate parameters of the model.

The aggregate resource constraint is

[8] This includes private as well as public expenditure on children aged 0-18. For details see Table 1 in Haveman and Wolfe [1995].

$$c_t = y_t - x_{kt} - x_{ht} - x_{zt}. \tag{14}$$

In (14) $y_t - x_{zt}$ is the measured output. The laws of motion for k and h remain the same as in (4) and (5). We need one more equation for the law of motion of intangible capital z. I specify it as

$$(1+g)(1+n)z_{t+1} = (1-\delta_z)z_t + x_z^\eta. \tag{15}$$

The steady state output is given by

$$y = b_y a^\xi, \tag{16}$$

where b_y is a constant but its value is likely to be different from b_y in (9). Parameter ξ is now defined as

$$\xi = \frac{1-\psi}{(1-\phi)(1-\theta_k-\eta\theta_z)-\phi\theta_h}. \tag{17}$$

The difference between (10) and (17) lies in the fact that in the latter equation there is a new term $\eta\theta_z$ in the denominator. If this term is zero, the cross-country implications of the extended model will be the same as those of the baseline model. However, if investment in intangible capital in positive, and Corrado et al. [2006] tell us that it is, then this product will be positive and the value of parameter ξ in the extended model will be higher than that in the baseline model.

3.1 Calibration

In the extended model, there are three new parameters: δ_z, θ_z and η. I use two targets in Corrado et al. [2006] and the combined share of labor and human capital in output as the third target to pin down these parameters. The calibrated values of these three and other parameters of the extended model are given in Table 1 and the details of the calibration strategy are in Appendix B.

The first parameter, δ_z, is the depreciation rate of intangible capital. Little is known about it and based on whatever limited information is available, CHS make certain assumptions about the depreciation rate of various components of intangible capital. I use their *estimates* of depreciation rates of the various components of intangible capital and compute a weighted average, where the weight of each component is its share in intangible investment. This gives a depreciation rate of 34%.

The other two parameters, θ_z and η, can be jointly identified by choosing a target for investment in intangible capital (see Appendix B). According to CHS, this investment was 15.7% of the measured output during the 2000-2003 period.[9] In order to separately identify these parameters I use the combined share of human capital and labor in measured output as the second target. In the context of a standard neoclassical model, it is common to assume that the share of physical capital in measured output is around one-third and the remaining two-third is shared by labor and human capital.[10]. This is further supported by the finding in Gollin [2002] that the labor share of income is between 65% and 80% in most of the countries. For calibration results in Table 1, I assume a combined share of labor and human capital in output of 65%.[11] It is important to note that this choice does not affect our estimate of ξ in (17) because θ_z and η appear together in that equation. However, this choice is important to make the model consistent with an important and generally agreed upon macroeconomic fact about relative factor shares.

In Table 1 the calibrated values of θ_k and θ_h are lower than the values of these parameters in (1). This is because in the extended model, these parameters represent the factor shares in total output which is $1 + \iota_{ik}$ times the measured output (ι_{ik} is the ratio of investment in intangible capital to measured output).

3.2 Cross-Country Income Differences

Based on the above calibrated parameters, the value of ξ is (17) is 3.386.[12] With this value of ξ we need a TFP ratio of just 2.972 to explain a fortyfold difference in output. Recall that this ratio was 4.053 in the baseline model. This is one of the main results of this paper that the

[9] This estimate, is much lower than 40% or 32% assumed by Parente and Prescott [1994] and Prescott [1998]. However, according to CHS, investment in intangible capital has been increasing over time. Hence this estimate cannot be considered a long term observation about the US economy. In the section on sensitivity analysis, I examine the sensitivity of my conclusions to the choice of this target.

[10] See, for example, Mankiw et al. [1992].

[11] This is the combined share of human capital and labor out of measured output. If we used total output instead of the measured output, the share would be around 56%.

[12] For cross-country income comparisons, we are interested in relative measured output i.e. $\frac{y_{mi}}{y_{mj}}$. However, $\frac{y_{mi}}{y_{mj}} = \frac{y_i}{y_j}$. To see this, note that for country i, $y_{mi} = y_i - x_{zi} = b_y a_i^\xi - b_{xz} a_i^\xi = (b_y - b_{xz}) a_i^\xi = b a_i^\xi$. Likewise for country j, $y_{mj} = b a_i^\xi$. Hence $\frac{y_{mi}}{y_{mj}} = \left(\frac{a_i}{a_j}\right)^\xi = \frac{y_i}{y_j}$.

inclusion of intangible capital in a standard neoclassical growth model significantly increases the model's ability to explain cross-country income variation.

