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CROSS-COUNTRY INCOME DIFFERENCES REVISITED: ACCOUNTING FOR THE ROLE OF INTANGIBLE CAPITAL

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This paper develops a new intangible investment database that is consistent and internationally comparable for a set of 60 economies over the period 1995–2011. I find that over time a growing share of total investment consists of intangible assets, rather than investment in tangible assets, like machinery and buildings. Across countries, the level of economic development of a country is positively associated with its investment intensity in intangibles. By including intangible capital as an additional production factor, this paper finds that we can account for substantially more of the variation in cross-country income levels. Depending on the assumptions regarding the output elasticities of factor inputs, the observed differences in intangible capital can account for up to 16 percentage points of the cross-country income variation.

JEL Codes: E22, O10, O47, O57

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1. INTRODUCTION

Living standards, as captured by average income per person, vary drastically across countries. According to the estimates of the World Development Indicators (World Bank, 2015), the ratio of 90^{th} to 10^{th} percentile in the world income distribution is at a factor of 28 in 2012.[1] What can explain such enormous differences in income per capita across countries?

Based on the Solow growth model economists have been seeking to provide answers around two proximate determinants: differences in *factors of production* and in *efficiency*. This analytical framework is formally known as development accounting. The main idea of this analysis is that by using cross-country data on output and inputs at one single point in time, development accounting quantifies how much of the cross-country variation in income can be accounted for by the observed differences in production factors and how much is left to be explained by the differences in efficiency as measured by total factor productivity (TFP). The latter is a residual, i.e. everything that cannot be accounted for by the

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[1]Real GDP per capita is calculated using constant internationally comparable dollars (i.e. adjusted for differences in relative prices—PPPs).

observable inputs.[2] The current consensus is that efficiency plays the largest role in accounting for cross-country income variation, while the observed differences in factor inputs merely account for a small share (Hall and Jones, 1999; Easterly and Levine, 2001; Caselli, 2005; Mutreja, 2014).

The goal of this paper is to extend the existing works on international income differences by accounting for an important factor of production that has been ignored so far—intangible capital. This is likely to be a promising extension, as the emerging research agenda on intangible investment has shown that intangible assets, such as brand equity, scientific research and development (R&D), and organization capital, have become increasingly the more important forms of investment in the modern economy and they have escaped the statistical net (Corrado and Hulten, 2010). In the System of National Accounts (SNA), investments are broadly defined as "the acquisition of fixed assets that is undertaken specifically to enhance future production possibilities." According to the guidelines of SNA 1993 revision, this includes physical assets such as machinery, equipment and buildings as well as a limited set of intangibles, namely software, mineral exploration, and artistic originals, which I will indicate by national accounts (NA) intangibles in the remainder. In SNA 2008, the investment boundary was extended to also cover expenditures on R&D.[3] However, this still omits other important intangible assets, such as brand equity and organization capital.

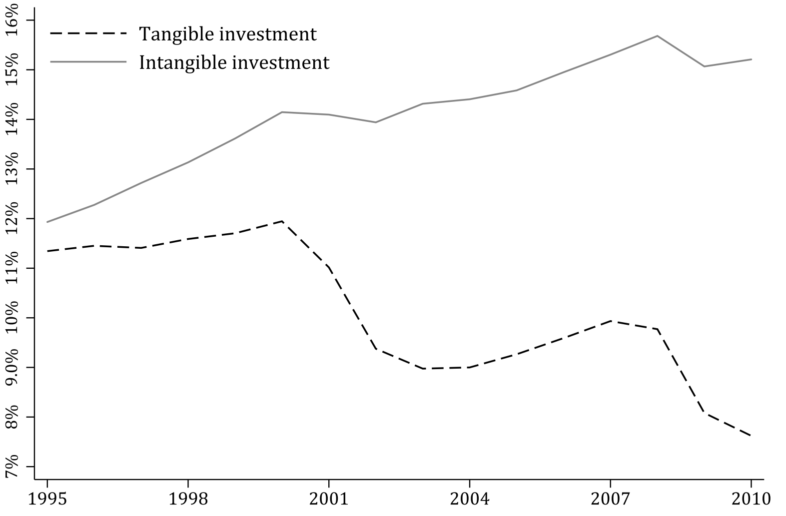
Thanks to the pioneering measurement work of intangible investment by Corrado *et al.* (2005, 2009), evidence is growing stronger that there is a gradual shift in investment composition towards intangible assets. In the US, for example, business intangible investment as a share of GDP had already exceeded the share of traditional investment in tangible assets (e.g. machinery and equipment) by the mid-1990s and has kept on rising over time (see Figure 1). Rather than being an exception, other country-specific studies and the research project commissioned by the OECD (2013) also show that investment in intangibles has been rising in both high-income economies and emerging economies.[4] In light of this evidence, it is clear that the traditional emphasis on physical capital as the only capital input is missing out on an important part of investments in the modern knowledge-intensive economy. This implies that inputs might account for more of cross-country income differences than generally known so far.

This paper is the first to explicitly account for a country's (business) investment in intangible capital as an additional production factor in accounting for income variation across countries. I first develop a novel database on intangible investment that is consistent and internationally comparable for a set of 60 economies over the period 1995–2011. The dataset, by itself, is a contribution to the rapidly growing literature on intangible investment as this is the first database

[2]Abramovitz (1956, p. 11) labeled it as "a measure of our ignorance."

[3]Since 2013 a small number of countries have started to capitalize R&D spending as investment (e.g. US, Australia) following the guidelines of SNA 2008. Most countries around the world, however, have not yet switched to SNA 2008. For this reason, R&D is still counted as *new intangibles* instead of *NA intangibles* in this paper.

[4]Other country-specific studies include Australia (Barnes, 2009), Brazil (Dutz *et al.*, 2012), China (Hulten and Hao, 2012), South Korea (Chun *et al.*, 2012), and Japan (Fukao *et al.*, 2009).



Note: Author's calculation based on the INTAN-Invest database

Figure 1. Intangible Investment Trend in the US (% of GDP) [Color figure can be viewed at wileyonlinelibrary.com]

providing internationally comparable data on intangibles for such a wide range of countries, including not only the advanced economies, but also major emerging economies like China and Brazil as well as much less developed countries, such as Honduras and Vietnam. This dataset offers two important insights. First, there is a strong positive association between the level of economic development of a country and its investment intensity in intangibles, reaffirming the important role of intangible capital in modern economic growth. Second, the share of investment in intangible assets as a percentage of (intangibles-adjusted) GDP has been increasing steadily over time, while the share of traditional investment in physical assets is highly volatile and had declined somewhat during the period of observation.