4 The Extended Model with Barriers to Technology Adoption

One way to interpret the intangible capital is that it is 'technology capital' because it includes investments in computerized information, innovative property and economic competencies. If we use this interpretation, we can study the effect of various barriers to technology adoption on output. This would be the same approach as the one taken by Parente and Prescott [1994]. They study the effects of exogenous barriers to accumulation of the technology capital and show that even a relatively small difference is barriers between countries could lead to a sizable difference in per capita outputs. In this section, I explore this idea using the extended model developed in the last section. I study two types of barriers: endogenous and exogenous. The exogenous barriers are the same as the ones studied by Parente and Prescott [1994]. My choice for the endogenous barriers is the lack of human capital. In the next two subsections, I explore the implications of these barriers for model's prediction about cross-country income differences.

4.1 Lack of Human Capital: A Barrier to Technology Adoption

It is well known that the lack of human capital impedes adoption of new technology. Nelson and Phelps [1966] were perhaps the first to explicitly recognize the importance of human capital for technology adoption. They wrote: "... education is especially important to those functions requiring adaptation to change. Here it is necessary to learn to follow and to understand new technological developments. ... To put the hypothesis simply, educated people make good innovators, so that education speeds the process of technological diffusion." [pp.69-70] Since then a large theoretical and empirical literature has emerged that demonstrates the importance of human capital for technology adoption.[13] Human capital could affect the adoption of new technology in a number of ways. First, more educated entrepreneurs are likely to be better informed about the latest technologies available. Being more informed, they are also more likely to appreciate the potential benefits of new technologies. Second, an educated labor force can more easily understand instructions to perform new functions and is likely to be less averse

[13] Notable papers that relate technology adoption to human capital include Nelson and Phelps [1966], Benhabib and Spiegel [1994], Caselli and Coleman [2001], Chander and Thangavelu [2004], Comin and Hobijn [2004], Benhabib and Spiegel [2005] and Beaudry et al. [2006]. Keller [2004], in his survey of the literature on international technology diffusion, lists human capital as one of the most important determinants of technology diffusion.

to change. Third, there is evidence of skill-bias in technological progress [Acemoglu [1998]]. If more advanced technologies require a higher level of skill, countries with a higher level of human capital are more likely to adopt these technologies. For example, Beaudry et al. [2006] find that computer technology was more quickly adopted in the US states that had abundant and cheap skilled labor. Fourth, some of the advanced technologies (especially in the agriculture sector) may not be appropriate for local conditions. A country with more and better scientists can more easily adapt these technologies to the local conditions. Fifth, some of the products that new technologies produce may not be in line with the local taste. Again more skilled scientists and engineers can adapt these technologies to produce goods and services according to the local taste. Sixth, educated consumers are likely to be more responsive to new and innovative products.

To sum up, there are strong reasons to believe that human capital plays an important role in technology adoption. In Figure 1 I plot per capita personal computers (a proxy for technology adoption) against average years of schooling (a proxy for human capital) in a sample of countries. The data on per capita personal computers in Figure 1a are from Comin and Hobijn [2004] and in Figure 1b are from nationmaster.com (an on-line database of world statistics). The data on average years of schooling are from Barro and Lee [2000] and refer to the average years of schooling of the population aged 15 or above. The sample in Figure 1a includes only leading industrial economies while the sample in 1b is more inclusive and includes rich as well as poor countries. Both panels of the figure show a positive association between per capita personal computers and average years of schooling suggesting that the countries with higher levels of human capital adopt new technology quickly.

To incorporate this idea in the model of the preceding section, I modify the model as follows. I assume that in addition to its uses in production and accumulation of human capital, the human capital has a third use: it complements the financial investment in technology capital to produce technology capital. In other words, the same investment in intangible capital would produce more intangible capital if the country had a higher stock of human capital. More specifically I modify the production function as

$$y_t = a_t k_t^{\theta_k} z_t^{\theta_z} [(1 - u_{ht} - u_{zt}) h_t]^{\theta_h}. \tag{18}$$

(18) differs from (12) in that I have added u_z to the production function. This is the fraction

of human capital that is devoted to the adoption of new technology. The law of motion for z is also modified to include human capital.

$$z_{t+1} = (1-\delta_z)z_t + (u_{zt}h_t)^{\nu} x_z^{\eta}. \tag{19}$$

The parameter ξ is now given by

$$\xi = \frac{1-\psi}{(1-\phi)(1-\theta_k-\eta\theta_z)-\phi(\theta_h+\nu\theta_z)}. \tag{20}$$

The only difference between (17) and (20) is the term involving ν. If $\nu = 0$, the value of ξ will be the same as in the extended model of the previous section. In order to find out that how the predictions of the model for cross-country income differences change we need to have some idea about the value of ν.

The parameter ν maps one-to-one into our target for u_z. We do not have any reliable estimates of the time spent in adopting new technology. However, it is most likely to be a small fraction of the total time allocated to production. In Table 2, I report three values for u_z and the corresponding values of ν and ξ. When u_z is 0.01, i.e. 1% of the total human capital in the economy is devoted to the adoption of technology, the value of ν is 0.04 and that of ξ is 3.39, which is almost the same as we found in the extended model of the previous section. With this value of ξ the TFP ratio needed to explain fortyfold differences in output is 2.97. Hence the addition of human capital as a barrier to technology adoption does not improve the ability of the model to account for cross-country income differences. When I increase u_z to 0.05, the value of ν increases to 0.20 and that of ξ increases slightly to 3.42. The TFP ratio falls to 2.94. A further increase in u_z to 0.10 causes TFP ratio to fall to 2.90. I conclude that for reasonable target values of u_z, the addition of human capital as an endogenous barrier to technology adoption does not improve the performance of the model to explain cross-country income variation.