Starting with the basic development accounting framework that features physical and human capital akin to Caselli (2005), I find that the observed differences in the traditional factors of production account for approximately 23 percent of the cross-country income variation in 2011. This result holds true whether the analysis is based on the total economy or the market economy which excludes public sectors such as Public Administration and Defence. Therefore, for the set of 60 economies that I cover efficiency is still the main factor accounting for international income differences, conforming to the findings of the existing literature (e.g. Easterly and Levine, 2001; Caselli, 2005; Mutreja, 2014). In the augmented development accounting analysis where intangible capital is included as an additional factor of production, I show that the variance accounted for by the observed differences in inputs increases significantly and systematically across a wide range of specifications. Depending on the assumptions regarding the output elasticity of intangible capital, the observed differences in factor inputs can account for up to 40 percent of the income variation, an improvement of 16 percentage points compared to the conventional analysis that ignores intangible capital. Even under a more conservative specification, I still find that including intangible capital leads to an increase of nearly 5 percentage points of income variation.

Before proceeding, it is helpful to place these results in a broader context. The emphasis on the comparability of the intangible investment series across a set of 60 economies has required rather restrictive assumptions that apply to all countries and measuring intangible investment in a less comprehensive fashion. For instance, I have only focused on three major intangible assets that can be well covered using standardized international databases, which leaves out intangible investment in, for example, firm-specific human capital. This means that the estimates constructed in this study do not reflect the full extent of intangible investment. Superior in this regard are the outcomes of the INTAN-Invest project (Corrado *et al.*, 2012) and other country-specific studies that mainly rely on national accounts and national survey data to measure intangible investment.[5] However, since such studies have not achieved the level of country coverage necessary for an informative development accounting exercise, I have developed my estimates specifically for this purpose.

A key finding of this paper is that intangible capital is important in accounting for cross-country income variation at a single point in time. This echoes with the macro-level studies that find intangible capital to be important for a country's growth over time (e.g. Corrado *et al.*, 2009; Fukao *et al.*, 2009; Dutz *et al.*, 2012). In both cases, the role of efficiency, measured by TFP, is diminished once intangible capital is accounted for.

Since my analysis is an accounting exercise, it can shed no light on whether investing more in intangible assets would lead to higher income or if causality runs the other way. However, there are prior firm-level studies that analyze the role of intangible capital in determining firm productivity and performance. For instance, using a large panel of company accounts data, organization capital is found to lead to higher firm productivity (Tronconi and Vittucci Marzetti, 2011; Chen and Inklaar, 2016;) and larger stock market returns (Eisfeldt and Papanikolaou, 2013), and it is also complementary to the exploitation of the productivity potentials of information technologies (Brynjolfsson and Hitt, 2000, 2003; Bloom *et al.*, 2012; Chen *et al.*, 2016). At the firm level, there thus seems to be a causal relationship between investment in intangibles and productivity. One of the main insights from my analysis is that high-income countries tend to invest more in intangibles than lower-income countries, which raises the question why firms in lower-income countries are not investing more. So far, the evidence on this is scarce, though Bloom *et al.* (2013) find that the adoption in Indian manufacturing firms of modern management practices—a form of investment in organization capital—is hampered by informational barriers. While it is a useful piece of evidence, this is a question that awaits further research.

The rest of the paper is organized as follows. Section 2 describes the general measurement procedure of intangible investment and how capitalizing expenditures on intangible assets changes the conventional gross domestic product

[5]See footnote 4 for the list of country-specific studies.

(GDP) concept. A brief discussion on the key features of the intangible investment data is presented in the second part of Section 2. Section 3 outlines the basic and the augmented development accounting framework and elaborates on the data that I use for analysis. Results, obtained across various specifications, and robustness checks are discussed in Section 4. Section 5 concludes and discusses the main limitations of the paper.

2. Measuring Intangible Inputs and Output

In this section, I describe the general approach used to measure intangible investment and show how capitalizing such investment requires a change in the measurement of GDP. Then, I discuss the list of intangible assets measured in this study as well as the key features of the data that I construct and use for the subsequent development accounting analysis. It is important to note that this section only provides a general overview of the measurement procedure. For a more extensive and detailed discussion on the data construction of intangibles, please refer to Appendix A.

2.1. *General Measurement Approach*

Before discussing how to measure intangible investment, a natural question to ask a priori is: why do we need to reclassify some of the expenditures on intangibles and capitalize them as investment? The argument is presented more formally in Corrado *et al.* (2005) based on the standard inter-temporal capital theory, but the logic is simple: "*any* use of resources that reduce current consumption in order to increase it in the future" should be capitalized and treated as investment. Expenditures on tangible assets, such as office buildings, machinery, vehicles, and equipment certainly satisfy this criterion, but so does much spending on brand equity, R&D, and organizational structures.[6] Expenditures on these assets, collectively termed *new* intangibles in this paper, contribute to (rather than detract from) the value of individual companies and growth of the economy.

While few would disagree with the potentially long-lasting benefits of intangible capital and their role as productive inputs, little is known about the size of intangible investment at the level of the economy.[7] The measurement of intangibles is particularly difficult as they are often created for internal use within the firm and suffer from a lack of observable market transaction data for valuation. To circumvent this measurement issue, researchers turned to use the cost approach as an alternative. The underlying assumption of the cost approach is that firms are willing to invest in intangible assets until the discounted present value of the expected income stream equals the cost of producing the marginal asset (Jorgenson, 1963).

[6]R&D projects, for instance, can take more than a decade to generate revenue and require large co-investments in marketing and advertising.

[7]Various proxy measures, such as business surveys, are used in firm-level studies (e.g. Black and Lynch, 2005; Lev and Radhakrishnan, 2005). But none of these proposed approaches yield the kind of comprehensive measure needed for national accounting or sources-of-growth analysis.

A key problem of this cost approach, however, is that it is not known with precision how much or what portion of intangible spending has long-lasting impact (i.e. longer than one year) and can be and should be treated as investment. In this paper, I follow the work of Corrado *et al.* (2005) which suggests a wide range depending on the specific asset. For own-account organization capital, 20 percent of managers' wage are counted as conducive to organizational development; for advertising, the literature suggests that about 60 percent of advertising expenditures have long-lasting benefit. While for R&D all expenses are treated as investment following SNA 2008.

To cumulate intangible investment flows (N) into capital stocks, one can use the usual perpetual inventory method (PIM) which accumulates past capital formation and subtracts the value of assets due to obsolescence. Physical capital is generally subject to value loss because they tend to be used up in production mainly due to wear and tear. Intangible capital, on the other hand, does not physically deteriorate due to its intangibility. It is more subject to the rise of superior knowledge that supplants the existing ones and thereby making the current intangible or knowledge stock obsolete.

By including some expenditures as investment, one also needs to adjust the GDP concept. More specifically, a country's nominal GDP as measured traditionally (Y) will be expanded as follows:

$$(1) \qquad GDP' = Y + N = \overbrace{C + I + \underbrace{N}_{added}}^{Expenditure\ \ side\ \ GDP} = \overbrace{L + K + \underbrace{R}_{added}}^{Income\ \ side\ \ GDP}$$

where N is the flow of new intangible investment added on to the expenditure side and R is the income from the flow of services provided by the intangible capital stock. In other words, intangible capital is now both a productive input (R) and a part of intangibles-augmented output (N). This new concept of GDP, denoted by GDP', is larger in magnitude than conventionally defined.

2.2. *List of Intangibles Measured and Overview of the Data*

I assemble internationally comparable data to estimate intangible investment for a set of 60 economies over the period 1995–2011 (see Appendix Table A1 for the full list of economies covered). I capture the following three intangible assets in this study: brand equity, R&D, and organization capital. Brand equity can be seen as the value premium that a firm can capitalize on from a product or service with a recognizable name as compared to its generic equivalent. Following Corrado and Hao (2014), I measure brand equity as the sum of expenditures on advertising and market research. R&D refers to the innovative activities leading mainly to the development of a new or improved product and it is measured by business expenditures on R&D. Organization capital can be thought of management know-how and the information a firm about its assets and how these can be used in production (Prescott and Visscher, 1980). Following the broad literature, organization capital is measured as a fraction of manager's wage compensation. Table 1 provides a general overview of the list of intangibles covered, how they

TABLE 1
List of Intangible Assets Measured and Data Sources

Asset type	Measured by	Depreciation	Data source*
1. Brand equity	Expenditures on advertising and market research	60%	WARC & ESOMAR
2. Scientific R&D	Business expenditures on R&D	20%	UNESCO & Eurostat
3. Organization capital	Wage compensation of managers	40%	ILO, PWT 8.1, BLS

*ILO: International Labor Organization; PWT: The Penn World Table version 8.1; BLS: Bureau of Labor Statistics; WARC: World Advertising Research Centre; ESOMAR: European Society for Opinion and Marketing Research; UNESCO-UIS: UNESCO Institute for Statistics; Eurostat: Statistical Office of the European Communities.

are measured, and the sources of the data used. Readers should refer to Appendix for more detailed discussions on the measurement issues.

It is important to emphasize that these do not include all intangibles investments in the economy. As noted earlier, investment in national accounts intangibles are already capitalized and included in investment and GDP statistics following the SNA 1993. There is hence no need to estimate NA intangibles to construct the GDP measure.[8] Corrado *et al.* (2005) include several other intangibles, namely architectural and engineering designs, firm-specific human capital, copyright and license costs, and new financial products, but these are relatively minor. According to the estimates of the INTAN-Invest project, a pioneering database providing country-level intangible investment data for a sample of 29 countries, the sum of these three assets account for over 50 percent of the total intangible investment. Thus, in terms of their shares in total intangible investment these three assets can be considered as the most important ones to capture.

Like many other studies on intangibles, I focus on market sector investment in intangible assets and omit public intangible investment due to measurement difficulties.[9] Hence, a country's market GDP (MGDP) after adjusting for business investment in intangible assets is calculated as follows:

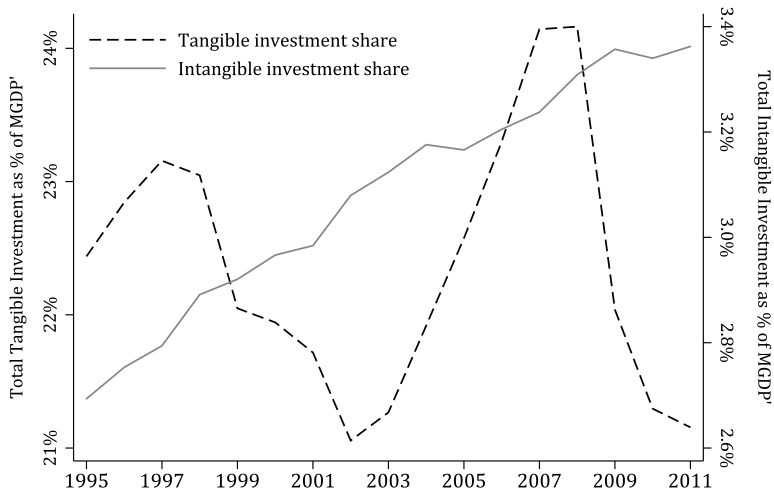
$$MGDP'_{c,t} = mY_{c,t} + N^{BE}_{c,t} + N^{RD}_{c,t} + N^{OC}_{c,t} \quad (2)$$

where m denotes the share of the market economy; Y denotes GDP calculations based on SNA 1993 revision, and intangible investments are represented by the letter N indexed by the asset-specific superscripts— BE, RD, and OC.

The intangibles data constructed in this paper offers several important insights. The first is that there has been a steady increase in the share of investment

[8]To have a full-fledged analysis on how the addition of total intangible capital affects the development accounting analysis, it would be ideal to isolate those national accounts intangible investments from total tangible investment (I) and reclassify them as intangibles. This is however not possible due to data constraints.

[9]The distinction between market and nonmarket (public) sector is the same as defined in EU KLEMS (O'Mahony and Timmer, 2009). According to NACE classification, sectors A-K plus sectors O and P consist of market sector. See Appendix B for more detailed discussions.



Notes: Author's calculation. The shares of tangible and intangible investments are averaged across countries.

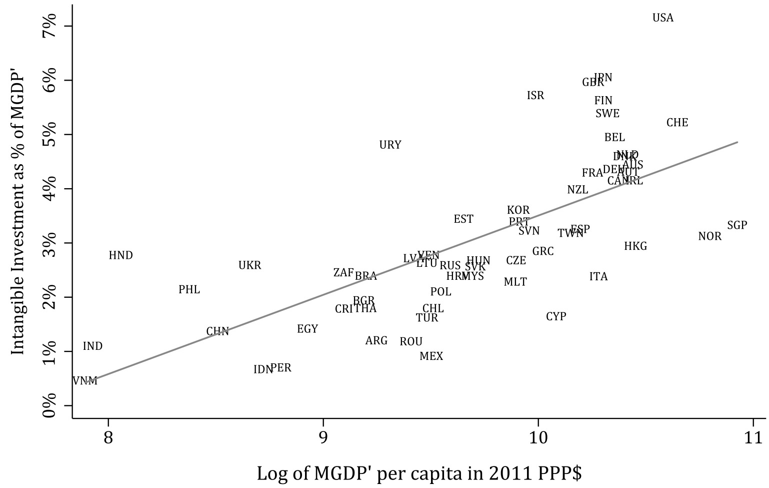
Figure 2. Cross-Country Average Investment Trend of Intangibles and Tangibles [Color figure can be viewed at wileyonlinelibrary.com]

in intangibles between 1995 and 2011 (Figure 2). Whereas, the same is not true about the share of traditional investment in physical assets, which had declined somewhat over time. These two contrasting investment trends or patterns seem to suggest that the modern economy is currently undergoing structural changes with investment composition shifting gradually towards intangible assets.

In addition, it is also interesting to note the difference in volatility of investment in tangible and intangible assets. Figure 2 shows that investment in intangible assets as a share of MGDP′ seems to be more stable and resilient to economic downturns, while traditional investment in tangible assets appears to be highly volatile and sensitive to external shocks.[10] This is reflected by the sharp decline in tangible investment share observed in 1997, 2001, and 2008. In chronological order, these three years are, respectively, associated with the Asian financial crisis, the dot-com bubble burst, and the global financial crisis.