The analysis above shows that adding the lack of human capital as a barriers to technology adoption only slightly increases the model's ability to explain cross-country differences in income. This conclusion could be the result of a narrow definition of technology capital z. In the analysis above, I have restricted the definition of technology capital to include intangible capital only. But there is a recent body of literature that emphasizes the role of investment-specific technological change [see, for example, Greenwood et al. [1997]]. The main idea is that technology is also embodied in new capital goods. To see if the results are driven by a narrow definition of capital, I use a broader definition of technology capital that includes tools and equipment in addition to intangible capital. The other details of the model remain the same. The only difference is that now k represents buildings and structures and z consists of machines, tools and equipment as well as intangible capital.[14] Since the barriers affect the accumulation of technology capital, it is interesting to see how important these barriers are when a broader definition of capital is used.

The results are reported in Table 3. Interestingly, the power of the model to explain cross-country differences is lower when a broader definition of technology capital is used. This is reflected in lower values of ξ in Table 3 than in Table 2. The values of ξ are lower because the corresponding values of ν are lower. The reason for a lower value of ν is that with a broader definition of technology capital, θ_z is higher because the output share of a broadly defined technology capital is greater than the share of a narrowly defined technology capital. Since the calibrated value of ν is inversely related to θ_z (see Appendix C), ν is lower. Intuitively, I choose ν to match the target of u_z i.e. the fraction of human capital devoted to the adoption of technology. For a given value of this target, if θ_z is higher, we need a correspondingly lower value of ν to match the target. More precisely, for a given target of u_z, the product $\nu\theta_z$ remains constant. Because of this joint determination of these two parameters, we get the counter-intuitive result that the value of ξ is lower when a broader definition of technology capital is used. Hence the conclusion above that when the lack of human capital acts as a barrier to technology adoption the ability of the model to explain the cross-country income differences does not improve much remains valid regardless of whether we use a narrow or a broad definition of technology capital.

4.2 Institutional Factors

In this section, I analyze the effect of exogenous barriers on cross-country income differences. I closely follow Parente and Prescott [1994] (from here on, PP). The basic model remains the same as in Section 4.1 except that now I add an exogenous factor s to the accumulation equation for the intangible capital. The law of motion for intangible capital becomes

$$z_{t+1} = (1 - \delta_z)z_t + (u_{zt}h_t)^\nu x_z^\eta s. \tag{21}$$

[14] The effects of this change on the calibration strategy are discussed in Appendix D.

The new variable s could be interpreted as an index of the institutional factors that affect the adoption of technology.[15] Here s is the reciprocal of π, the measure of barriers, in PP. For this subsection, I assume that TFP is also the same across countries and the only thing that differs is the quality of institutions that support the adoption of technology. The income of country i relative to that of country j is then given by

$$\frac{y_i}{y_j} = \left(\frac{s_i}{s_j}\right)^{\theta_z \xi}. \tag{22}$$

Our objective is to find out what is the required ratio between s_i and s_j to generate a relative income of forty. For the analysis below, I set $u_z = 0.05$.[16] I normalize the index of the quality of institutions in country i (the rich country) to one. The required index of the quality of institutions in country j (the poor country) is given by: $s_j = 40^{-1/\theta_z \xi}$. The calibrated values for θ_z and ξ are 0.13 and 3.42. This gives $s_j = 2.5 \times 10^{-4}$. This is in stark contrast with PP who required s_j to be 0.13. In simple words, in PP's model, one needs a 7.7-fold difference in s between rich and poor countries to generate a fortyfold difference in income ($1/0.13 = 7.7$). In my model one needs a 4000-fold difference in s to generate the same difference in income ($1/0.00025 = 4000$). The question is what drives such a huge difference? The answer is: the value of θ_z. PP calibrate θ_z to be 0.55. In my calibration it is just 0.13. If I use a value of θ_z equal to 0.55 in my model, I need a 7.1-fold difference in s to generate a fortyfold difference in income.[17] This is very close to what PP found. However, if I did that it would not only require an unreasonably high investment in intangible capital but would also imply a combined share of labor and human capital in output of just 16%. Hence our target of investment in intangible capital together with the target of a two-third share of output for human capital and labor, pose additional discipline on parameter θ_z. The conclusion is that with reasonable calibration of θ_z, we need very large differences in barriers to explain the observed income disparity.

[15]Some influential papers that show institutions matter for economic development include Hall and Jones [1999] and a number of papers by Daron Acemoglu, Simon Johnson and James Robinson. The argument in the latter set of papers is summarized in Acemoglu et al. [2005]. In these papers, institutions are the prime cause of the different development experiences of countries. Although these papers are silent on the exact mechanism through which institutions affect development, they do suggest that the effects of institutions on development are multidimensional and one such dimension is their effect on technology adoption. For example, Hall and Jones [1999] write: "In addition to its direct effects on production, a good social infrastructure (*i.e. quality of institutions*) may have important indirect effects by encouraging the adoption of new ideas and new technologies as they are invented throughout the world."[pp.96-97, italics are mine.] A recent paper that explicitly models the effects of institutions on technology adoption is Acemoglu et al. [2007].

[16]The conclusions are not changed when other values of u_z are used.

[17]If I use $\theta_z = 0.55$ in my model, the required value of s_j is 0.14.

Once again, it is interesting to see how the conclusion in the preceding paragraph would change if I used a broad definition of technology capital. Recall that in the preceding paragraph the important number to watch is the product $\theta_z \xi$. With a broader definition of technology capital, the two elements of this product move in the opposite direction: θ_z increases whereas ξ decreases. The net result is that now the model needs a 70-fold difference in s to generate a fortyfold difference in output. In this case, unlike the previous subsection, using a broader definition of capital improves the model's ability to magnify differences in s to generate differences in income. But still we need huge differences in s to generate the observed income differences. To sum up, regardless of the definition of technology capital, the calibrated model of this paper implies that huge differences in exogenous barriers are needed to generate the observed income differences. This finding is at odds with the findings in Parente and Prescott [1994] and Klenow and Rodriguez-Clare [2005] that a small difference in barriers could explain the observed income differences.

5 Sensitivity Analysis

I have shown above that even with a reasonably small investment in intangible capital, the ability of the neoclassical model to explain cross-country income differences is significantly improved when intangible capital is added to the model together with physical and human capital. In this section I study the sensitivity of this conclusion to changes in some of the parameters and target about which, in my opinion, we have less reliable information than others. My strategy for the analysis in this section is the following. I shall pick a parameter or a target, one at a time, and try two or three different values for it other than the one used in the analysis above. I shall then study two things. First, what happens to the comparison between the baseline model and the extended model at different values of the parameter or the target. Second, in the extended model, how changes in the value of the parameter or the target affect the ability of the model to explain cross country income differences. All the relevant numbers are reported in Table 4. The rows in **bold** show the parameter or target values used in the analysis above. These are my preferred values. Although in the table I have reported both the value of ξ and the TFP ratio, for the ease of exposition, in the analysis below I shall refer to the TFP ratio only.

The first parameter that I have chosen to perform the sensitivity analysis is σ. For the results reported above I used $\sigma = 2$. Macroeconomists would generally agree with a value of σ which is around 2 or 3 because a higher value would imply unreasonably high preference to avoid risk on the part of the consumer. My choice of 2 falls on the lower end of this range. I now consider two higher values of σ. These values are 2.5 and 3.0. First, let us compare the required TFP ratio in the extended model under different values of σ. We saw above that when σ is 2, the required TFP ratio to explain fortyfold income differences is 2.97. When σ is 2.5 the TFP ratio falls to 2.31. When σ is 3 the TFP ratio falls further to 1.77. When σ is higher, the effective discount factor β is lower and consumers become impatient. Since share parameters are matched to fixed investment targets, we need higher values of these parameters to induce impatient consumers to keep their investments at the target levels. Higher share parameters result in a higher ξ and a hence a lower TFP ratio. This analysis shows that at higher values of σ the extended model does a better job of explaining cross-country income variation. Hence my preferred value of $\sigma = 2$ actually reduces the power of the model some what. Next, let us compare the baseline and the extended models under different values for σ. We have already seen above that when σ equals 2 the required TFP ratio to explain fortyfold income differences falls from 4.05 in the baseline model to 2.97 in the extended model. When σ equals 2.5, the TFP ratio falls from 3.12 in the baseline model to to 2.31 in the extended model. When σ equals 3, the TFP ratio falls from 2.37 in the baseline model to 1.77 in the extended model. Hence my conclusion, that the inclusion of intangible capital in the model enhances the model's ability to explain income variation, remains intact at higher values of σ.

The second sensitivity parameter is the depreciation rate of human capital (δ_h). There is no reliable estimate of δ_h available and a common practice, which I too have followed above, is to assume that depreciation rate of human capital is the same as that of physical capital. A lower depreciation would generate higher differences in output based on the same TFP differences i.e. one would need smaller TFP differences between rich and poor countries to generate the fortyfold differences in output that we aim at. First, let us see how TFP ratio varies with δ_h in the extended model. Table 4 shows that when $\delta_h = 0.01$ the TFP ratio is just 1.03 i.e. if TFP in rich countries is just three percent higher than that in the poor countries, it will generate fortyfold output differences. This is indeed remarkable. If δ_h is 0.04, 0.08 and 0.16 the required TFP ratios are 2.21, 2.97 and 3.61. Hence the extended model does a good job of generating income differences even when depreciation of human capital is doubled. Next, I compare how the baseline and extended model compare at different values of δ_h. The TFP ratio falls significantly when we move from the baseline to the extended model. Especially in the case of $\delta_h = 0.16$ the TFP ratios fall from 5.08 in the baseline model to 3.61 in the extended model. Hence the main conclusion, that the inclusion of intangible capital in the model enhances the model's ability to explain income variation, is not sensitive to my choice of δ_h.