Third, the world's leading investor in intangible capital is the US, which has an average intangible investment share of over 7 percent of MGDP′. Vietnam, on the other hand, has the smallest share (i.e. slightly over 0.5 percent of MGDP′). The positive slope of the fitted line shown in Figure 3 suggests that there is a strong positive correlation between the level of economic development of a country and its investment intensity in intangible assets, which is above 0.67. This, of course, could mean that rich countries tend to invest more in intangible assets or that, intangible assets tend to make these investing countries richer.

[10]An important caveat to note is that the seemingly stable and resilient intangible investment may well be related to how intangibles are (mis)-measured (e.g. counting a constant 20 percent of the managers' compensation as investment in organization capital).



Notes: Author's calculation. The line shown in the figure is OLS regression line. The shares of intangible investment are averaged over time.

Figure 3. Intangible Investment and Level of Economic Development [Color figure can be viewed at wileyonlinelibrary.com]

3. Development Accounting and Data Analysis

In this section, I revisit the basic development accounting technique and set the stage for the extension of the basic model, which already features physical capital and human capital as factor inputs, to further include intangible capital. Then, I elaborate on the data that I use for the development accounting analysis and briefly discuss how the key variables of interest are constructed.

3.1. *Development Accounting Framework*

The point of departure for empirical analysis is the benchmark Hall and Jones (1999)'s production function:

$$Y = A \cdot K^{\alpha}(Lh)^{\gamma} \tag{3}$$

where Y is a country's GDP, K is the aggregate physical capital stock and Lh is employment adjusted for labor quality (i.e. number of workers L multiplied by their average human capital h). The superscripts α and γ are the output elasticities of capital and labor,[11] and A denotes the state of technology or productivity with which production factors are combined to produce output. Assuming that the production function features constant returns to scale (i.e. $\gamma = 1 - \alpha$) and normalize the function by the number of workers, equation (3) can be rewritten as follows:

[11]In growth or development accounting the output elasticities of factor inputs are equal to their income shares if inputs earn marginal product and firms maximize profits. I will speak of *output elasticities*, instead of *income shares*, throughout the paper.

$$y = A \cdot k^{\alpha} h^{1-\alpha} \tag{4}$$

where y is the output per worker, k is the capital-labor ratio for physical assets (i.e. K/L). Equation (4) can be used to answer the question: how much of the variation in output per worker y can be attributed to variation observed in physical capital k and human capital h, each weighted by their output elasticities, and how much is left to be accounted for by the differences in technology A or total factor productivity (TFP)?

Akin to Caselli (2005), I define $y_{KH} \equiv k^{\alpha} h^{1-\alpha}$ as the so-called factor-only model and for ease of exposition rewrite equation (4) accordingly as:

$$y = A \cdot y_{KH} \tag{5}$$

where both y and y_{KH} are observable. In the tradition of variance decomposition, this equation can be further transformed as follows:

$$var[\log(y)] = var[\log(A)] + var[\log(y_{KH})] + 2cov[\log(A)],\ \log[(y_{KH})] \tag{6}$$

The explanatory power of observed input differences is then defined as:

$$\text{VAF} = \frac{var[\log(y_{KH})]}{var[\log(y)]} \tag{7}$$

where VAF denotes the fraction of income variances accounted for by the observed differences in factor inputs. The higher the value of VAF, the more the variance can be accounted for by the observable inputs. In the work of Caselli (2005), this ratio or fraction is alternatively labeled as the success rate: how successful are observable factor inputs in accounting for cross-country income differences?

I extend the basic framework to further include intangible capital R as an additional production factor and denote its output elasticity by a constant parameter β. Then, the augmented production function in per worker terms becomes:

$$y' = A \cdot y_{KRH} = A \cdot k^{\alpha} r^{\beta} h^{1-\alpha-\beta} \tag{8}$$

where $y_{KRH} \equiv k^{\alpha} r^{\beta} h^{1-\alpha-\beta}$ denotes the *augmented* factor-only model; the superscripts α and β represent the output elasticities for tangibles and intangibles; and y' is GDP of the market sector adjusted to include intangible investment constructed per equation (1). Again, following Caselli (2005) the decomposition of the variation in GDP per worker is now given by:

$$\text{VAF}' = \frac{var[\log(y_{KRH})]}{var[\log(y')]} \tag{9}$$

The prime interest is essentially the difference between VAF and VAF$'$. If intangible capital is important in accounting for international income differences, one would expect the value of the latter to exceed the former. In fact, the larger the difference between the two ratios, the larger the role of intangible capital in accounting for income variation.

3.2. *Basic Data*

The basic data I use are obtained from various sources. Countries' (nominal) GDP, total investment in tangible assets,[12] and number of workers are extracted from the United Nations National Accounts database, human capital (h) comes from the standard database of Barro and Lee (2013), and total investment in intangibles (N) is constructed in this paper. Since both GDP and investment are denominated in local currency unit (LCU) and are expressed in nominal terms, I first estimate real GDP per worker ($RGDPWOK_{c,t}$) and real value of tangible investment ($I_{c,t}$) in international comparable dollars as follows:

$$y_{c,t} \equiv RGDPWOK_{c,t} = GDP_{c,t}/P_{c,t}/ppp_{c,2011}/emp_{c,t} \tag{10}$$

$$I_{c,t} = GFCF_{c,t}/P^{I}_{c,t}/ppp_{c,2011} \tag{11}$$

where the subscripts c and t denote country and year, respectively; P is the GDP price deflator with 2011 as base and ppp is the GDP PPP divided by the exchange rate in 2011 and is taken from the World Development Indicators (World Bank, 2015). Physical capital stock K is calculated using the perpetual inventory method:[13]

$$K_{c,t} = I_{c,t} + (1-\delta_K) \cdot K_{c,t-1} \tag{12}$$

where I is the real value of investment in tangible assets (i.e. nominal GFCF deflated by the investment price deflator P^I) and δ^K is the rate of depreciation for physical capital K, which is set equal to 0.06 following the broader literature (e.g. Caselli, 2005).[14] For initial capital stock calculation K_0, I follow the standard

[12]Investment is measured by gross fixed capital formation (GFCF). Since Taiwan is not covered in the UN NA database, I alternatively extract its (nominal) GDP and total gross fixed capital formation (I) from the PWT 8.1 database.

[13]It would be ideal to measure capital services rather than capital stocks as a capital input measure, as a capital services measure would capture the larger return of shorter-lived assets. However, the data requirements are much more demanding for estimating capital services than for capital stock and there is no readily available data to measure capital services. For instance, one would need additional information on the user cost of capital to calculate capital services. The user cost of capital requires the rate of return on capital and the rate of asset-specific inflation. The former is generally hard to measure with precision (e.g. Inklaar, 2010) and data on the asset-specific capital gains are not available for many countries. Due to these practical constraints, total capital stock (both tangible and intangible) based on perpetual inventory method is used as a measure of capital input, rather than the preferred services measure. Note, the existing studies on international income difference generally relied on a stock measure as well for capital input (e.g. Caselli, 2005; Mutreja, 2014), so the results obtained in this paper by adding intangibles as an additional capital input can be directly compared to previous studies.