The third sensitivity parameter is the depreciation rate of intangible capital (δ_z). Following CHS I have chosen a high value for δ_z. Here I consider two lower values for it. The first lower value is 0.17 which is half of my preferred value (0.34). The second lower value is 0.08, which is the same as the depreciation of physical and human capital in the main analysis. The TFP ratio in the extended model falls from 2.97 to 2.69 to 2.27 as the value of δ_z is decreased from 0.34 to 0.17 to 0.08. Hence the model can explain more of the cross-country income variation when δ_z is lower. Since there is no δ_z in the baseline model, the TFP ratio for the baseline model is reported to be 4.05. The inclusion of intangible capital improves the performance of the model more when δ_z is less. Hence the main conclusion is further strengthened when δ_z is lower.

The next sensitivity target is ι_h. This is the target for investment in human capital as a fraction of measured output. The choice of this target determines the product $\phi\theta_h$ jointly.[18] A higher ι_h would lead to a higher value of $\phi\theta_h$, which in turn would lead to a higher value for ξ and a lower TFP ratio. Hence the performance of the model improves when a higher target is chosen for ι_h. My choice of $\iota_h = 0.127$ is based on estimates in Haveman and Wolfe [1995]. In their estimates of investment on children, they include both direct and indirect expenditures by parents and all relevant expenditures by the government. I exclude the indirect parental expenditures (i.e. the opportunity cost of mother's child care time) and get $\iota_h = 0.127$. I now try two lower values of this target. The first is 0.086. This would be the investment in children if we included the total expenditure by the government but only half of the direct expenditure by parents. The second lower value of the target is 0.053. This is based on public investment alone and excludes all private investment. These lower targets will lower the calibrated product $\phi\theta_h$, lower ξ and increase the TFP ratio. The question is by how much. First, consider the extended model. When the target for ι_h is lowered from 0.127 to 0.086 to 0.054, the TFP ratio increases from 2.97 to 3.90 to 4.82. These are significant increases and I conclude that the

[18] I use a separate target for skill premium to determine ϕ and θ_h uniquely. Since ϕ and θ_h appear as a product in the expression for ξ, the choice of skill premium is irrelevant for the question I am investigating in this paper.

performance of the model depends crucially on our target of investment in children. However, looking at the estimates by Haveman and Wolfe [1995], we can have faith in our preferred target. Next consider the comparison between the baseline and extended models at various values of ι_h. It is clear from Table 4 that regardless of the value of ι_h, the performance of the baseline model is significantly improved when it is extended to include the intangible capital. Hence the main result of the paper that intangible capital is important is not affected by the value of this target.

The next sensitivity target is investment in intangible capital as a fraction of measured output. I denote this fraction by ι_{ik}. This target pins down η and θ_z jointly. Following the estimates in CHS, I chose $\iota_{ik} = 0.157$. This is based on their estimates of investment in intangible capital in the US during the period 1999-2003. However, according to CHS, this investment has been rising over time and if we consider the average for the post-WWII period, it would be close to 0.10. It is instructive to see that how the model fares when a lower target for ι_{ik} is chosen. I now consider two lower targets: 0.10 and 0.05. When ι_{ik} is lowered from 0.157 to 0.10 to 0.05, the TFP ratio in the extended model increases from 2.97 to 3.29 to 3.64. When I compare these with the baseline model TFP ratio of 4.05, I conclude that improvement in the ability of the model to explain cross-country income differences when intangible capital in included, crucially depends on the target of ι_{ik}. My main conclusion that the inclusion of intangible capital reduces the TFP ratio from 4.05 (in the baseline model) to 2.97 (in the extended model) will have to be modified if investment in intangibles was less than my target of 15.7%. For example, if this investment were 10% (i.e. $\iota_{ik} = 0.10$), the TFP ratio in the extended model would be 3.29. This is still quite an improvement over the TFP ratio of 4.05 in the baseline model but the difference is not as much as it was before. This result that the performance of the model is eroded when we use a lower target for investment in intangible capital is hardly surprising. In fact, the main point of the paper is that this investment is not too small and hence by excluding intangible capital from the analysis we omit some of the variation in output that the neoclassical model is capable of explaining.

The last sensitivity target is u_h i.e. the fraction of time invested in human capital. My preferred choice of u_h is based on the ratio of average years of schooling to average life expectancy in the US. Here I try both a lower and a higher target for u_h. The lower target is 0.10 and the higher target is 0.20. First, consider the extended model. a lower u_h results in a higher TFP ratio and vice versa. However the differences are not very big. For example, when u_h is lowered from 0.155 to 0.10, the TFP ratio increases from 2.97 to 3.13. When u_h is increased to 0.20 the TFP ratio decreases to 2.81. I conclude that the performance of the extended model is not much influenced by a different target value for u_h. Next compare the baseline model with the extended model for different values of u_h. In all cases, the TFP ratio declines significantly. For example, when u_h is 0.05, the TFP ratio falls from 4.31 in the baseline model to 3.13 in the extended model. Hence my conclusion that intangible capital improves the performance of the model is unaffected by the choice of the target for u_h.

6 Concluding Remarks

In this paper I construct a variant of the neoclassical growth model to study its implications for cross-country income differences. The model features intangible capital in addition to physical and human capital . I use recent estimates of investment in intangible capital to pin down some key parameters of the model. The main findings of this study are: 1) the addition of intangible capital to an otherwise standard neoclassical growth model more than doubles the ability of the model to account for cross-country variation in income, i.e. the same TFP ratio that generates fortyfold difference in output can generate 114-fold difference in output when intangible capital is added to the model; 2) differences in barriers to technology adoption, whether endogenous or exogenous, do not appear to be important determinants of cross country income differences.

The main limitation of the model is out-of-steady-state dynamics. The model of this paper exhibits very slow transition to steady state. This is hardly surprising given that the combined share of three types of capital (i.e. $\theta_h + \theta_k + \theta_z$) is 0.78 in the extended model. Hence the model cannot explain growth miracles. In order to do so, one needs to exclude human capital from the model and assume an implausibly high investment in intangible capital.

Nevertheless, the model clearly demonstrates that the neoclassical model can explain a large fraction of cross-country variation in income. It also shows that factor accumulation is more important than previously thought and investments in software, R&D, product promotion etc. are as important as investments in machines and human capital. This last point brings the neoclassical model a step closer to the endogenous growth models. Although *growth* in the model is still exogenous, the *level* of development depends on investment in R&D and other related activities.

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A Calibration of Parameters: The Baseline Model

The following two constants will be used throughout the appendix.

$$
\begin{aligned}
D_{i1}(n, g, \beta, \delta_i) &= \beta[(1+g)(1+n) - (1-\delta_i)] \\
D_{i2}(n, g, \beta, \delta_i) &= [(1+g)(1+n) - \beta(1-\delta_i)],
\end{aligned}
$$

where $i = \{h, k, z\}$. I now describe the calibration strategy for the parameters in the baseline model.

The targets of population growth rate, per capita consumption growth rate and depreciation of physical capital match one-to-one with parameters n, g and δ_k. Parameter σ is chosen from the empirical literature. Parameter β, the modified discount rate, depends on n, g, σ and $\tilde{\beta}$, where $\tilde{\beta} = 1/(1+r)$ and r is the target real interest rate. Specifically, $\beta = \tilde{\beta}[(1+g)(1+n)]^{1-\sigma}$.

I pick θ_k to match the steady-state target for x_k/y. From the steady-state solution of the model,

$$
\theta_k = \frac{x_k^{SS}}{y^{SS}} \frac{D_{k2}}{D_{k1}}, \tag{23}
$$

where SS in the superscript refers to steady-state values. Hence θ_k is linear in our target of investment in physical capital.

I pick ψ to match the steady-state target for u_h, the fraction of time spent on accumulating human capital. From the steady-state of the model,

$$
\psi = u_h^{SS} \frac{D_{h2}}{D_{h1}}. \tag{24}
$$

Once I have determined ψ, I pick ϕ and θ_h jointly to match the steady-state target for x_h/y. The steady-state of the model gives,

$$
\phi\theta_h = \frac{x_h^{SS}}{y^{SS}} \Big(\frac{D_{h2}}{D_{h1}} - \psi \Big). \tag{25}
$$

It is important to point out that for the question of interest, it is the product $\phi\theta_h$ that matters. However, to identify ϕ and θ_h separately I pick θ_h to match some empirical estimate of the skill premium (SP). To do so, I define the SP as the ratio of the combined share of human capital and labor to the share of labor in output, i.e.

$$SP = \frac{1-\theta_k}{1-\theta_k-\theta_h}.$$

This gives,

$$\theta_h = (1-\theta_k)\Big(1-\frac{1}{SP}\Big).$$

This completes the calibration of all the parameters in the baseline model.