[14]The investment price deflator for tangible assets, P^I adjusted for PPP, is calculated as GFCF at current national prices divided by GFCF at constant national prices. Both data series are retrieved from the UN NA database.

approach proposed by Harberger (1978) by assuming the steady-state relationship from the Solow growth model:

$$K_0 = I_0/(g+\delta_K) \tag{13}$$

The initial capital stock K_0 for an asset is related to the investment in the initial year I_0, the (steady-state) growth rate of investment g and the rate of depreciation δ. Unlike intangible investment data that is only available for 17 years (i.e. 1995–2011), tangible investment I is, for many countries, available since 1960.[15] Therefore, to make the best use of the existing data, tangible capital stock K is constructed for a much longer time series than intangible capital stock, which I turn to discuss in the next subsection.[16] The (physical) capital-labor ratio is calculated as:

$$k_{c,t} = K_{c,t}/emp_{c,t}^{PWT} \tag{14}$$

As for human capital h, I rely on the recently updated data on educational attainment for population aged 25 and over from Barro and Lee (2013).[17] Following the broad literature, I measure human capital h of country c at time t as a function of average years of schooling (s) as follows:

$$h = e^{\phi(s)} \tag{15}$$

The function $\phi(s)$ from equation (15) takes the following form as in earlier studies (Caselli, 2005; Inklaar and Timmer, 2013). The rationale for this form is that early years of schooling is believed to have a higher rate of return than later years. This assumption is also empirically supported by the cross-country Mincerian wage regressions (Mincer, 1974). To be precise, $\phi(s)$ is piece-wise linear with the rate of return based on Psacharopoulos (1994):

$$\phi(s) = 0.134 \cdot s \qquad \text{if } s \leq 4;$$

$$\phi(s) = 0.134 \cdot 4 + 0.101 \cdot (s-4) \qquad \text{if } 4 < s \leq 8;$$

$$\phi(s) = 0.134 \cdot 4 + 0.101 \cdot (s-4) + 0.068 \cdot (s-8) \qquad \text{if } s > 8;$$

[15]To be precise, 1960 (29 countries), 1965 (2 countries), 1966 (1 country), 1968 (1 country), 1970 (18 countries), 1980 (1 country), 1989 (2 countries), 1990 (6 countries).

[16]With a rate of depreciation of 6 percent, a much longer time series is also needed to calculate tangible capital stock, especially for the initial capital stock. To note, there are nine East European countries that do not have a reasonably long time series of tangible investment (i.e. dating back to 1970), I will drop them in the subsequent development accounting analysis for robustness check. For countries that have a negative average growth rate, I reset it to 4 percent, which is the mean geometric growth rate observed for the other countries.

[17]The educational attainment data provided by Barro and Lee (2013) is available every five years, going back to 1950 and most recently up to 2010. For 2011, it is assumed that the 2010 average years of schooling will prevail.

Unlike the basic data discussed previously where y and k are calculated both for the total economy and for the market economy,[18] data on intangibles is solely constructed for the market sector. The real value of market investment in intangibles n, expressed in international comparable dollars, is computed as follows:

$$n_{j,c,t}=N_{j,c,t}/P^{N}_{j,c,t}/ppp_{c,\ 2011} \tag{16}$$

where N denotes nominal intangible investment flows; P^N is the asset-specific price deflator for intangibles and is imputed based on the US data (see Section 3.3 for more detailed discussions on intangible price deflator); ppp is the GDP PPP divided by the exchange rate in 2011 taken from WDI. Intangible capital R is then calculated using PIM:

$$R_{j,c,t}=\left(1-\delta_j^R\right)\cdot R_{j,c,t-1}+n_{j,c,\mathrm{t}} \tag{16}$$

where δ^R is the country-time-invariant depreciation rate for asset j from Table 1. The initial capital stock is computed based on the steady-state assumption:

$$R_{j,0}=n_{j,0}/(g_j+\delta_j^R) \tag{17}$$

where $n_{j,0}$ is the real value of intangible investment in 1995, and g is the average growth rate of the intangible investment series between 1995 and 2011. Given the relatively high rates of depreciation assumed for intangible capital, a time span of 17 years is sufficiently long for the initial capital stock to have only little impact on the development accounting analysis as the true value of the initial stock will be depreciated by 2011, the year I use for cross-country analysis.[19] Intangible capital-labor ratio is computed as follows:

$$r_{c,t}=(R^{BE}_{c,t}+R^{OC}_{c,t}+R^{RD}_{c,t})/\left(s^M\cdot emp_{c,t}\right) \tag{18}$$

where s^M denotes the share of employment in the market sector (see Appendix B2 for a more detailed discussion).

To have a general overview of the data, a brief summary of some descriptive statistics is provided in Table 2. As can be seen, Vietnam is the poorest country in the sample with the least amount of physical and intangible capital, while Singapore has the highest income per worker. The US has the highest level of both intangible capital and human capital. Figure 4 correlates tangible capital per worker with intangible capital per worker, both of which are normalized relative to the US values. As can be seen, these two capital-labor ratios are highly correlated (correlation coefficient is approximately 0.77). This suggests that countries with higher tangible capital per worker tend to have more intangible capital per worker as well.

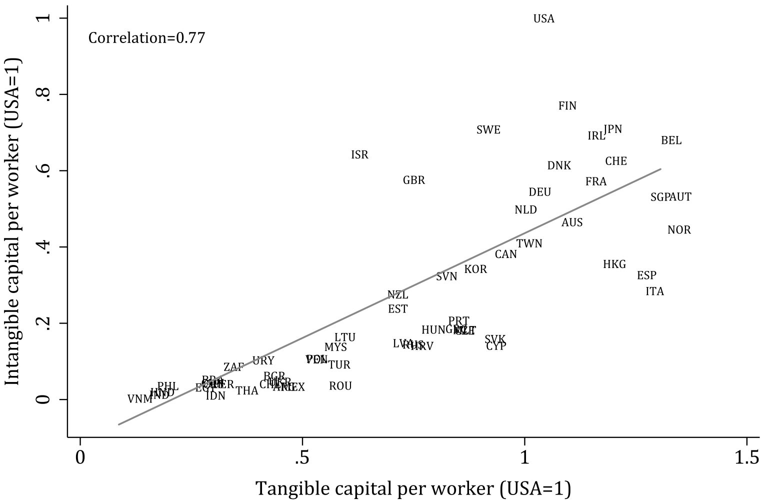
[18]Due to lack of data, human capital h is only calculated for the total economy and is assumed to be the same for the market economy.

[19]Even for asset with the lowest rate of depreciation (e.g. R^{RD}=20%), the initial capital stock would wear out almost completely after 17 years: $(1\text{-}0.2)^{17}=0.02$. This still holds true if the depreciation rate is just 15 percent: $(1\text{-}0.15)^{17}=0.06$. Thus, a time span of 17 years is already long enough to measure intangible capital stock with precision.