B Calibration of Parameters: The Extended Model

In the extended model, there are three additional parameters: δ_z, θ_z and η. However, due to a wedge between actual output (y) and measured output (y_m), the calibration strategy for some of the other parameters needs to be adjusted. I introduce some more notation to describe modifications in the calibration strategy. Let ι_{pk} be the ratio of investment in physical capital to measured output i.e. $\iota_{pk} \equiv x_k/y_m$. Let ι_{ik} be the ratio of investment in intangible capital to measured output i.e. $\iota_{ik} \equiv x_z/y_m$. And let ι_h be the ratio of investment in human capital to measured output i.e. $\iota_h \equiv x_h/y_m$. Then (23) can be written as

$$\theta_k = \frac{\iota_{pk}}{1+\iota_{ik}}\frac{D_{k2}}{D_{k1}}, \tag{26}$$

because in the extended model

$$\frac{x_k}{y} = \frac{x_k/y_m}{y/y_m} = \frac{\iota_{pk}}{1+\iota_{ik}}.$$

Similarly, (25) becomes

$$\phi\theta_h = \frac{\iota_h}{1+\iota_{ik}}\Big(\frac{D_{h2}}{D_{h1}}-\psi\Big). \tag{27}$$

ϕ and θ_h can still be separately identified using a target for the the skill premium (SP). However, the SP is now defined as

$$SP = \frac{1-\theta_k-\theta_z}{1-\theta_k-\theta_h-\theta_z}.$$

The modified expression for θ_h is

$$\theta_h = (1 - \theta_k - \theta_z)\Big(1 - \frac{1}{SP}\Big).$$

I now turn to the three new parameters in the model. I pick δ_z to match the target depreciation rate of intangible capital. The other two new parameters η and θ_z are picked jointly to match the target investment in intangible capital. The steady state solution of the extended model gives

$$\eta\theta_z = \frac{\iota_{ik}}{1+\iota_{ik}}\frac{D_{z2}}{D_{z1}}. \tag{28}$$

Once again, it is important to note that it is the product $\eta\theta_z$ that matters for the question of interest. However, the two parameters can be separately identified using as target the combined share of human capital and labor in the measured output. This share is defined as

$$\textsc{shc} = (1 - \theta_k - \theta_z)(1 + \iota_{ik}), \tag{29}$$

where SHC is the combined share of human capital and labor in the measured output. The last equation gives the following value for θ_z.

$$\theta_z = 1 - \theta_k - \frac{\textsc{shc}}{1+\iota_{ik}}. \tag{30}$$

This completes the calibration of parameters in the extended model.

C Calibration of Parameters: The Extended Model with Barriers

In the extended model with barriers there is one new parameter: ν. I need two targets to pin down ν and the product $\phi\theta_h$. These targets are the fraction of time spent on accumulating human capital (u_h) and the fraction of time spent on accumulating intangible capital (u_z). Given these two targets the following two expressions solve for the desired parameters as functions of known parameters and targets.

$$\begin{aligned}
\phi\theta_h &= \frac{\iota_h}{1+\iota_k}\Big(1-\frac{u_z}{1-u_h}\Big)\Big(\frac{D_{h2}}{D_{h1}}-\psi\Big),\\
\nu &= \frac{\theta_h}{\theta_z}\frac{u_z}{1-u_h-u_z}\frac{D_{z2}}{D_{z1}}.
\end{aligned}$$

D Calibration of Parameters: Broad Definition of Technology Capital

The calibration of parameters remains the same except that now we need to broaden the definition of technology capital (z) to include a fraction of physical capital k. Let us assume that a fraction κ of investment in physical capital should be considered investment in technology capital. This investment is in addition to the investment in intangible capital all of which is already considered investment in technology capital. Then the calibration strategy will remain the same as in the last two sections except that we need to redefine investments in technology capital and non-technology physical capital. These investments are

$$\begin{aligned}
\frac{x_z}{y_m} &= \iota_{ik}+\kappa\iota_{pk}, \text{and}\\
\frac{x_k}{y_m} &= (1-\kappa)\iota_{pk}.
\end{aligned}$$

First of these equations simply says that now investment in technology capital comprises of two components. The first component is investment in intangible capital. The second component is κ fraction of investment in physical capital. The second equation says that investment in physical capital (that does not embody new technology) is $1-\kappa$ fraction of the total investment in physical capital.

Table 1: Calibrated Parameter Values and Targets (Baseline and Extended Models)

Parameter	Baseline Model	Extended Model	Targets	Target Values
g	0.02	0.02	Growth in p.c. consumption	2.34%
n	0.01	0.01	Growth in population	1.17%
β	0.92	0.92	Real interest rate	5%
σ	2.00	2.00	Empirical literature	-
δ_k	0.08	0.08	Empirical literature	-
δ_h	0.08	0.08	Same as δ_k	-
θ_k	0.36	0.31	x_k/y_m	0.20
θ_h	0.39	0.34	Skill premium	2.45
ψ	0.28	0.28	Fraction of life spent in school	0.155
ϕ	0.50	0.49	x_h/y_m	0.127
δ_z	-	0.34	Estimates in Corrado et al. [2006]	-
θ_z	-	0.13	Combined share of L and H in Y_m	0.65
η	-	1.29	x_z/y_m	0.157
ξ	2.64	3.39		
TFP Ratio	4.05	2.97		

Table 2: Target Values for u_z and Corresponding ξ, ν and TFP Ratios

Target u_z	ν	ξ	TFP Ratio
0.01	0.04	3.39	2.97
0.05	0.20	3.42	2.94
0.10	0.43	3.46	2.90