TABLE 2
Descriptive Statistics of the Basic Data for 2011 (Market Economy)

	Variable description	Min.	Mean	Max.	S.D.
y'	Real market output per worker	7666 (VNM)	65747	139955 (SGP)	33430
k	Physical capital per worker	15485 (VNM)	126681	233007 (AUT)	63191
r	Intangible capital per worker	77 (VNM)	7429	26839 (USA)	6731
h	Human capital per worker	1.97 (IND)	3.00	3.70 (USA)	0.435

Note: All numbers presented in the table are based on the market-sector of the economy for a set of 60 economies.



Notes: Author's calculation. The line shown in the figure is OLS regression line.

Figure 4. Correlation Between Tangible and Intangible Capital Per Worker [Color figure can be viewed at wileyonlinelibrary.com]

3.3. *Intangible Investment Price Deflator*

Currently, there is very limited knowledge on the appropriate price measures of intangible investment as these assets tend to be internally generated and lack observable market data for valuation. The existing studies have primarily relied on the non-farm business output price deflator as a proxy for the price of intangibles and apply this deflator uniformly to all intangible assets (Corrado, *et al.*, 2009; Corrado *et al.*, 2013;). It could be argued however that rather than the uniform business output price deflator, more appropriate asset-specific deflators would be the price indices of the industries that produce (in part) intangible assets, such as management consulting industry for organization capital, advertising and marketing research industry for brand equity, and R&D services industry for R&D.

Since price deflators for intangible-producing industries are not widely available for the other economies, I use the US, where the data are available, as the benchmark country and impute the asset- and country-specific intangible price deflators as follows:

$$RP^N_{j,t,US} = P^N_{j,t,US} / P^I_{t,US} \tag{19}$$

where RP^N denotes the relative intangible price deflator of the US, $P^N_{j,t,US}$ is the price deflator of the asset-specific intangible-producing industry obtained from US Bureau of Economic Analysis, and $P^I_{t,US}$ is the tangible investment price deflator provided by the UN NA data. Assuming that the relative price between intangible and tangible investments are constant across countries, I derive intangible investment price for the other economies as follows:

$$P^N_{j,c,t} = P^I_{c,t} \times RP^N_{j,t,US} \tag{20}$$

It is important to emphasize that the price of intangibles calculated per equation (20) is only a crude proxy and a practical choice needs to be made. Robustness to the choice of intangible price deflator, rate of depreciation of intangible capital stock, and other assumptions made during the data construction process will be examined in the next section.

4. Empirical Results

In this section, I discuss the main empirical findings, first with results of the basic development accounting analysis which only features physical and human capital, followed by the analysis augmented to include intangible capital as an additional factor of production. By varying the output elasticities of factor inputs, I compare and contrast the findings across various specifications and discuss the robustness of the main result.

4.1. *Basic Development Accounting Analysis*

With data on y, k and h, and setting the output elasticity of physical capital α equal to 1/3 as suggested by the literature, the variance of the basic factor-only model for year 2011, $var[log\,(y_{KH})]$, is 0.088 and the observed actual income variance, $var[log\,(y)]$ is 0.387 (see the first row of Table 3). This result suggests that, for a sample of 60 economies, only about 23 percent of the income variances can be accounted for by the observed differences in factor inputs. This fraction remains largely unchanged if I drop those nine former Soviet Union countries that do not have a sufficiently long tangible investment series going back to 1970.[20]

[20]The rationale for this sensitivity check is that for those countries that have a short investment series, the initial capital stock (calculated based on the steady-state assumption) has a non-trivial impact on the development accounting analysis because about 14 percent (i.e. 1980–2011, $(1-0.06)^{32}$) to over 25 percent (i.e. 1990–2011, $(1-0.06)^{22}$) of the initial capital stock is still in use in 2011. Only for countries with a reasonably long investment series (i.e. time span of 42 years or more), would the true value of the initial capital stock be (nearly) depreciated away by 2011.

TABLE 3
Variance Accounted For: Basic Model For 2011

	Coverage	Var[log(y)]	Var[log(y_{KH})]	VAF
Own data	Total Economy (60)	0.387	0.088	22.7%
Own data, excluding former USSR	Total Economy (51)	0.432	0.101	23.4%
Data from PWT 8.1	Total Economy (60)	0.452	0.109	24.1%
Own data	Market Economy (60)	0.432	0.101	23.3%

Note: Market economy indicates that the analysis is based on market- GDP, -investment, and – employment. The share of variance accounted for in the last column is calculated based on values to the seventh decimal point. For brevity, variance values to the third decimal point are shown in the table.

TABLE 4
Alternative Data from PWT 8.1

	Variable names	Codes	Description
y	Real output per worker	*rgdpe*	Expenditure-side real GDP at chained PPPs (in mil. 2005 US$)
k	Capital-labor ratio	*ck*	Capital stock at current PPPs (in mil. 2005 US$)
L	Number of workers	*emp*	Number of persons engaged (in millions)
h	Human capital	*hc*	Human capital index, based on years of schooling

To check whether this result is plausible, I compute the VAF of the basic factor-only model by solely using the PWT8.1 data constructed by Feenstra, Inklaar, and Timmer (2015) for 2011 (see Table 4 for the variables used). The counterfactual variance using PWT8.1 data, $var[log\,(y_{KH})]$, takes the value 0.109 and the observed variance of $var[log\,(y)]$ is 0.452, resulting in a fraction of 24 percent of the income variances accounted for by factor inputs. This rate is very similar to the prior finding. If I narrow the focus down to the market sector of the economy (i.e. y is the market output per worker, k is the capital stock accumulated by the market sector, and L is the market share of employment), the variance accounted for remains nearly identical (about 23 percent). So regardless of the coverage of the economy (i.e. market or total), in the *basic* factor-only model the differences of the observed factor inputs can account for no more than 25 percent of cross-country income differences and the rest is attributable to the differences in efficiency measured by TFP.

A caveat to bear in mind is that these results rest on the restrictive assumption that the output elasticity of physical capital is time-invariant and constant at 1/3. According to various recent studies (Rodriguez and Jayadev, 2010; Inklaar and Timmer, 2013; Karabarbounis & Neiman, 2014), there is robust evidence that the labor share of income has been declining over time around the world. Under the assumption of constant returns to scale, this means that the income share of capital is increasing and income shares are typically used to approximate output elasticities. As a consequence, using 1/3 as the output elasticity for capital is a simplification which may not reflect the reality. Figure 5 plots the change of VAF as a function of the output elasticity of capital α. This analysis illustrates that as long as the output elasticity of capital is less than 50 percent (i.e. $\alpha \leq 0.5$), most of the variation in income is still accounted for by TFP. It is also reassuring that the

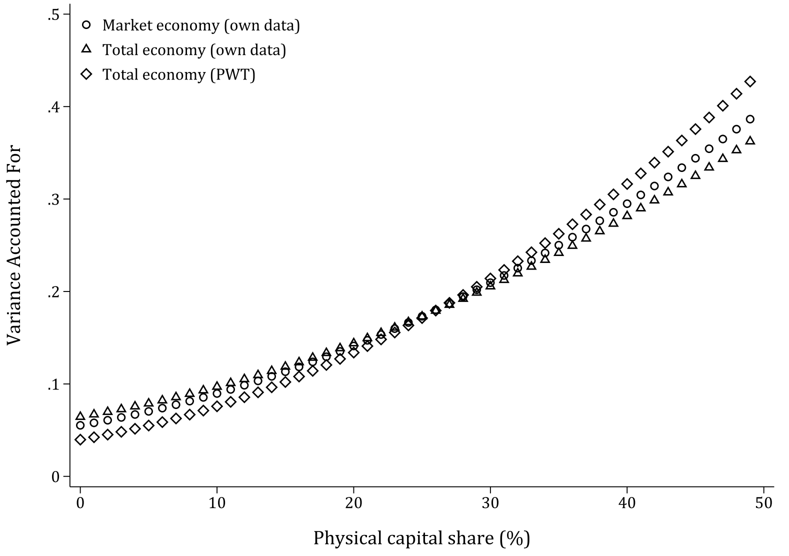


Figure 5. Variance Accounted for by Varying Output Elasticity of Physical Capital

variance accounted for remains fairly similar across different data sources and coverage of the economy.

4.2. *Augmented Development Accounting Analysis*

To examine how much of the income variation can be accounted for by intangible capital, I now turn to examine the *augmented* factor-only model. The first challenge is to pin down the output elasticity of intangible capital β and the resulting changes of output elasticities brought to labor γ and physical capital α.[21] In a growth accounting framework, Corrado *et al.* (2009) find that after capitalizing intangible investment in the US, the total capital share of income (i.e. $sK + sR$) rises to 40 percent, of which about 62.5 percent accrues to physical capital and 37.5 percent accrues to intangible capital (i.e. $\alpha'=0.25$ and $\beta=0.15$), and the labor share of income drops to 60 percent.[22] I take these shares as the baseline but also as the upper-bound specification for the development accounting analysis. Given that the US invests most intensively in intangibles assets, it is unlikely for the other economies to have an income share of intangible capital to be higher than the share of the US.

As shown in Table 5, the counterfactual variance, $var[log\,(y_{KRH})]$ under the upper-bound specification, takes the value 0.177 and the market output variance $var[log\,(y')]$ becomes 0.445. This leads to a significant improvement in the variance accounted for from 23 percent under the basic development accounting

[21]After capitalizing intangible investment, labor income share changes from $s_L=(P^L L)/(P^L L+P^K K)$ to $s_L=(P^L L)/(P^L L+P^K K+P^R R)$.

[22]Similar pattern-changes, but in much larger magnitude, also emerged in studies that rely on econometric estimation. For a sample of EU countries, Roth and Thum (2013) find the following output elasticities for these factor inputs: $\alpha'=0.30$, $\beta=0.25$, and $\gamma'=0.45$.

TABLE 5
Variance Accounted For: Augmented Model For 2011 (Market Economy)

	Output elascities	Var[log(y′)]	Var[log(y_{KRH})]	VAF′	Δ
Lower-bound	α=0.33 & β=0.05	0.445	0.124	27.9%	*+5%-points*
Mid-range	α=0.33 & β=0.10	0.445	0.166	37.2%	*+14%-points*
Upper-bound (Baseline)	α=0.25 & β=0.15	0.445	0.177	39.8%	*+16%-points*

Δ: denotes the difference in the variance accounted for by the augmented model as compared to the basic model (i.e. VAF′−VAF) in percentage points.

analysis to nearly 40 percent.[23] Even if I calibrate the model to a more conservative specification with the output elasticity of physical capital unchanged (i.e. α=1/3 as previously used) and the output elasticity of intangibles accounting for merely 5 percent (i.e. β=0.05), the VAF′ ratio still has a sizable increase of about 5 percentage points as compared to the *basic* model that ignores intangible capital.

It is clear that the exact value of VAF′ is sensitive to the choice of the output elasticities. This sensitivity prevents the paper from drawing firm conclusions about the exact improvement of the additional variance accounted for by intangibles. The qualitative evidence, however, is clear: intangible capital systematically improves the explanatory power of observed input differences in accounting for income variation. As shown in Figure 6 where I keep the output elasticity of labor fixed at 60 percent (i.e. γ=0.6) and only vary the output elasticities between two capital inputs,[24] the variance accounted for is increasing steadily as I increase the share of intangible capital (and thus decrease the share of tangible capital).

4.3. *Robustness of the Main Result*

Despite the fact that the quantitative implication is sensitive to the choice of the output elasticities of factor inputs, the main result is that including intangible capital systematically improves the explanatory power of observed inputs differences in accounting for income variation across countries. In this subsection, I test the robustness of this main result using various alternatives. The baseline is the upper-bound result from Table 5 (i.e. output elasticity of intangibles at 15 percent). I discuss how this baseline result changes when I make alternative choices in various stages of the data construction process.

First, investment in organization capital is measured by the wage compensation of the managers, but data on wage compensation by occupation is not widely available outside the US. My main results are based on the assumption that the relative wage of managers to an average worker is the same for all the other

[23]This main result remains consistent if the analysis is based on another year. For instance, if the analysis is based on 2005 the variance accounted for increases to 42.2 percent, accounting for even more income differences than the baseline result in 2011.

[24]This can be seen as the most conservative specification, as labor share has been declining over time as argued previously in the text. Thus, using 60 percent for the labor share (after adjusting for intangible capital which would also decrease labor share, see footnote 18) should be the maximum possible. Since the variation of human capital is less than the other capital inputs, changing the labor share to any value less than 60 percent would only increase VAF by factor inputs. In other words, the improvement shown in Figure 6 is on the conservative side.

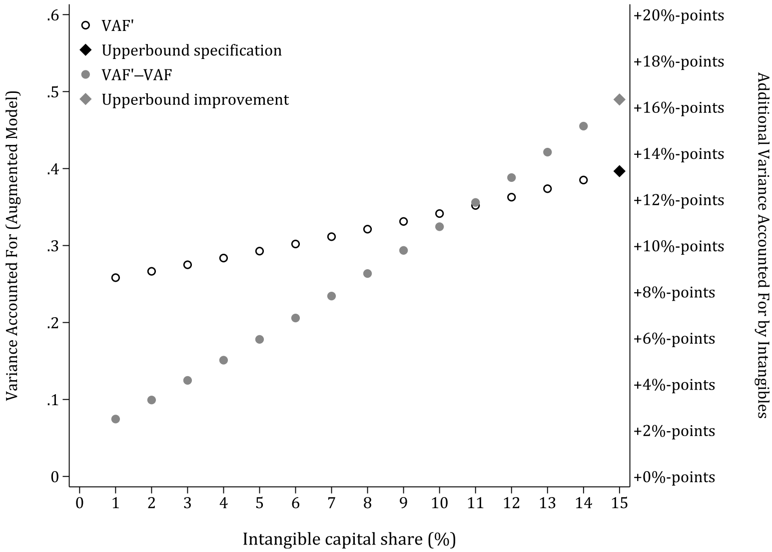


Figure 6. Changes in VAF by Varying Output Elasticities of Capital Inputs [Color figure can be viewed at wileyonlinelibrary.com]

countries as in the US. Based on the scant earnings data provided by the International Labor Organization, a fairly strong negative relationship can be observed between a country's level of investment and its wage differentials. Thus, using the US relative wage would mean that I am likely to underestimate the actual level of investment in organization capital for most of the other economies covered in my sample, as countries at a lower level of development tend to have a larger wage differential than the benchmark economy—the US. In light of this evidence, I provide an alternative measure of investment in organization capital that allows for the relative wage of managers to an average worker to differ by country (i.e. R_c).[25] As shown in the first row of Table 6, applying this alternative measure of organization capital has little impact on the main result.