Table 3: Target Values for u_z and Corresponding ξ, ν and TFP Ratios (with Broader Definition of Capital)

Target u_z	ν	ξ	TFP Ratio
0.01	0.02	2.89	3.59
0.05	0.09	2.91	3.55
0.10	0.19	2.94	3.51

Table 4: Sensitivity Analysis

Sensitivity	Baseline Model		Extended Model	
Parameter or Target	ξ	TFP Ratio	ξ	TFP Ratio
σ				
2.0	**2.64**	**4.05**	**3.39**	**2.97**
2.5	3.24	3.12	4.40	2.31
3.0	4.27	2.37	6.44	1.77
δ_h				
0.01	21.68	1.19	137.59	1.03
0.04	3.50	2.87	4.66	2.21
0.08	**2.64**	**4.05**	**3.39**	**2.97**
0.16	2.27	5.08	2.87	3.61
δ_z				
0.34	**2.64**	**4.05**	**3.39**	**2.97**
0.17	2.64	4.05	3.73	2.69
0.08	2.64	4.05	4.51	2.27
ι_h				
0.127	**2.64**	**4.05**	**3.39**	**2.97**
0.086	2.15	5.55	2.71	3.90
0.054	1.88	7.10	2.34	4.82
ι_{ik}				
0.157	**2.64**	**4.05**	**3.39**	**2.97**
0.100	2.64	4.05	3.10	3.29
0.050	2.64	4.05	2.86	3.64
u_h				
0.100	2.52	4.31	3.23	3.13
0.155	**2.64**	**4.05**	**3.39**	**2.97**
0.2000	2.76	3.81	3.56	2.81

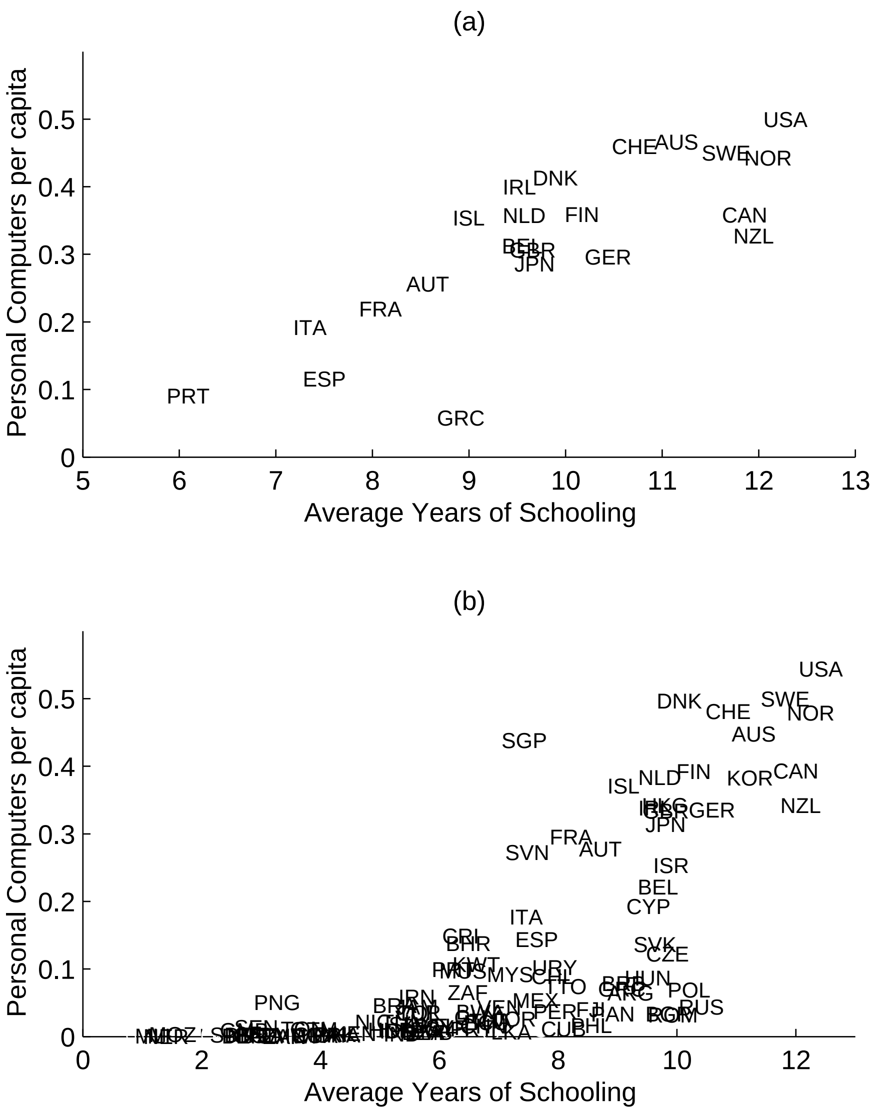

Figure 1: Human Capital and Technology Adoption