Second, due to data constraints, the intangible investment data of some countries have mainly relied on imputations. For instance, business investment in R&D for Brazil is approximated based on the data from Mexico (see the Appendix for greater detail). In the second and third rows of Table 6, I show that the main result remains unchanged to alternative country samples. It is not sensitive

[25]The alternative wage differential R_c is based on the limited earnings data by sex and occupation from the ILOSTAT database. I use the ISCO 2008 classification and retrieve the wage data for two occupational categories: Managers and Total for 2009, 2010 and 2011, the only three years that have the wage data available. In total, 35 countries are covered by ILO. Since there is little variation over time, I take an average of the ratio (*Managers and Total*) and held it constant for all years. Hence, the alternative measure of organization capital assumes a country-variant but year-invariant wage rate for managers. For the rest of the 24 countries that have no earnings data by occupation, I simply use the wage differential from a "similar" country that has a comparable level of GDP per capita and are geographically located close to one another. The wage data for the US is extracted from the Occupational Employment Statistics database provided by the US Bureau of Labor Statistics.

TABLE 6

Robustness Analysis of the Main Result

	Var[log(y′)]	Var[log(y_{KRH})]	VAF′	Δ
Baseline result from Table 5	0.445	0.177	39.8%	*+16%-points*
(1) Alternative OC	0.443	0.171	38.6%	*+15%-points*
(2) Dropping GRC&ESP	0.456	0.181	39.7%	*+16%-points*
(3) Dropping sample	0.403	0.160	39.7%	*+16%-points*
(4) Alternative δ_j	0.445	0.183	41.1%	*+18%-points*
(5) Alternative K_0 & R_0	0.445	0.177	39.8%	*+16%-points*
(6) Alternative price P^{BS}	0.445	0.173	38.9%	*+15%-points*
(7) Alternative price P^{GDP}	0.445	0.172	38.6%	*+15%-points*
(8) Alternative price P^I	0.445	0.173	38.9%	*+15%-points*

Note: "Alternative OC" denotes alternative measures of investment in organization capital. 'Dropping sample' means Brazil, Egypt, Honduras, and Venezuela are dropped from analysis. Alternative prices in (6)–(7), denote intangible price deflator proxied by non-farm business output price deflator (P^{BS}), the GDP price deflator (P^{GDP}), and the tangible investment price deflator (P^I).

Δ: denotes the difference in the variance accounted for by the augmented model as compared to the basic model (i.e. VAF′−VAF) in percentage points.

to dropping Greece and Spain two countries with anomalously large amount of investment in organization capital, or dropping Brazil, Egypt, Honduras, and Venezuela, countries whose investment in R&D is imputed.

In row (4) of Table 6, I show that the main result is also robust to using lower rates of depreciation as the rates assumed by Corrado, *et al.* (2009) might have been too high. Take R&D and organization capital for example, other studies have suggested to use a rate of 15 percent to depreciate both capital stocks (Hall, 2007; Eisfeldt and Papanikolaou, 2013). For brand equity, I lower the depreciation rate to 50 percent following the empirical evidence surveyed in Bagwell (2007).[26] In addition, the main result is not affected if the average growth rate of intangible investment, g, per equation (17) is calculated based on early years of observation (i.e. 1995–1999), since investment in intangibles were much lower in the 1990s than later on.

Last but not least, if other price proxies were used to deflate intangible investments, for instance the tangible investment price deflator ($P^I_{c,t}$), the GDP price deflator ($P_{c,t}$), or the non-farm business output price deflator ($P^{BS}_{c,t}$), the resulting intangible capital stock correlate very highly (correlation above 0.98) and the main result of the analysis also remains largely unchanged (see the last three rows of Table 6).

5. Concluding Remarks

Why do some countries produce so much more output per worker than others? I revisit this question by accounting for the role of intangible capital, a form of investment that has become increasingly more important in the fast-changing modern economy. Based on various data sources, I first develop a new

[26]The main result remains largely unchanged if I use higher rates of depreciation than the baseline rates (i.e. $\delta_{BE}=70$ percent, $\delta_{RD}=30$ percent, and $\delta_{OC}=50$ percent. The VAF is 38.6 percent, an improvement of 15 percentage points.

intangible investment database that is consistent and internationally comparable for a sample of 60 countries and over a time span of 1995–2011. I find a high positive correlation between a country's level of GDP per capita and its investments in intangibles. In a development accounting framework, I show that the fraction of cross-country income variation accounted for by the observed differences in factor inputs increases substantially after taking intangible capital into account. In my baseline result, observed input differences can account for approximately 40 percent of income differences, which is notably higher than the 23 percent if only differences in physical and human capital are accounted for.

Furthermore, the potential of intangible capital to account for international income differences is likely to be greater than what the results in the paper suggest, as the set of intangible assets I cover is only a subset of the full list of intangibles identified by Corrado *et al*. (2005).

Although the evidence in this paper is encouraging, it is important to note the limitations as well. First, the measurement of organizational structures is based on a rather arbitrary assumption that 20 percent of managers' compensation are conducive to organizational development. This assumption lacks empirical evidence and may partially explain why intangible investment is seemingly stable and resilient to economic downturns since compensation is relatively stable during business cycles. Second, there are still many unresolved yet highly important issues surrounding the measurement of intangible capital. For instance, I have not adequately addressed the issue of appropriate price deflators for the asset-specific intangible investments. Assumptions made in this regard may have non-trivially affected the quantitative results. Third, the standard "one-size-fits-all" output elasticities of inputs (e.g. 1/3 or 1/4 for physical capital) are simplifications which may not reflect the reality. As noted by Inklaar and Timmer (2013), the explanatory power of variation in observed inputs could be larger if output elasticities of inputs are country- and year-specific. This limitation, however, does not discredit the contribution of this study to the literature as the results are comparable to earlier studies that also assumed a common output elasticity of factor inputs (e.g. Caselli, 2005; Mutreja, 2014). Lastly, the analysis is based on capital stocks rather than capital services, which would have been a more appropriate measure for capital input since shorter-lived assets should have a larger return in production as it would be indicated by its user cost. But while these are limitations, my analysis is still a useful step forward. By focusing attention on low levels of investment in intangible assets in lower-income countries, this paper suggests a research agenda for trying to uncover the determinants of this low investment and thus a promising new direction for understanding international income differences.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher’s web-site:

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